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PREFACE

Preparation of this report occurred over the period November 2017 to May 2018. It has taken a little more time than expected, but the scope of the issues warranted detailed attention.

We would like to thank most sincerely the rural innovation leaders who generously made their time available to meet and discuss aspects of the review with us over the period. We met over 100 people in business, in RDCs, in research organisations, and in Commonwealth, state and territory governments. We would have liked to meet more, but time was catching up.

We would also like thank the 188 people who responded to the expert opinion survey. The purpose of the survey was to calibrate the strength and depth of opinion conveyed during the Consultations element of the Review. We are conscious that the Survey was detailed and challenging and required some considerable thought to be given to responding to the statements and hypothesis contained in it. We very much appreciate the perseverance of people who completed the survey instrument

Several graphics from the Survey are included in the report narrative. Detailed responses to all questions are included as a separate volume to the Report.

I would also like to thank members of my team, Dr Mark Matthews and Don Scott-Kemmis, in preparing the report and Laura Matthews and Anthony Doma from Clarivate Analytics for their assistance in provision of bibliometric data and its interpretation.

Members of the reference group, led by Dr Philip Wright, provided invaluable assistance through comment and suggestions.

Above all, I would like to thank Tim Lester, Executive Officer at the Council of RDCs who the project from inception to completion. Tim's willingness to be involved in the journey from what started as a simple 'audit' of the rural innovation system to a report that provides a detailed analysis of the outlook and prospects for rural innovation and the rural sector was fundamental to the success of the project.

Dr John Howard
Howard Partners
August 2018

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Executive Summary

This Review of the Rural Innovation System responds to Terms of Reference issued by the National Research and Innovation Committee¹ to:

... describe the performance and impact of Australia's rural innovation system. The project will collate and analyse evidence across a range of metrics to present a comprehensive review of the system's overall performance, highlighting areas of strength, opportunities for improvement, and gaps in our knowledge base.

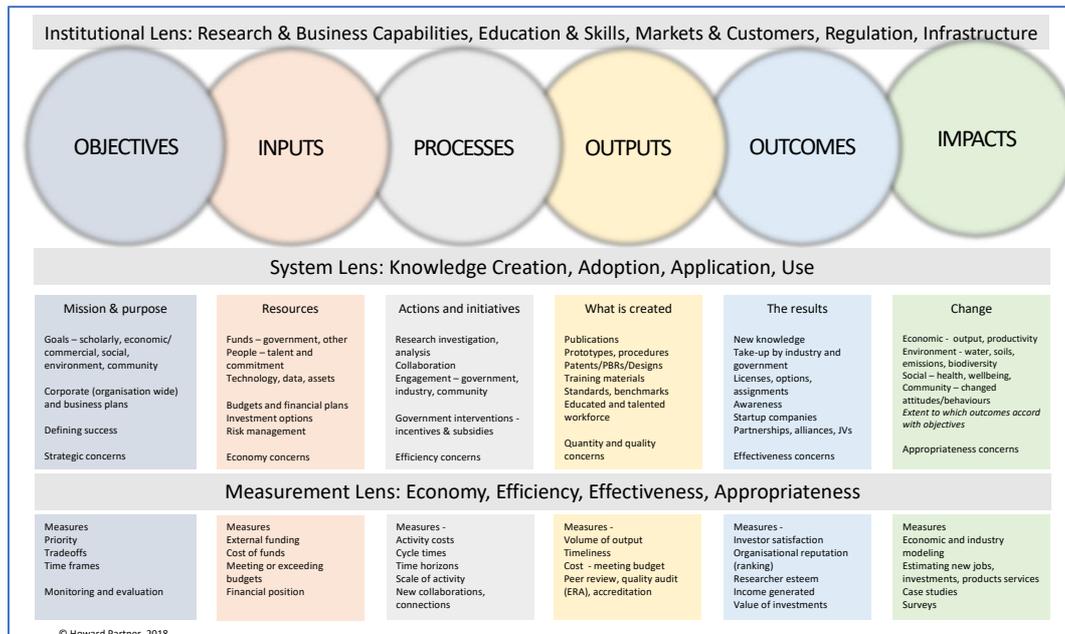
Specifically, the project will:

- Assess the performance framework used to assess the national innovation system for application to the rural innovation system, and propose adjustments as necessary
- Identify and collate evidence against agreed metrics under the performance framework
- Identify gaps in the available evidence
- Develop a comprehensive report assessing the performance of Australia's rural innovation system in national and international contexts
- Recommend opportunities for improvement.

This Report responds to these requirements. In particular:

- The performance framework adopted for the national innovation system performance review (Innovation and Science Australia, 2016) is summarised in Appendix 10. The approach taken in this Review incorporates and extends the ISA methodology to reflect a broader view of innovation as foreshadowed in our response to the Request for Proposal for this project.
- The body of the Report contains an extensive body of evidence against agreed metrics that relate to the performance of the Rural Innovation System. This is presented in terms of a *logical framework* that addresses objectives, resources (inputs), processes (methods, collaboration), outputs (papers, patents, standards), outcomes (new knowledge adopted and applied), and impacts (change) in an institutional framework. This is represented in Figure 1 below.

Figure 1: Rural Innovation System Performance Review Framework



¹ The R&I Committee is an Advisory Committee to the Agriculture Senior Officials Committee (AGSOC) and is responsible for the oversight of the development and implementation of the National Primary Industries Research Development and Extension Framework (the Framework) and also provides advice on the overall performance of the primary industries research innovation system.

This report also includes:

- An extensive discussion of gaps in the system
- This Report is a very comprehensive assessment of rural innovation system performance.
- The Report also recommends opportunities for improvement.

In the context of the Terms of Reference, and consultations undertaken during the Review, a discussion of the rationale for public investment in Rural Research, Development and Innovation is provided in Section 2 (from page 3).

The following key points emerged in undertaking the Review and in the research and analysis leading to the preparation of this Report. These are further detailed in Sections 3 and 4 of the Report.

Key points regarding performance and impact

General

- As an essential component of Australia's rural sector, the effective performance of the rural innovation system is vital to Australia's economic future. Contrary to what some assume, the rural sector is very much part of the "new economy", particularly in the development, application, and use of advanced technologies.
- There are, however, many challenges remaining. These can be met with a vision and strategy for the sector involving national, industry, business, and the community commitment to future value creation.

Context, challenges, and opportunities

- The rural innovation system has evolved through several "waves", beginning with mechanisation in the agrarian revolution of the 1700s, the emergence of agricultural sciences followed by the impact of the biological sciences, and more recently, the impact of digital applications, data, and analytics, and more recently in a "disruption" of the industry and business models with support for AgTech and GeneTech start-ups through greater availability of risk capital.
- Many challenges and opportunities are being articulated for the rural sector, including a \$100 billion farm production output by 2030 and a national AgTech initiative.
- The rural innovation and production system is being strongly impacted by the growing importance of Global Value Chains (GVCs), making a "connected" innovation approach even more essential.
- There is a growing appreciation of the economic significance of the "biologically derived" economy.

Issues to consider

- The contribution of agriculture to GDP has been falling, but when put in a value chain context to include manufacturing and services, the contribution is much more significant. A diversified Food and AgTech sector is emerging and attracting interest from innovators and investors operating across the value chain.
- Farm profitability has been increasing, particularly for larger farm businesses – but the scope for increasing further returns is contingent on reducing *input* costs, anticipating trends in demand, and niche marketing will be a significant driver of profitability for many rural businesses.
- Addressing demand-side issues, including finding new customers, is fundamental for the future of the rural sector.
- Agility, flexibility, responsiveness, and the flow of ideas are critical issues for rural innovation and rural production system performance. The two aspects are mutually reinforcing.
- There is a broad understanding that collaboration across the innovation system and the value chain is essential.
- Many opportunities have been identified for a robust rural sector future, including a focus on health and wellness and prospects in foodservice around platform technologies.

Innovation system dynamics

- It is difficult to look at the system from one point in time; it has been evolving dynamically. Evolution has occurred through "cumulative evolution" across technologies and institutional change.

- Digital transformation is occurring across the sector, associated with the emergence of what is being termed "digital agriculture" and "smart" farming".
- Data, analytics, and artificial intelligence are being adopted and applied across the rural sector, in much the same way as other technology-driven sectors in the economy. But investments in these areas involve risks and must meet ROI criteria.
- There has been a pattern of consolidation and concentration among global agribusiness companies and a flurry of agribusiness listing on the ASX listing in recent years. Trading and Investment Banks see opportunities in high growth agribusiness ventures.
- There is a more recent trend towards disaggregation with the emergence of start-ups and new technology-based businesses that are attracting substantial risk capital investment. There are opportunities for start-ups to build businesses around IP export.
- Expert Opinion responses indicated that the future of the Australian rural innovation system would increasingly rely on best practice commercialisation methodologies that attract entrepreneurs and venture capital.

Areas for performance improvement

- Respondents to the Expert Opinion Survey overwhelmingly indicated that Australia requires an overarching strategic vision for rural innovation based on market and technological change, biodiversity, and climate change. This vision is used to coordinate state/territory level innovation support.
- Experts were in overwhelming agreement that mindsets in the rural sector have not developed to reflect the realities of modern globally connected innovation and the severity of long-term environmental challenges.
- Experts were also overwhelmingly of the view that present government policy places too much emphasis on 'here and now' productivity and efficiency challenges and insufficient attention on new market and longer-term industry facing opportunities.
- Experts also saw significant opportunities in developments in digital technologies as a basis for "creating a revolution in agricultural productivity and value chain development.
- Regional universities have a crucial role in enabling regional rural innovation. Still, there is a need for greater policy integration across Commonwealth and State/Territory agencies with research, education and training and regional development within their remits.
- CRCs have been important for rural innovation. Commonwealth and State/Territory Governments might consider collaborating with RDCs and businesses to establish CRC type arrangements, following the model of the CRC for Northern Australia.
- Rural RDCs, as currently structured, are regarded by Experts as having been an enhancing factor in rural innovation. There was some support for the view that RDC roles should be made more contestable by private research providers. Experts generally did not agree that RDCs had displaced alternative user mechanisms for delivering research.
- The established Commonwealth-State/Territory collaboration infrastructure in primary industries provides a good starting point to develop a strategy covering all aspects of Australia's Rural Innovation System.

Review Findings

The findings of the Review provide a basis for drawing several far-reaching conclusions about rural innovation system performance – conclusions which provide a basis for addressing strategic policy and initiatives directed towards rural innovation performance:

Australia's rural research system is generally good and is recognised as such

We have good people and capacity and do good work. This is primarily so in discovery and applied research but is weaker in interdisciplinary research. This weakness is a factor of defining research and recognising research performance in disciplinary silos (fields of research), the lack of incentives for integration between university research facilities, and competition for funding between universities.

The delivery of research and development is central to the broader rural innovation system, but the two things are different and should not be conflated.

Research extends the knowledge base and develops knowledge to answer specific questions. Innovation is about applying that knowledge within environmental, business, and social systems to solve problems.

The innovation system is not the same as the economic system. Still, innovation is a crucial driver of improvement and growth within the economic system – commonly referred to as growth in productivity and international competitiveness.

The economic system provides the context for understanding the performance of the innovation system - the purpose of rural innovation and what are we (as a nation) want to achieve.

However, the innovation system itself cannot be relied upon to do all the heavy lifting to deliver improvement in the economic system.

Improvement is also required and will have implications for several other systems that contribute to economic system performance. These include the education and training system, innovation ecosystems, international trade, investment and market access, the natural environment and biodiversity system, the financial system, the transport, storage, and logistics system, the regulatory, certification and inspection system, and the agri-political system itself.

Rural industries perform a more central function than delivering farmer productivity and profitability.

The products of rural industries, and the capacity to produce them sustainably, are strategic national assets with social, cultural, economic, and environmental importance and implications.

In one way or another, *the outputs of rural industries and production are currently associated with almost half (48 per cent) of Australia's overall contribution to combined final consumption and fixed capital formation in other countries.* This is mainly via final consumption expenditure by households, for which the direct 'biologically derived' contribution is 57 per cent.

In contrast, the Australian biologically derived contribution to gross fixed capital formation in the rest of the world is far lower at around seven per cent (93 per cent non-biologically derived). In terms of the intermediate inputs that flow on to production overseas, Australia's biologically derived contribution is also lower, at 11 per cent.

Crucially however, the dominance of intermediate outputs over final consumption and fixed capital formation restricts the overall role of biologically derived economic activity to around 12 per cent of the economy. These 'biologically derived' outputs can be categorised as food, fibre and economic 'feedstock', and the overall system is described as the 'bio-economy'.

As stressed throughout this Report, modern technologies – especially regarding the 'circular economy' - are opening the potential for an increased 'biologically-derived' contribution to economic activity. There are opportunities for the rural sector to pick up new sources of value creation.

Given the influence of modern technologies, it no longer makes sense to conceptualise the rural economy simply as 'primary' production. The strands of biologically-derived activity that originate in primary production spread throughout modern economies – and have the potential to increase in prominence over future decades.

Analysis of global value chains shows that the production component has the least potential for value creation and capture within the system.

Opportunities for value capture are much greater at either end of the chain, including through research and technology for improved pre-production inputs (including soils and water and responses to climate change) and sales, service, and marketing in post-production components.

A production-focused R&D effort currently dominates Australia's rural innovation system. Upgrading engagement and participation within global value chains is a recognised and well-researched approach to improving value captured by a domestic economy. Various forms of innovation are useful to achieve that upgrade.

Australia performs well in international comparisons regarding investment in food processing but lags a long way behind the US and China. Australia has virtually withdrawn from investment in fibre manufacture (wool, cotton, forest products).

On the bright side, aquaculture is exhibiting strong growth and is an area of immense global opportunity - but there are environmental health and biosecurity challenges to address.

Conversely, the ability to evaluate and measure asset values and competitiveness drivers is easier where it relates to the production sector and more complex at either end of the value chain.

This will continue to represent a challenge for impact assessment and performance evaluation.

Systematic engagement with global value chains offers Australian businesses the opportunity to increase value capture through the spill-in benefits of new knowledge and capacity.

Engagement with Global Innovation Networks provides an opportunity to amplify and strengthen locally based R&D efforts. Capturing and 'owning' a supply chain (including a global supply chain) is an effective strategy deployed by many food and fibre businesses. The approach of a string of commercial intermediaries 'clipping the ticket' from production through to consumption is a losing scenario.

The opportunities to improve the performance of the rural innovation system are therefore based upon:

- Broadening the understanding of activity from delivery of RD&E to engaging with the intersecting and overlapping components of the economic, environmental, and social systems, of which innovation is just one part of the process.
- Broadening the discussion from an assessment of farm-production-focused efforts to coverage of the entire bioeconomy
- Developing a national industrial strategy for the bioeconomy to increase local value creation and capture through innovation supports upgrading our participation in global value chains and global innovation networks.
- Building and maintaining a strong focus on achieving necessary scale in operations and efforts

The ultimate challenge is to re-establish the agriculture-food-health-environment link across multiple policy domains.

Achieving this outcome requires leadership and 'systems integration'.

Leadership is required at the political level, across Ministerial Portfolios and States and Territories. It is not a matter of establishing another Council or Committee – there are plenty of those. It is a matter of focusing leadership on a vision and overarching strategy for the agriculture-food-health-environment. Strategy is not just about exploiting opportunities; it is also a matter of facing the risks if we do not.

The rural innovation system is complex – and complicated. To perform effectively, “integrators” are required to ensure that components are consolidating and complementary and not ‘failing’ due to misplaced competition for resources, skills, and talent.

The Department of Industry and Innovation has experimented with “Advocates” to build connections and scale in accessing global markets.

Integrators would be free agents and not tied to any organisational allegiance or seek commercial gain from service activity fees.

Detailed assessment of Rural Innovation System performance

The assessment of innovation system performance in terms of the logical framework outlined in Figure 1 are summarised below. Extensive detail is provided in Section 5 of the Report (from page 57 below).

Strategies and Objectives: setting directions and leadership

- There has been no shortage of rural industry research, development, and innovation strategies over the last six years. This is apart from the numerous reports and papers released by the Learned Academies, financial institutions, think tanks, and consultants, detailed Research Report 2.
- The strategies exhibit very little cross referencing and accumulation of perspectives about how to capture opportunities and address constraints. Very little mention is made of resources required to implement strategies and the challenges in implementation. Few of the reports look at *both* short term (horizon 1) and long term (horizon 3) perspectives.
- We have reached the stage where we know enough about short-term strategies and opportunities based on existing knowledge. It is time to turn our thinking to how Australia can realistically position itself in global value chains.
- Leadership in the development of strategy is required, focusing on integrating perspectives across the value chain.

Allocation of Resources: frameworks and priorities

- The National Primary Industries RD&E Framework aims to provide a shared strategic direction and priorities for national and sector level primary industries RD&I in Australia that enhance the productivity and resilience of Australia's primary industries. Nonetheless, there is a concern about the clarity and coherence of system objectives.
- There are numerous Rural Research, Development and Innovation investment frameworks adopted by governments, research organisations and universities, also referenced in Research Report 2.
- Nationally, research investment should balance four areas of research endeavour: *discovery* (generation of new knowledge); *integration* (cross and interdisciplinary research to gain new insights); *application*; and *translation*. The review indicates that the emphasis is shifting away from discovery towards application.
- It is estimated that there was \$3.1 billion invested in RD&I in 2014-15. Historically, State governments have invested more in rural RD&I than the Commonwealth, although the gap is narrowing.
- Over the last five years, business investment in RD&I has been increasing in plant and animal production and related products. Still, there is a view that the private sector's commitment should be greater.
- Australian businesses maintain a comparatively high level of investment in food products and beverages but no material investment in textiles or wood and wood products.
- Australia maintains strong investment in research facilities and equipment across the public and private sectors.
- Experts considered that public RD&I investment should target high-performing institutions to create more robust capability and focus on 'national challenges.
- Experts were also concerned about low levels of collaboration and would like to see a greater commitment to interdisciplinary research projects and programs.

- Research providers were concerned with investment cycle times and what they saw as an excessive process orientation in grants administration.

Processes: the way the system works

- Processes can be highly structured for accountability and control or relatively unstructured where there is a priority on agility, flexibility, and responsiveness to meet requirements for innovation.
- Research investment processes are multifaceted and vary across agencies and research fields, but there is scope for improvement.
- There is concern about what appears to be excessive government attention to compliance and control.
- There should be consistency across research organisations in legal and contracting documents and approaches.
- There is scope for better use of Customer Relationship Management (CRM) Systems to improve industry, business, and government engagement processes.
- Design thinking offers opportunities to improve and redesign a range of processes.

Outputs: The way resources are used

- ARC/ERA information indicates that research outputs from universities have grown enormously over the five years 2008-2015, and particularly since 2015.
- Except in biochemistry and cell biology, patenting and commercialisation income have been relatively modest.
- According to Clarivate Analytics InCites data, there has been substantial growth in publications across all research fields since 1993, mainly by universities in the biological and environmental sciences.
- CSIRO and the Universities of Queensland and Sydney have maintained a solid and prominent commitment to publication in agricultural sciences.

Outcomes: Effectiveness in Achieving Intended Results

- Australian universities have world-class research capability in most research fields relating to agricultural sciences and in many fields relating to biological sciences, particularly genetics, plant biology, zoology, and ecology.
- Researchers have recorded high levels of esteem in biochemistry and cell biology, plant biology, genetic and environmental science, and management.
- According to Clarivate Analytics and InCites data, there are some indications of a shift in research emphasis and impact from the agricultural sciences to the biological sciences.
- Although commercialisation income is small, there have been several successful start-ups in the AgTech and GeneTech areas (including CropLogic and Nexgen Plants).
- The “extension” space has become highly contested: intermediaries that survive will produce unique value, adding value to a transaction or relationship that is not easily replicable.

Research, Development, and Innovation Impact

- Approaches to assessing research impact are not well developed.
- There is a concern with using “big numbers” to demonstrate impact; assumptions, data sources, and methodologies are not always transparent – or credible.
- There is limited information on commercialisation impacts regarding jobs created, new sales, new investments, and exports.
- Case study approaches are important, and there is an argument for adopting consistent approaches across all components of the rural innovation system.
- Very few “stories” provide in-depth insights into how innovation has happened - and the pivotal decisions made.

Monitoring and evaluation

- There is limited availability of data that informs stakeholders about the economy, efficiency, effectiveness (value for money) of the RD&I system.

- Performance measures should include indicators related to the long-term environmental sustainability of rural industries by preserving natural capital.
- The rural innovation system would be enhanced by emphasising general 'public benefit' data provision relative to specific technology development projects.
- Better provision of general 'public good' data would be improved by allowing farmers and others to share data whilst protecting confidentiality

Critical interactions with other national socio-economic systems

Innovation outcomes reflect a complex interplay between *several independently operating but connected national socio-economic systems* that operate at the regional, national, and international levels. These systems include, but are not limited to:

- The science and research system
- The education, training and talent acquisition system, and the labour market institutions
- Rural, regional development systems
- Natural environment and biodiversity management systems
- The international trade and commerce system
- The financial system, including banking, early-stage investment capital, private equity, insurance, and risk mitigation instruments
- Regulation certification and inspection systems that shape product markets
- Transport, communications (including digital communications), logistics, and energy systems
- The public policy system (also referred to as the agri-political system).

Actions and initiatives taken in one socio-economic system may be offset or suppressed if complementary and supporting actions and initiatives are not taken in other systems.

For example, during the consultation for the Review, it was said that delays and problems encountered in delivering Australia's digital communications system were a significant brake on rural innovation, as they were in the Consultations for the Innovation Science Australia Strategic Plan (Innovation and Science Australia, 2017a). Weaknesses and lack of innovation in transport networks were also often mentioned in Consultations as a brake on innovation. There was also a strong view that rural innovation requires a robust and supporting regional policy.

The following additional matters were raised about other systems impacting on performance:

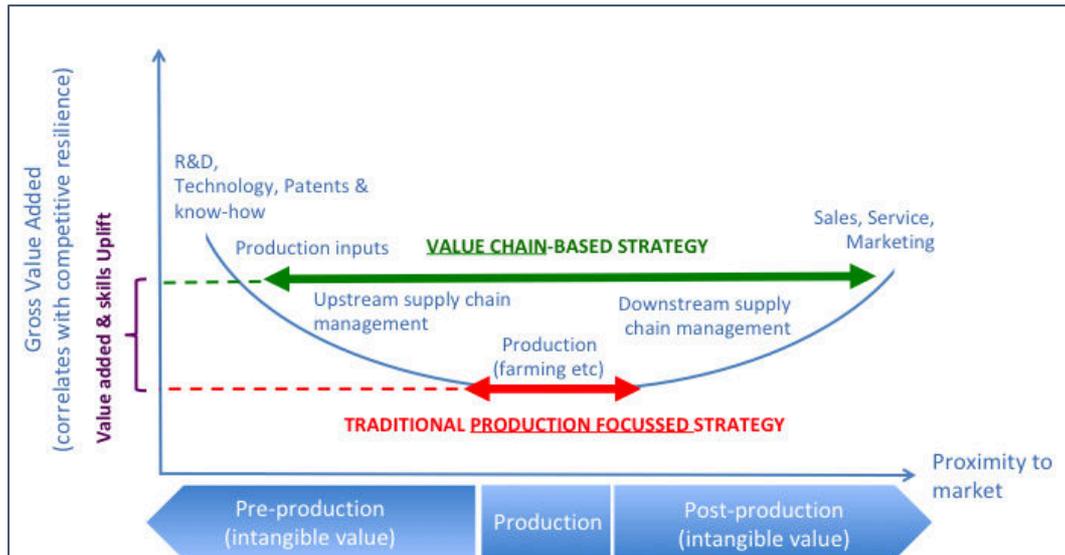
- There is a concern, reflected in the Expert Opinion Survey, that the Education and Training System has not kept pace with the evolution of the rural innovation system.
- There is also a concern about declining university student enrolments in agriculture, forestry, and related courses. However, Review Consultations indicated that rural industries called on a broadening range of knowledge, skills, and capabilities – including management.
- Innovation ecosystems, precincts and clusters, and co-working spaces have become a major focus of policy attention and investment by State and Territory Governments, Universities, and leading businesses.
- The regional development system could be better aligned with the rural innovation system. However, universities have a crucial role in supporting and enabling rural innovation.
- The rural enterprise (entrepreneurial development) system supports the growth of a new entrepreneurial approach in rural businesses.
- Experts indicated that more could be done to strengthen the natural environment and biodiversity management system.
- Experts indicated that the performance of the Internal Trade and Foreign Investment System was generally favourable, as was the Financial System and the Regulation, Certification, and Inspection System.

- Experts indicated concern about the infrastructure system, particularly about energy – but were supportive of the potential from farm businesses to diversify into locally generated energy systems.
- Experts also had concerns about the performance of the agri-political/public policy system.

Approaching innovation from a global value chain (GVC) perspective

The Report also argues that rural innovation should be approached from a “Whole of Value Chain” perspective. Figure 2 below is a version of the well-known ‘smiling curve’ relationship between position/span in value chains and the level of value-added. It highlights the higher value-added associated with activities removed from production *per se*.

Figure 2: Production versus Value Chain Approaches to Innovation



Source: Based on Shih (1996) and taken from SDG-ED (2018)

Not included in the depiction of the value chain in Figure 2 is the “natural capital” base - land, soils, forests, water, and oceans. Many stakeholders argued during the Consultations that investment in the preservation, restoration, and repair of natural capital in the light of human intervention and climate change can, and will, deliver very substantial returns to the economy over the longer term.

At the other end of the value chain spectrum are investments in foodservice and food delivery platforms, generating substantial returns to investors as consumers change consumption preferences and adapt to changes in urban and housing design.

The implication is that unless attention is given to the whole value chain and how global value chains are configured and are evolving, innovation strategies risk being too focused on the lower value-added production segments of value chains whilst neglecting the important higher value-added (but sometimes but harder to measure segments).

The Review argues strongly that rural innovation involves a much broader set of imperatives than “farm-based” innovation.

Towards a new vision for rural innovation

This report lays out the elements of a new vision for the future of rural innovation in Australia. This vision is based on 're-booting' our mind-sets by extending the scope of our thinking in the following key dimensions:

- *Conceptually* – shifting towards a more pragmatic 'business-centred' approach to rural innovation that positions it as part of a broader Industrial Strategy for biologically-derived economic activity in Australia. This perspective also recognises that our rural innovation system must move away from a narrow 'production' focus and do more to identify and exploit opportunities in the activities that are both 'upstream' and 'downstream' to rural production.

Examples of upstream activities are research, intellectual property, and competitive strategy. Examples of downstream activities are integrated supply chain management and global brand positioning. In other words, by being truly 'systemic' in our approach to rural innovation – strategically spanning more segments of value chains in our innovation foci.

- *Accurately* – drawing attention to the pervasive impact of rural industries in providing the source of a myriad of biologically-derived production inputs that spread throughout modern economies – and linking these economies together via global value chains based on biologically-derived inputs. It is no longer good enough to think about the rural economy only as part of 'primary production'.
- *Ambitiously* – providing a new collective sense of purpose around which a wide range of actors in the rural innovation system can better coordinate their distinctive contributions: exploiting the emerging opportunities associated with the transition to less environmentally damaging 'circular economies'. This is a transition in which biologically derived economic activity is likely to increase dramatically. *Modernity is biological.*

As such, this review aims to establish the fundamental guiding principles that we can use as we move forward in re-invigorating the rural economy and better exploiting our extensive and valuable natural capital.

Accompanying attachments and reports

This Report contains several Appendixes. These cover:

1. Trends and outlook for Rural production, drawing on ABARES and IBIS data
2. A summary of institutional capacity and capability for rural research, development and innovation across the Commonwealth, States, Territories, and universities
3. A discussion of the connection between RD&I investment and economic growth
4. A detailed overview of the dynamics and evolution of the Rural Innovation System
5. A discussion that addresses building a more sustainable and collaborative RD&I system, drawing on pre-existing material prepared by members of the Review Team and country reports from the ACOLA *Securing Australia's Future* project
6. People and organisations contacted during Review Consultations
7. A list of participants in the Expert Opinion Survey
8. Additional comments provided by Expert Opinion Survey participants
9. The Terms of Reference and supporting commentary
10. An overview of the Innovation and Science Australia (ISA) approach to measuring innovation performance

A comprehensive bibliography is provided.

The report should be read in conjunction with other documents prepared for the Rural Innovation System Review:

- A Summary Report
- Research Report No 1: Rural Innovation Outcomes and Global Value Chain Analysis
- Research Report No 2: Previous Reports, Statements, Reviews
- Research Report No 3: Key Institutions in the Rural Innovation System

Recommendations

Drawing on the *System Performance Review* analysis and other material referenced during the Review, several recommendations are made for performance improvement:

Vision and strategy

1. Articulate and promote an integrated *Industrial Strategy* for the Australian rural economy – a strategy in which innovation *per se* is closely entwined with the other systems and commercial competencies that determine success and failure in contributing to the global economy. *The Strategy should embrace the whole value chain and the farm sector.*

Global value chains

2. The Industrial Strategy to address the potential to increase participation in the system of Global Value Chains (GVCs) - on the basis that innovation and broader competitive positioning can be enhanced by:
 - a. Developing and widely disseminating statistical data on the evolving nature and extent of Australia's participation in GVCs.
 - b. Providing commentary that highlights the implications for future competitive strategy throughout the sector.
 - c. Highlighting how developments in digital and genetic technologies are combining to create a revolution in agricultural productivity and value chain development.

The biologically derived economy

3. Commission a robust economic modelling-based assessment of the full direct and indirect (embodied) contribution of *biologically derived economic activity* to the Australian economy and deliver a base-line evaluation against which future progress could be calibrated.

The science and research system

4. Develop a national *Research, Development, and Innovation (RD&I) investment Strategy* that encourages collaboration and co-location across research organisations and in conjunction with industry to provide the necessary critical mass and avoid potential duplication of effort. This Strategy should address -
 - a. A balance in support for RD&I investments in new knowledge creation, translation, and competitive capabilities such as market development and global market positioning.
 - b. High priority National Challenges
 - c. Innovation related activities that help potential adopters of new technologies mitigate the risks encountered when investing in new concepts and methods.
 - d. Investment in *multidisciplinary* research that meets end-user needs.
 - e. Collaboration among researchers with complementary expertise and data sets across fields of research
 - f. Cross-sectoral capability (like LWA) to address environment and biodiversity issues across the rural innovation system
5. The Rural R&D for Profit Program be extended guided by a clear strategy and longer-term funding commitment.

Monitoring and evaluation

6. Develop a Monitoring and Evaluation Framework for RD&I Investment that delivers and maintains:
 - a. Nationally relevant data sets
 - b. Performance measures that give emphasis to ensuring the long-term sustainability of the industry and the environment

1. Introduction

Key points

- The Review is comprehensive and has drawn on a range of sources to reach conclusions and recommendations.
- As an essential component of Australia's rural sector, the effective performance of the rural innovation system is vital to Australia's economic future. The rural sector is very much part of the "new economy", particularly in developing, applying, and using advanced technologies.
- There are, however, many challenges that can be met with a vision and strategy for the sector involving national, industry, business, and the community commitment to future value creation.

1.1 Review purpose

This Review of the Rural Innovation System responds to Terms of Reference issued by the National Research and Innovation Committee² to:

... describe the performance and impact of Australia's rural innovation system. The project will collate and analyse evidence across a range of metrics to present a comprehensive review of the system's overall performance, highlighting areas of strength, opportunities for improvement, and gaps in our knowledge base.

Specifically, the project will:

- Assess the performance framework used to assess the national innovation system for application to the rural innovation system, and propose adjustments as necessary
- Identify and collate evidence against agreed metrics under the performance framework
- Identify gaps in the available evidence
- Develop a comprehensive report assessing the performance of Australia's rural innovation system in national and international contexts
- Recommend opportunities for improvement.

In responding to the Terms of Reference, this Report also addresses the fundamental question: "How does rural innovation (the successful application of new ideas/ideas successfully applied) drive change and improvement in public and private value creation for the economy, the rural industries, rural businesses, and rural communities"?

The specific requirements for the Review are set out in the Terms of Reference at Appendix 9.

1.2 Approach to the review

The Review has been undertaken based on:

- An extended process of Consultations involving 56 meetings with 100 participants from government, industry and business, and the research sectors over the period November 2017-February 2018. A further 70 people were invited to participate in Consultations but were not available. A list of participants is at Appendix 6.
- A research project on Global Value Chains aimed at achieving a better understanding of outcomes as reflected in the nature and extent of Australia's participation in Global Value Chains (GVCs). The results of the project are reflected in *Research Report No. 1*
- An *Expert Opinion Survey* to quantify the strength of opinion on a range of views and opinions put forward during consultations regarding system performance. These were presented as hypotheses that respondents

² The R&I Committee is an Advisory Committee to the Agriculture Senior Officials Committee (AGSOC) and is responsible for the oversight of the development and implementation of the National Primary Industries Research Development and Extension Framework (the Framework) and also provides advice on the overall performance of the primary industries research innovation system.

could indicate agreement or disagreement on a five-point scale. These are used in the narrative for this Report.

A total of 188 responses were received, representing a response rate of 30 per cent. Participants in the Survey are listed in Appendix 7, excluding 25 people who did not wish to have their participation publicised. Additional comments provided by respondents are included in Appendix 8.

- Research performance and impact analysis using Excellence in Research Australia (ERA) data and publication and citation data from the Clarivate Analytics' InCites platform (using *Web of Science* data). This material is included in Sections 5.4 (from page 91) and 5.5 (from page 97).
- Familiarisation with the extensive body of knowledge in previous government or government-commissioned policy statements, reviews and evaluations, industry presentations, contributions from the Learned Academies, unsolicited contributions from policy think tanks and global consulting firms, and scholarly material published in books, journals, and papers. These are referenced in the Report Bibliography from page 245.

1.3 Contemporary perceptions of Australia's rural sector

There is a view among some economic and other public commentators that the agriculture, fisheries, and forestry sector is an "old economy" industry. However, even a quick familiarisation with the sector indicates that *the rural sector is very much part of the new economy*, with the widespread application of advanced biology and biochemistry (including cell biology, microbiology, genetics), computer and data science, analytics, artificial intelligence, and robotics and mechatronics.

Consequently, the rural industries now compete against a myriad of other sectors for the new skills that the industry requires, including information and communication technologies, many branches of engineering, and data science and analytics. There are also reported shortages in the biological and marine sciences. *There is a substantial skills shortage, which constrains sector growth and productivity.*

There is an acknowledgement that more work must be done to make rural-based employment stand out and be attractive to young, talented people. Without more action to improve the sector's image, move it away from the traditional idea of the "noble farmer" and promote it as a genuinely fulfilling career choice, the perception of rural industries will exacerbate the skills problem.

Mick Hay, Managing Director of Rimfire Resources, a specialist agribusiness recruitment company, is passionate about raising the sector's profile to see it as exciting, global, diverse, geographically spread, and on the cutting edge of technology.

"When I speak to high school or university students studying agriculture or related subjects and degrees, I tell them they've absolutely made the right decision investing in a career in agribusiness."

Mick says, "External sector perceptions have certainly improved, but there's still more to be done. One of our sector's main challenges is that people don't really understand the full length, breadth, and depth of opportunities in agribusiness, and that's where there's room for us all to tell more of our success stories."

Mick is right because now is not the time for the sector to take its foot off the pedal. Yes, progress is being made, but if the industry is to grow as expected, make the productivity gains required to feed the world and keep abreast of new technology, we need more people to come across to agriculture. As Professor Pratley says, we must 'maintain the rage' about attracting talent to agriculture if we are going to be able to meet the needs of an expanding industry[iv].

<http://www.agrifutures.com.au/news/overcoming-the-agriculture-sector-skills-shortage/>

Australia's rural sector is a dynamic and vibrant part of Australia's economic system and vital to the nation's future economic performance. It connects to the systems that constitute the Australian economic, social, and environmental systems in multiple ways. It is undergoing fundamental change through a succession of "waves of innovation" over the last 100 years that have been having and will continue to have a transformative and disruptive influence.

2. Background: The Rationale for Public Investment in Rural Research, Development, and Innovation

This section addresses the question raised as a *front of mind issue* in the project, particularly during consultations: “why should governments invest in Rural Research, Development and Innovation”? The discussion below provides a snapshot of the extensive discussion in the academic, policy, and practitioner domains.

Key Points

- Public investment in rural science and research performs a major role in updating and extending the stock of useful knowledge. It underpins the education and training of the research workforce – in industry, government, and research organisations.
- Public research sits behind creating new scientific instruments, diagnostics, and treatments for animal and plant diseases.
- Public research enhances the capacity for solving problems and mitigating biological, chemical, and physical risks.
- Public research investment allows Australia to leverage participation in international R&D networks, offsetting the disadvantages of Australia's relatively small research capability.
- Public research performs a role of early-stage venture capital investment in high growth technology-based firms. Many of Australia's high performing rural enterprises grew out of public research.
- Public research can reduce technical uncertainty and risk in adopting and applying new technologies.

The academic, policy, and practitioner literature identifies several dimensions of the contribution that publicly funded research makes to economic and social development (B. R. Martin & Salter, 1996; Matthews, 2009; Reid, 2014):

1. To create national benefits, correct market failures and encourage "spillovers"
2. Increasing the stock of useful knowledge
3. Educating and training skilled graduates
4. Creating new scientific instrumentation and methodologies
5. Increasing the capacity for scientific and technological problem-solving in industry, government, and the social sector.
6. Leveraging international R&D investment and stimulating professional interaction
7. Creating new firms and improving business performance
8. Reducing technical uncertainty and risk
9. Preparedness in relation to unexpected events and incidents.

Comments about each follow

2.1 Create national benefits, correct market failures, and encourage “spillovers.”

The 2011 Productivity Commission Report, *Rural Research and Development Corporations* (Australia. Productivity Commission, 2011), argued that the basis for the government to invest in rural R&D on behalf of the community dovetails from unpriced ‘spillover’ benefits to third parties that often attach to research investments, but

... such spillovers do not automatically justify a government funding contribution. Many research projects that a private party would be willing to invest in without any contribution from government will generate spillover benefits for others in the community.

Thus, the key purpose of government funding should be to address instances where there are insufficient commercial incentives [or risks] for private investment in socially valuable R&D — or in

other words, where government funding will induce socially valuable R&D that would not otherwise have been undertaken (Australia. Productivity Commission, 2011).

Thirty years ago, prominent Harvard Emeritus Professor Lewis Branscomb, posed a simple rule about identifying the benefits of publicly funded research: "let the primary intended beneficiary pay for research" (L. Branscomb, 1998). Thus:

- If research is to serve a *firm's commercial interest*, it will be recouped in profits from that commercialisation; no government funds should be employed.
- If the *government makes the market* (as in defence); the government pays.
- If the *government invests in the nation's skills and knowledge, going far beyond the private investments justified by market rewards*, the people benefit; the people's government pays.
- When *firms under-invest* in relation to defined public interest, such as reducing environmental risk or accelerating medical progress; government and the private sector may share the costs.

The cost-sharing ratio should reflect the best understanding of the likely distribution of public and private benefits.

2.2 Increasing the stock of useful knowledge

Public investment in research has often been justified because universities, as 'communities of scholars' and publicly owned research organisations could produce the objective and *disinterested* information upon which national social and economic policies and industrial programs can be built. Citizens skilled in rational inquiry can develop, support and re-enforce those policies and programs. This has provided a case for extensive government funding of universities (Florida, 1999).

With public resources becoming increasingly scarce, this unrequited funding model has come under increasing challenge. Research organisations have responded by ensuring that academic work is revealed as actively constructed as *interested*. This occurs as governments and corporations provide resources to support defined areas of research and scholarly inquiry ("priorities"), and students pay for courses and programs in which content is developed and targeted for market segments.

Nonetheless, research funding organisations and governments value the contribution of universities and public research organisations and their brilliant scientists to produce knowledge that is prepared on an objective, independent and autonomous basis - free of commercial interest or bias. The results of this research are published in scholarly peer-reviewed journals and monographs that create a stock of potentially useful knowledge (Howard, 2004b).

Scientific and technological brilliance might remain as narratives in academic journals for many years: but they are available for future application and use by innovators grappling with contemporary problems or visualising opportunities. In this respect, there is a continuing and vital role for discovery and invention carried out in research and academic settings to extend the frontiers of knowledge.

Inventions and discoveries that may initially have been considered useless can become useful when adopted and applied through the insights, intuition, and ingenuity of innovators and entrepreneurs in business, government, or the not-for-profit sector. It follows that an innovator might not be the inventor.

More recently, aspects of public policy have sought to encourage research organisations to be more financially independent and achieve a return on their investments in the creation of knowledge assets. Selling the work of an institution for a profit (commercialisation) is a strategy that is often advocated as governments seek to provide a rationale for their research investments. There is a continuing

interest in commercialisation income (Licenses, Options and Assignments) and numbers of start-ups formed (Australia. Department of Industry and Science, 2015; Greenaway & Rudd, 2014).

There is a risk, of course, in encouraging universities to focus too heavily on undertaking useful research and its commercialisation that capacity for discovery and fundamental research that corrects renews and extends the accumulated stock of knowledge will be dissipated. While that stock is reflected in patent portfolios, it is also held tacitly by eminent scientists and in facilities and teams at research centres and institutes across the country.

This is a critical issue to address in fields of research that are unique to Australia's agricultural, biological, and environmental characteristics.

There is a concern across the research sector about the declining numbers of mid-career researchers who will become the esteemed scientists of tomorrow.

2.3 Educating and training skilled graduates

It is often argued that the most important form of knowledge transfer occurs through the minds of educated graduates (Howard Partners, 2005). It is not a simple transfer as graduates must often learn how to translate theory-based knowledge into practice-based knowledge for application in commercial and public sector contexts (Bradley et al., 2008).

In Australia and many other countries, there is an acknowledgement that very few people who undertake PhD and post-doctoral research will be able to build academic careers based on that knowledge. There is a concern among universities that businesses do not value PhD qualifications - although they are highly sought after in the public sector in the agricultural, biological, and environmental research domains.

Consulting firms recruit PhDs from *any* discipline because they have demonstrated a cognitive ability to identify and articulate a problem and set about solving it. This is potentially a significant misallocation of resources earmarked for public research (Sharma, 2013).

There is a tradition of research and industry engagement in post-doctoral and PhD programs in the USA and Europe. This is beginning to emerge in Australia, particularly in regional universities. UNE, for example, offers a Doctor of Philosophy (Innovation) as a project-based, a higher research degree that links professional and industry expertise with academic theory in creating innovation.

CSIRO has instituted an Industry PhD (iPhD) program that "seeks to attract high calibre candidates with the vision of developing Australia's future research leaders". It brings together partners from industry, universities, and CSIRO to develop Australia's future research leaders. The program actively promotes collaboration between academia, industry, and the research sectors to shape the future of industrial research training.

Many of the newly established AgTech and GeneTech companies employ staff with PhDs. For example, at Huon Aquaculture, 21 of their staff members in January 2018 have done PhDs. According to Fisheries RDC, "they have more academic power than the University of Tasmania in salmon farming".

With the growth of knowledge-intensive AgTech and GeneTech start-ups and new technology-based firms, the demand for staff and consultants educated to the PhD and post-doctoral level is likely to increase.

There will also be an expectation that staff will maintain contact with research institutions to keep abreast and update knowledge.

2.4 Creating new scientific instrumentation and methodologies

Researchers continually develop new equipment, laboratory techniques, and analytical methods to tackle specific research problems. Increasingly methods are embedded in software and Applications.

This is an area where there is a two-way flow of basic procedures and users of research results. However, there have been few attempts to assess the benefits of this form of public research activity. Innovation surveys rarely include the impact of instrumentation developed by publicly funded scientists (B. R. Martin & Tang, 2006).

Historians and biographers have shown many examples of scientific instrumentation or research methodologies bringing benefits to industry (Winchester, 2018). Analysis of university licensing shows that firms tend to license mainly research tools and techniques from universities.

Surveys have shown that the companies rate instrumentation as the second most important output of publicly funded research, particularly in pharmaceuticals, electrical engineering, and aerospace sectors.

In the rural sector, universities and research organisations have been active in developing new vaccines and methodologies associated with AgTech and GeneTech.

At the same time, the private sector is highly active in developing instrumentation, diagnostics and testing equipment used in research laboratories and paid for with public research funds.

2.5 Leveraging international R&D investment and stimulating professional interaction

Australian central government agencies (Treasury, Finance, and Prime Minister and Cabinet) have tended to be opposed to large research expenditure, particularly when annual budgets are being drawn up and have been strong proponents of the push to purchase research from overseas. There has been comparatively little appreciation that rural research can capture benefits in Australia because of some of the unique situations being addressed. The reality is that research is a global enterprise, and Australia should pull its weight in this endeavour.

Former Agriculture Minister John Kerin noted in his reference work, *The way I saw it; the way it was* (Kerin, 2017) that -

By having research expertise in Australia, we can also engage with both public and private sector research organisations overseas and interrogate and freely adapt available public research findings. For research to be effective in Australia requires that our researchers be 'in the game', be specialised and at the forefront of thinking and discovery. Otherwise, we go backwards regardless of those who ignorantly say that 'charity begins at home' (Kerin, 2017).

Kerin notes that it has recently been estimated that up to 86 per cent of Australia's wheat varieties have come from genetic material through the International Maize and Wheat Improvement Center (CIMMYT). Australia also contributes to the global seed vault of the world's genetic plant material held on a Norwegian island in the Svalbard Archipelago located halfway between the north of Norway and the North Pole. The collection contains some of the remaining examples of the wild races in nature of our major food crops.

Innovation is most likely to come from integrating knowledge and ideas and from insights garnered from many sources, nationally and globally. Some of these are technical, some practical, and others aesthetic.

Innovation is generally associated with groups of people and teams working collaboratively (and increasingly globally) rather than the sole inventor persevering in a stand-alone autonomous laboratory.

To keep Australian rural industries competitive on world markets requires ongoing research and thereby expenditure in what is still an emergent industry with new crops and products continually capturing consumer interest. While it is true that research in many industry areas is rapidly transferred overseas, it has been demonstrated that research into Australian agriculture and the environment can be captured here because of Australia's uniqueness or difference.

The research findings of other industrially developed and developing nations such as India are freely available, and Australia needs to have researchers capable of taking advantage of them. There are many trade benefits in having respected scientists and administrators with international reputations. Moreover, Australia must address research challenges with our neighbours and other countries, for example, highly transmissible virus diseases and plant and animal invasions.

Increasing attention is now being given to the contribution of 'the crowd' as a source of innovation insight (Libert & Spector, 2009; Surowiecki, 2004). Public and private organisations are tapping into the 'wisdom of the crowd' internationally through various crowdsourcing methods, including innovation contests, competitions, and tournaments (Terwiesch & Ulrich, 2009).

2.6 Increasing the capacity for scientific and technological problem-solving

Publicly funded research is allocated towards increasing scientific and technical problem-solving capacity in several ways. These are canvassed below.

2.6.1 Investment in research infrastructure

The Australian Government has invested in research infrastructure projects across Australia through a range of sources, including:

- The National Collaborative Research Infrastructure Strategy (NCRIS)
- The Super Science Initiative
- The Education Investment Fund (EIF)
- The Collaborative Research Infrastructure Scheme (CRIS)
- The Australian Research Council's (ARC) Linkage Infrastructure, Equipment and Facilities (LIEF) scheme.

Significant research facilities for rural research cover -

- Facilities owned and operated by the CSIRO, including the Australian Animal Health Laboratory (AAHL)
- Australian Plant Phenomics Facility - measures the phenotype (physical attributes) of plants leading to the development of new and improved crops, healthier food, more sustainable agricultural practices, improved maintenance and regeneration of biodiversity and the use of crops to develop pharmaceuticals.
- National Imaging Facility (NIF) – a national network that provides state of the art imaging of animals, plants, and materials for the Australian research community.

State Governments have major investments in research facilities through State Agricultural Research Institutes, often collaborating with universities. Universities have also developed strong research and problem-solving facilities by creating research infrastructure.

Australian rural research infrastructure is extensive, although capabilities and performance are not well known outside the research sector and the organisations that invest in them.

Further information on research infrastructure asset creation is included in Section 5, Appendix 2, and Research Report No 3, *Key Institutions in the Rural Innovation System*.

2.6.2 Fixed-term investments in research institutes, centres, and projects

The CRC program is a highly regarded framework for fixed-term investments using public research funds. Apart from the CSIRO, it is one of the few Commonwealth research investment programs that has lasted for more than 20 years (it was established in 1992).

The CRCs have been exceptionally successful and have assisted the RDCs, the CSIRO and the universities to spend some of their funds more effectively. There have been four major Reviews of CRCs since their inception in 1992 (Australia. Department of Industry Science and Technology, 1995; Howard Partners, 2003; Miles, 2015; O'Kane, 2008).

From time to time, governments make substantial investments for the formation and operation of national or state-based research centres and institutes, intended to function on a fixed-term basis – usually between three and five years, sometimes with provision for review and renewal. There are many forms and models of fixed-term research institutes. While many are funded by the leading research investment agencies (ARC and NHMRC), some are supported by departments and agencies with specific policy remits. A competitive application process mostly determines investment decisions.

Universities also support fixed-term research institutes and centres with autonomy and independence from mainstream research and faculty administration. It is usually required that such centres demonstrate a capacity to achieve research excellence and be financially viable (usually through teaching, external funding, and commissioned research income).

RDCs also invest in research institutes, centres, and longer-term projects on a fixed-term basis – for example, the Precision to Decision project and the UNE Smart Farm project.

Many fixed-term investments tend to be formed around the endorsement of program and project objectives rather than explicitly building institutional research capacity and capability. The NH&MRC has invested on a continuing basis in several national health and medical research institutes. Their continuation is closely connected to the capacity and reputation in world-class research and leading-edge clinical practice.

The Commonwealth has continued to support CSIRO and its predecessor organisations for more than a century in agriculture. A very high proportion of its work is still in food and agriculture. State Governments have supported leading agricultural research institutes over many years.

There is little research on the effectiveness of fixed-term investment models for research and innovation in terms of governance, organisation, and capacity to achieve results.

2.6.3 Investments in construction and maintenance of databases

Governments have invested in developing and maintaining databases and scientific collections over many years. These can be important as a research resource and a reference point for animal and plant security.

Australian Plant Pest Database

The Australian Plant Pest Database (APPD) is a national, online database of pests and diseases of Australia's economically important plants, providing the rapid location of voucher specimens and efficient retrieval of detailed data.

With access to over 18 existing plant pest collections ('contributing databases') the APPD has access to over one million pest voucher specimens making it possible to quickly retrieve details of insects, nematodes, fungi, bacteria, and viruses that affect plants of economic and ecological significance.

This information provides a powerful tool to assist bids for market access and to justify measures to exclude potentially harmful, exotic organisms, help in emergency plant pest management, and support relevant research activities.

<http://www.planthealthaustralia.com.au/resources/australian-plant-pest-database/>

2.7 Creating new high growth firms

There has been a long-held policy interest in creating new technology-based firms (NTBFS) based on applying knowledge generated through research. Creating new companies by graduating (or non-graduating) university students and academic staff, based on research results or knowledge acquired through education, is also an important mechanism for "commercialising" academic research results. Often these companies are formed independently of a university or research organisation and the involvement of technology transfer offices.

In the past five years, numerous technology-based companies have been created to develop and market products that apply information and communication technologies (ICT) and deliver services based on a range of digital and data platforms.

Once a new company is created, graduate students are often hired to pursue further product development.

ARC Linkage Grants are often sought to support this research. Grants under the Entrepreneurs Program have also been awarded to many companies in this category. Considering the success of many of these companies, the industry impact of knowledge diffused in this way is likely to be substantial. In many cases, larger companies eventually acquire the start-up companies, thus providing more resources for continued product development and more extensive marketing (National Academy of Engineering 2003).

2.8 Reducing technical uncertainty and risk

There is a widely accepted premise that many potential innovations require investments in reducing *technical uncertainty and risk* (via increasing the likelihood of success and decreasing the likelihood of failure) (Bernstein, 1996; L. M. Branscomb & Auerswald, 2001; L. M. Branscomb et al., 2000; Hartman & Meyers, 2001; Matthews, 2005, 2015, 2016; Matthews & Frater, 2003; United States. Advanced Technology Program, 2000)

These investments may be significant, and the uncertainty may not be resolved with available technological know-how (or simply, the project may not work). This gives rise to levels of risk that may

be commercially unacceptable, although there are potentially significant knowledge spillover benefits to the industry and the economy.

Knowledge spillovers collectively reduce the investment risks numerous firms and entrepreneurs face – acting both in specific geographical locales (such as an innovation precinct or cluster) and/or for industry segments. Each entity stands to benefit from the shared experiences of other entities grappling with similar challenges.

Competitive advantage is created by firms being better than average at navigating investment risks.

For example, experienced 'serial' entrepreneurs will tend to face lower than average investment risks when innovating because they are better positioned to judge, and cope with, the risks they will face. This advantage can be reflected in a less severe 'valley of death' (less deep and/or shorter duration in negative territory) than average (most importantly) access to and cost of capital. For investors, risks can be spread using pooled funding arrangements, typical of the venture capital investment model.

As indicated in Section 2.1 above, the *sufficient* reason for public investment (including subsidised collective investment through an RDC) is the potential for interventions to create and/or amplify broader *spillover benefits*, or *additionality*, that are desirable from an industry development and national or state/territory economy perspective.

From this perspective, intervention rationales must weigh up the potential public and private benefits enabled by public spending that creates *additionality* that can amplify *spillover driven* reductions in the investment risks businesses face.

The more effective these interventions, the greater the reductions in investment risk and, therefore, the potential to create (or defend) jobs, value-added and asset values in rural industry supply chains in ways that would not otherwise occur.

2.9 Prescience and preparedness

Another aspect of uncertainty and risk management impacted upon by science and R&D is how research outcomes are expressed in a better grasp of the uncertainties and risks that we may face in the future – “prescience” - and the responses that we make that aim to reduce the future impact of these uncertainties and risks – “preparedness” (Australia. Productivity Commission, 2007; Matthews, 2006, 2009).

Prescience emphasises how public science translates substantive uncertainties about what may happen into the quantifiable risks (likelihoods and consequences) that drive efforts to mitigate these risks.

For example, research on biosecurity concerns aims to identify, understand, and then mitigate the threats posed by pests and diseases to rural industries. When a new, undetected threat is identified, biosecurity research kicks into gear. It sets out to understand often complex processes of cause and effect to develop and (if possible) test and/or model ways of dealing with the threat(s) that have been detected.

The information generated by this type of biosecurity R&D is usually widely disseminated to alert stakeholders to new threats (prescience) and provide practical advice on gearing up to deal with these threats (preparedness).

The economic impacts of potential biosecurity threats can be understood in (broadly) the same manner as the “valley of death” syndrome. Risk-adjusted net present value (NPV) estimates factor-in widely available information relevant to both prescience and preparedness, reducing the likelihood of encountering “nasty surprises”, i.e., unexpected, and highly disruptive shocks to production and asset values.

These critical processes of factoring in risks mean valuable economic outcomes arising from science and R&D, which may be invisible or harder to measure directly than patents, start-ups, etc., *but* can have significant national economic impacts, for example, by mitigating threats to stocks of plantation or native standing timber.

The critical difference between this prescience and preparedness impact pathway and the conventional innovation impact pathway is that translating uncertainty into quantifiable risks allows Expected Value (EV) estimates.

Without prescience outcomes, businesses (and governments) cannot use risk management tools and techniques to prepare for economic and environmental threats with any precision and priority. For example, R&D aimed at breeding disease resistance or drought tolerance into crops should be driven by a better understanding of the long-term risks these crops will face due to climate change and other threats.

2.10 Conclusion

Consideration of accountability, transparency, and value for money requires the development of principles and guidelines to guide the investment of public funds. These generally relate to developing a “business case” for investment that cover objectives, matters related to cost, risk, and expected return, how success will be measured *for the industry and the economy*, and arrangements for ongoing monitoring and reporting.

Several RDCs have spread this risk by supporting early-stage venture capital funds and other investment vehicles.

The approach described above provides a robust and coherent framework for developing and assessing accountability, transparency, and value for money in ways that explicitly recognises this important investment risk management dimension. The ability of public sector intervention design and implementation to balance the need for the calculated risk-taking that amplifies knowledge spillovers in innovation is central to these considerations.

Being too risk-averse or not risk-averse enough both limit the ability of these interventions to make a difference and demonstrate value for money. The trick is to maximise the odds of getting the best possible balance in this respect. This is especially challenging for the public sector because restricting investments to those that the private sector would be able to handle eliminates the ‘public value’ of this use of taxpayers’ funds and displaces private investment. However, investing in highly uncertain opportunities risks wasting taxpayers’ funds.

Neglecting the prescience to preparedness impact pathway via which science and R&D generate (in the final analysis) public value distorts where we look for valuable outcomes by placing an unwarranted emphasis on innovation over other critical outcome pathways.

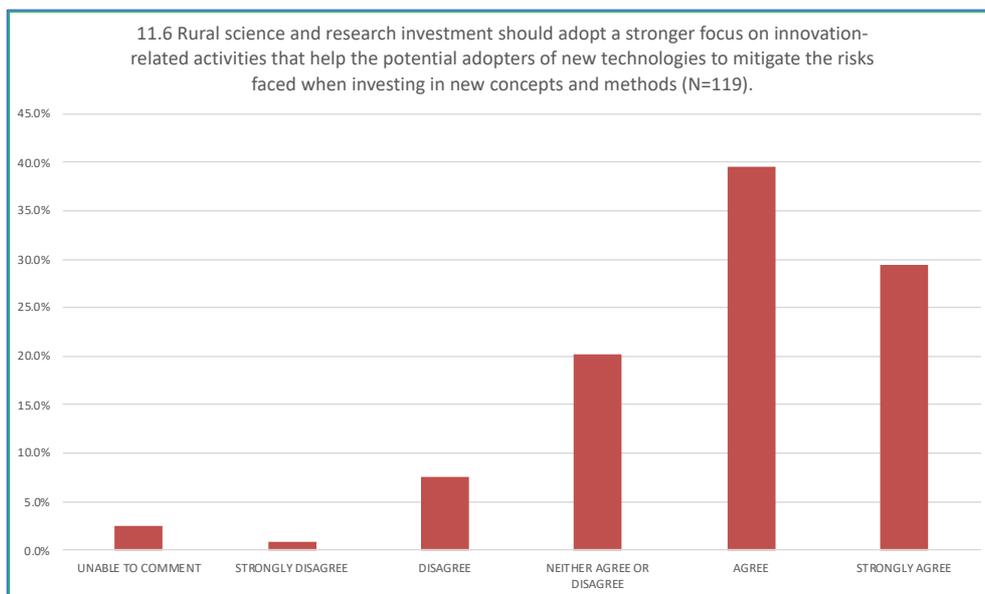
This means that decision-making for public investments must use transparent methods that are (ideally) most sophisticated than those used in the private sector – reflecting governments’ distinctive role as ‘uncertainty and risk manager of last resort.’

In the Expert Opinion Survey, rural Innovation Experts were asked for their opinion on the proposition that:

Rural science and research investment should adopt a stronger focus on innovation-related activities that help the potential adopters of new technologies to mitigate the risks faced when investing in new concepts and methods

Responses are reflected in Figure 3

Figure 3: RDI focus on innovation-related activities that help the potential adopters of new technologies to mitigate the risks



The Experts agreed with the proposition.

3. Context, Challenges, and Opportunities

Key points

- The Primary Industries Ministerial Council has endorsed a set of Primary Industries Research, Development and Extension priorities, but these are not widely known outside the sector.
- The rural production system is undergoing change because of the impact of current and future technology opportunities.
- The rural innovation system underpins the rural economic system in a complex and dynamic way.
- There are several economic and social systems that interact with the rural innovation, including the education and training system, the rural and regional development system. The new enterprise development (entrepreneurial support) system
- The rural innovation system has evolved through several “waves”, beginning with mechanisation in the agrarian revolution of the 1700s, the emergence of agricultural sciences followed by the impact of the biological sciences, and more recently, the impact of digital applications, data, and analytics, and more recently in a “disruption” of the industry and business models with support for AgTech and GeneTech start-ups through greater availability of risk capital.
- The rural innovation and production system is being strongly impacted by the growing importance of Global Value Chains (GVCs), making a “connected” innovation approach even more essential.
- There is a growing appreciation of the economic significance of the “biologically derived” economy

This Report addresses the fundamental question: “How does rural innovation drive change and improvement in public and private value creation for the rural industry (agriculture, forestry, fishing industries), rural businesses, and rural communities”.

This question is being addressed regarding *food and fibre drawn from activities concerned with agriculture, fishing, and forestry*. It picks up the growing AgTech sector and “pre-production” issues around land, water, soils, and climate.

This Report also departs from the conflation that innovation equates to research and development (R&D). Too often, discussion of innovation defaults to a debate about expenditure on R&D and R&D outcomes.

Innovation is about outcomes; it is about change.

The starting point for the Review was “innovation is the successful application of ideas to create value”. This definition has several implications:

- Ideas can come from anywhere, including researchers, farmers, suppliers, and overseas. Ideas often come from needing to solve a problem or capture an opportunity.
- Ideas may be embodied in new technologies, including new varieties, breeds, chemicals, and types of equipment. Still, they may also be non-technological such as new approaches to branding, new business models, new organisations, new approaches to collaboration and coordination.
- The *application* of ideas is shaped by many factors, including capability, confidence in the future, the cost of capital, risk, the availability of advice, infrastructure to access inputs, information, and markets.
- An inclination to seek ideas and to assess and perhaps apply them is influenced by attitudes to change, growth and risk and incentives shaped by technological and market opportunities.
- Value creation is often in economic benefits but might also manifest in less tangible social or environmental benefits.

Hence, the opportunities for innovation and the extent to which producers pursue such opportunities are influenced by the myriad of factors that shape decision-making by the many actors in the innovation system.

Innovation can create value for all or some of the following dimensions:

- The economy
- Industry sectors
- Businesses, including but not limited to farmers
- The community, particularly rural communities
- The environment – including protection, preservation, and repair of natural capital assets
- Future generations.

There is no single or agreed, set of metrics relating to rural innovation performance. This Report addresses innovation performance from the perspective of a Research, Development and Innovation *logic framework* that reflects several systems that contribute to overall innovation performance and value creation in the dimensions referred to above.

3.1 The Innovation Science Australia (ISA) challenge for rural innovation

The recently published Innovation and Science Australia strategy, *Australia 2030: prosperity through innovation, a plan for Australia to thrive in the global innovation race*. (Innovation and Science Australia, 2017b) throws out a challenge for Australia's rural sector - Page 47:

Australia has 2.8 per cent of the worldwide market in agriculture, down from 3.15 per cent in 2000.

Australia has a similar profile to Canada regarding population size, GDP per capita, and annual wages. Yet Canada captures 4.2 per cent of the global agricultural market share, even though Canada has less arable land than in Australia, and agriculture contributes to a higher percentage of GDP in Australia.

Export activity can be stimulated by entering into new trade agreements and capitalising on existing ones. Australia has recently negotiated deals with China, Japan, and Korea. This is a promising development with good initial results (for example, a 12 per cent rise in agricultural exports to Korea).

Governments can stimulate export activity by entering into new trade agreements and capitalising on existing ones. More significant gains are expected to accrue from the China–Australia Free Trade Agreement with scheduled periodic eliminations of tariffs to 2026.

However, Australia has yet to conclude a free trade agreement with India and will need new contracts with the European Union and the United Kingdom after Brexit.

ISA identifies a critical issue for progressing rural innovation as defining a vision and how to get there – involving national, industry, business, community, and future value creation.

This must be done within the natural resource constraints that many other countries do not have.

3.2 Rural research priorities and strategies

In 2015, the Commonwealth Government developed a set of *farmer*-oriented priorities to target rural research, development, and extension (RD&E) investment. The Priorities, published in the *Agricultural Competitiveness White Paper* (Australia. Minister for Agriculture, 2015) are:

- advanced technology, to enhance innovation of products, processes and practices across the food and fibre supply chains through technologies such as robotics, digitisation, big data, genetics, and precision agriculture.
- biosecurity, to improve understanding and evidence of pest and disease pathways to help direct biosecurity resources to their best uses, minimising biosecurity threats and enhancing market access for primary producers.

- soil, water and managing natural resources, to manage soil health, improve water use efficiency and certainty of supply, sustainably develop new production areas, and improve resilience to climate events and impacts; and
- adoption of R&D, focusing on flexible delivery of extension services that meet primary producers' needs and recognising the growing role of private service delivery.

Through the Primary Industries Ministerial Council (PIMC), the Commonwealth, State and Northern Territory governments, the rural R&D corporations, CSIRO, and universities have developed the *National Primary Industries Research, Development and Extension (RD&E) Framework* to encourage greater collaboration and promote continuous improvement in the investment of RD&E resources nationally. PIMC endorsed the Framework, including the overarching statement of intent in November 2009 (National Primary Industries Research and Development Framework, 2009).

The Purpose of the Framework is set out in the following terms:

Innovation and RD&E are key drivers to improving productivity and Australia's competitiveness in the primary industries sector and making best use of Australia's natural resources under a changing climate and market place.

The National RD&E Framework facilitates greater coordination among the Commonwealth, State governments, CSIRO, RDCs, industry and university sectors to better harmonise roles in primary industry RD&E and promotes effective collaboration to maximise benefits to Australia.

Agencies will build capability in fields strategically important to their jurisdictions and industries. Over time, capability will be consolidated into stronger national centres or networks, and it will become more apparent where prospects in a particular industry or field lie. Agencies may also exit capability in some areas that are not strategically relevant³.

The Framework Outcomes are reproduced below.

National Primary Industries RD&E Framework Outcomes	
1.	To provide shared strategic directions and priorities for national and sector level primary industries RD&E in Australia that enhance the productivity and resilience of Australia's primary industries.
2.	Research capability will more comprehensively and holistically cover the present and future strategic needs of stakeholders nationally.
3.	Public research capability will become more integrated, interdependent, and specialised, and have larger critical mass with less fragmentation across the nation.
4.	Efficiency and effectiveness of RD&E will be improved and therefore returns on investment will improve.
5.	RD&E investment will improve the capability of the national system in priority areas and ensure effective and efficient use of resources, including infrastructure.
6.	The Parties will collaborate to retain and build capability in fields strategically important to their jurisdictions and industries.
7.	The national research capability will be an integral component of a wider innovation agenda, supporting development and extension.
8.	Research undertaken in one location will be developed and extended nationally for primary industries.
https://www.npirdef.org/framework-outcomes	

PIMC has endorsed the following specific RD&E strategies:

- Fourteen sectoral strategies: beef, cotton, dairy, fishing and aquaculture, forestry, grains, horticulture, new and emerging industries, pork, poultry, sheep meat, sugar, wine, and wool.
- Four cross-sectoral strategies: animal welfare, biofuels and bioenergy, climate change and water use in Australian agriculture.
- Another four cross-sectoral strategies are underway: animal biosecurity, food and nutrition, plant biosecurity, and soils.

3.3 The rural innovation system and the rural economic system

Innovation is, quite simply, “the successful application of new ideas” (Dodgson et al., 2015). An *Innovation System* is a theoretical construct that describes “a system of interconnected organisations (public, private, and not for profit) to create, store and transfer the knowledge, skills and artefacts that define new technologies.” (OECD, 1997). There are many similar definitions from eminent innovation policy analysts around the world.

³ <https://www.npirdef.org/framework-purpose>

Rather than attempt to pin down a hard and fast definition of the rural innovation system, the following paragraphs address several issues concerned with what the innovation system is, what it does, and what it is not.

3.3.1 The innovation system is not the same as the economic system.

An innovation system is not the same as the economic system – a system for producing, allocating resources, and distributing goods and services within a society, an industrial sector, or a given geographic area. An economic system includes the combination of the various organisations, agencies, entities, decision-making processes, and consumption patterns that comprise a given community's economic structure. As such, an economic system is also a type of social system.

There is an overwhelming tendency to look at innovation systems in a structural framework and talk about the actual and potential interactions within it. A substantial component of innovation policy and strategy is directed towards improving connections and interactions to enhance economic performance. Improving the connections between research organisations, business, government, and the non-government sector is currently a major policy focus – and has been for many years. This is essentially an *efficiency* argument.

There is a surfeit of wiring/hydraulic/spaghetti diagrams that attempt to map innovation system connections. These often represent logical, normative, or even ideal representations. Still, they cannot capture the complications inherent in very intricate systems or the “switches” that may open or close connections at short notice.

There is a common misconception that innovation begins with creating knowledge and a progression occurs through transfer to application. But knowledge creation is itself a very complex system with a great deal of knowledge is created in the process of application.

Moreover, application and practice often bring forward the creation of new knowledge and integration of existing knowledge, which often stimulates the development of new theory.

The knowledge used in an innovation context may come from a variety of sources distant in time (it may be old knowledge re-used or re-configured) and location. It is increasingly likely to come from other countries.

3.3.2 The innovation system is complex, dynamic, and personal.

Innovation systems, like economic systems and business systems, are dynamic - they undergo constant change and adjustment. They reflect complex knowledge demand and supply interactions, but mainly without a robust market mechanism to coordinate them. However, there is still a legacy tendency to see innovation systems in transactional terms, such as the buying and selling of Intellectual Property. Innovation systems work based on sharing knowledge and building long-term trust-based relationships⁴.

⁴ A feature of innovation systems is the *sharing* of knowledge. For example, traditionally scholars take part in networks and go to conferences to *share* knowledge, to “give papers”, rather than sell it. People in business may, however, be motivated to go to conferences to generate sales or capture business opportunities. But, as scholars become more businesslike in sourcing research income and looking research collaboration opportunities, the boundaries are becoming increasingly blurred.

Innovation systems must be sufficiently agile, flexible, and responsive to new situations and circumstances with new industrial, trade, and market opportunities. The need for agility may strain established institutions and organisations, private and public, to respond to change.

These strains can be exacerbated where rules, cultures and established behaviours bind organisations.

Corporate Board risk aversion (dictated by financial institutions and shareholder value analysts) and university missions that focus on building eminence (through publication and position in global rankings) together with limited management talent (in business, government, and universities) provide situations that inhibit agility and flexibility.

Our recent work for Innovation Science Australia and this project confirms that improved connections cannot be built around structures and transactions: people work on a relational basis, created on a solid underpinning of trust. There is an adage - *people do business with people they trust*. From this perspective, social capital drives success – not the system divorced from that all-important social capital dimension.

In addition to improved connections between people and organisations, value-added economic and innovation performance is also be delivered by *investments* that build capacity and capability within the interconnected institutions. Innovation policy is concerned about the extent to which these investments have been or will be *effective* in delivering private and public value. There is the related consideration of *appropriateness regarding emerging trends, priorities*, and strategic policy objectives and directions.

3.3.3 The innovation system *supports* the economic system.

For policy analysis, it is helpful to approach our economy and society through the structure and functioning of many inter-related 'systems': an innovation system; entrepreneurial system, the industrial relations system, the financial system, the legal system, the biodiversity system, socio-cultural systems, the political system, the income security system, the public health system, the system of public expenditure management and control, the system of intergovernmental relations, and so on.

The innovation system (i.e., connections and connectivity) cannot be expected to do the heavy lifting for improved economic performance on its own.

Investments in many other areas, such as public infrastructure, including transport, communications (digital connectivity), energy, business investment in new and replacement assets, and the growth in private consumption expenditure, have had and will continue to have a major impact on economic performance.⁵

There are close relationships between the innovation system, science and research, and education and training. These relationships are complex and dynamic. While research in Australia is often an important contributor to rural innovation, there are many other drivers and contributors: imported

⁵ Consumer demand is, of course, the most important driver of economic performance. Since 1945 Australia has addressed this through immigration policies that have supplemented the Australian workforce for nation-building construction and the protected manufacturing industry. There is a current policy concern with low personal income growth, which is a drag on growth in consumption expenditure.

chemicals and equipment; new knowledge from overseas; opening of export market opportunities; adaptation by farmers.

3.3.4 The innovation system is not the same as the science and research system

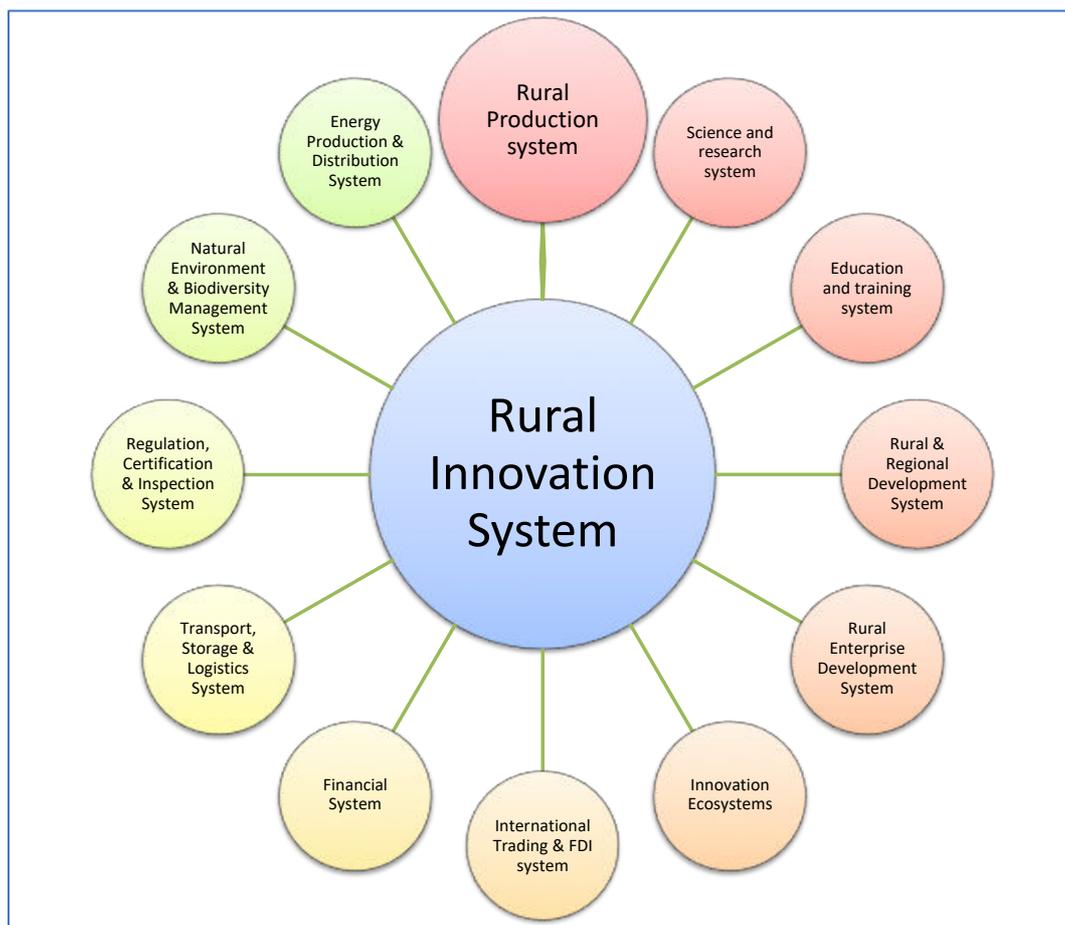
A discussion of the connection between science and research investment and innovation is provided in Appendix 3, on page 186 of this Report.

3.4 Complementary socio-economic systems: a challenge for systems integration

As indicated earlier, our view is that the regional innovation and economic performance is *the outcome of the interplay between several complementary, but separately constituted, "systems" that operate at a rural and regional level.*

A major challenge for rural innovation strategy is to ensure that the separately constituted economic and social systems are strong and robust and are well-integrated to ensure that value is created for the regional economy (for example, increase in regional gross product), for business and industry (sales, exports, profits), the broader community (jobs, wages, and living standards), and the natural environment (preservation of natural capital). These systems are represented in summary form in Figure 4 below.

Figure 4: Regional Economic Development: A Challenge for Systems Integration



Brief comments on each system follow:

- The *rural economic system* – the production, distribution and sale of food and fibre products and services derived from agriculture, fishing, and forestry activities.

- The *science and research system* – the production and translation of knowledge relevant and applicable to rural production that takes place in universities, Commonwealth and State Research Organisations, and the private sector.
- The *education and training system* – the education and training of people in universities, vocational education and training organisations, and schools who will work and/or establish businesses in rural production.
- The *rural and regional development system* – the economic, social, and environmental policies and strategies that encourage and sustain rural production and rural communities.
- *New rural enterprise development (entrepreneurial) system* – the business development policies and strategies that encourage and sustain existing and new businesses in rural production, including farm businesses and AgTech and GenTech start-ups.
- *Innovation ecosystems* (precincts, districts, co-working spaces) – relationships and connections between people and businesses that encourage development and growth in rural production
- The *international trading and foreign investment system* – the institutions and organisations that support trade in rural products and services and encourage investment in rural enterprises.
- The *financial system* – the banking, private equity, venture capital and other entities that underpin trade and innovation in the rural sector.
- The *transport, storage, and logistics system* - the economic infrastructure that supports rural production, and the opportunity for innovative solutions to reduce costs, increase productivity and create new value.
- The *regulation, certification, and inspection system* – the regulatory framework that covers rural production, certifies food and fibre health and provenance, and maintains food security and safety. Innovation in these areas can have a major impact on value creation.
- The *natural environment and biodiversity management system* – the natural capital that forms the foundation for much rural production, which requires innovation to ensure protection, preservation, and restoration.
- The *energy production and distribution system* – the production and distribution of energy required in rural production, including innovative approaches such as biomass and alternative energy sources.
- *The agri-political system* – the framework of political leadership, representation, and advocacy across the production system

We have not addressed in the Review the *rural health and community services system* which, in numerous ways, impacts on rural innovation and economic performance. For example, researchers are addressing innovative ways to address work health and safety issues and concerns. We have also not included discussion about the labour market and industrial relations system.

The performance of constituent socio economic systems will, in aggregate, contribute to rural innovation and impact on the capacity of the rural industries to deliver economic and social outcomes relating to productivity, competitiveness, social well-being and environmental sustainability.

3.5 Globalisation and global value chains (GVCs)

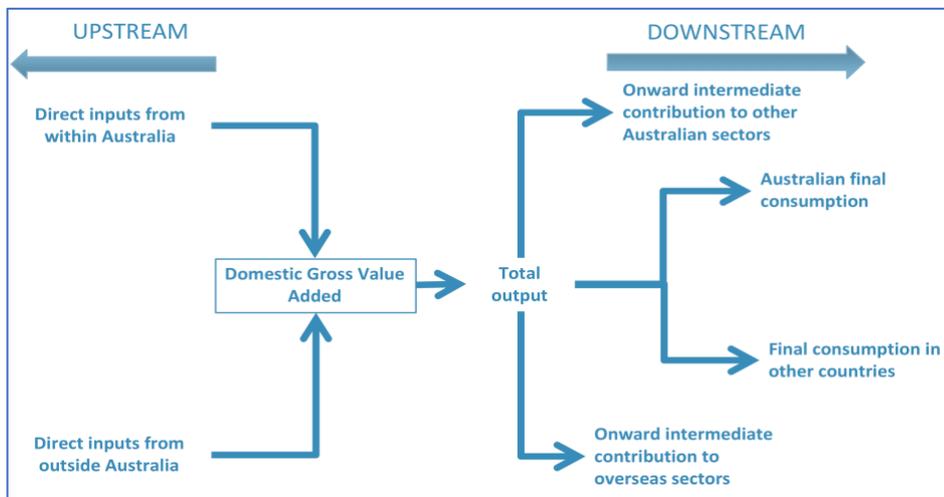
This Section specifically addresses that part of the project requirement to “develop a comprehensive report assessing Australia’s rural innovation system in national *and international* contexts” (emphasis added).

In general, ‘globalisation’ means that the level of value-added and hence (in general terms) productivity and employment, is driven by international linkages across global value chains (GVCs). This implies that innovations that facilitate stronger GVC participation will help to lift value-added and, in so doing, generate useful knock-on economic benefits.

3.5.1 Structure of a global value chain

Figure 5 provides a conceptual overview of the structure of a value chain. It highlights the ways in which the level of value added in an industry sector relies on inputs from both other countries and other domestic industries and on flows of outputs to both other industries and final consumption (including fixed capital formation) both in Australia and overseas.

Figure 5: Conceptual overview of a value chain



Source: the authors

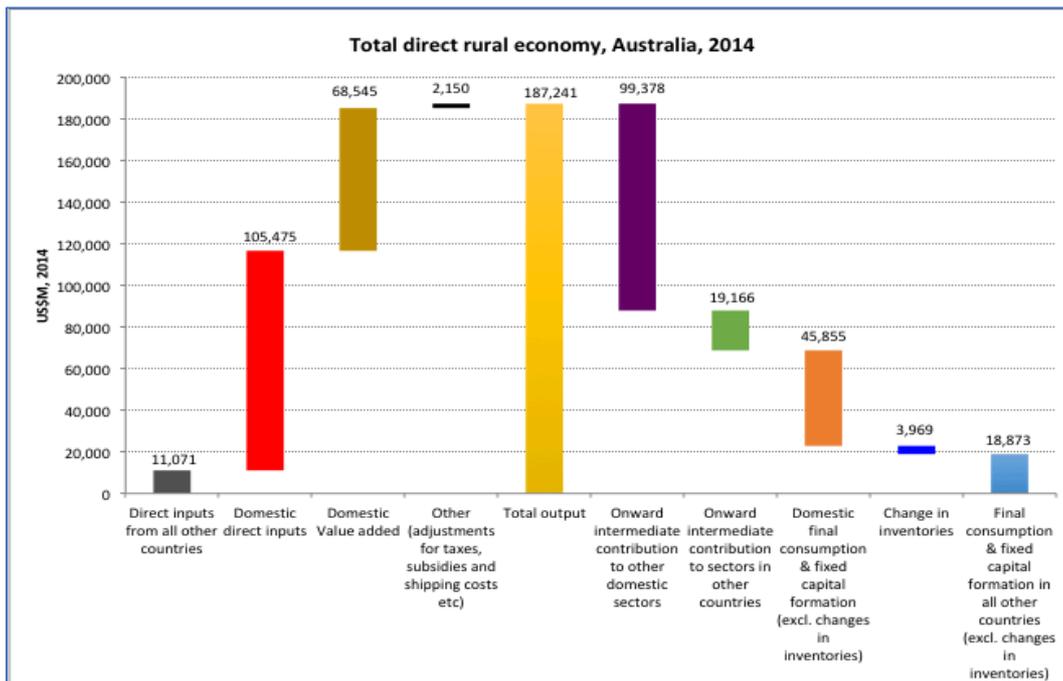
As a 'system', these dependencies provide a useful way of thinking about the role of innovation in the rural economy. Innovation shapes the relative dependence on domestic and imported inputs to value-adding activities. Innovation also shapes the inward flows upon which this value added relies.

From this perspective, as the analysis conducted for this Review demonstrates, Australia's rural industries are not strongly engaged with GVCs. Consequently, the potential to increase the economic contribution of the sector rests, in part, upon finding ways to increase GVC participation – there is a limit to domestic final and intermediate demand relative to global demand.

Critically, enhanced innovation performance can be a factor in driving success in increasing GVC participation – but is not in itself sufficient. It is broader competitive and industrial strategy considerations that drive increased GVC participation.

The Australian economy, when compared to a similar economy like Canada, has stronger correlations between value added and both domestic intermediate inputs and domestic outputs across different industries. Again, this points to Australia's relative lack of engagement in GVCs. Thus, Canada can benefit more easily and directly from economic growth in the global economy.

Figure 6: Illustration of Australia's value chain profile



Source: Analysis of the World Input Output Database.

3.5.2 The GVC approach to innovation

The GVC approach recognises that the success of individual national economies rests on competing over the shares of value-added in the global system – a competitive process in which onward ‘downstream’ economic success tends to be linked to adding value to imported ‘upstream’ inputs (what countries export is influenced by what they import, especially when high-tech inputs and capital equipment are required).

After reviewing the relevant literature on the innovation–GVC relationship, Matthews and Lacy concluded that a focus on GVCs impacts on innovation by providing a new and realistic imperative for competitive strategy:

When national innovation strategies shift their focus from nationally focused to internationally engaged performance, considerations for the frame of reference evolve to take into account international leverage opportunities i.e., how can we maximise the benefits we obtain from global engagement in value-adding?

A GVC-focus encourages innovation strategy to consider not just how exports will be achieved and the associated domestic value added increased (or protected), but how imports embodying technology and know-how will be leveraged to achieve this enhanced export performance.

In other words, recognition of the importance of GVCs encourages a more systemic approach to the global economy that considers the indirect/embodied drivers of competitiveness – not just the drivers that exist within a national boundary. (Matthews & Lacy, 2017).

This leverage-based approach has been further developed to consider the implications for sub-national innovation strategies specifically geared to exploit the potential for ‘connected innovation’.⁶ Namely a perspective in which:

- The effectiveness of a national innovation strategy can be amplified by treating it as a means of enhancing international participation in both Global Value Chains (GVCs) and Global Innovation Networks (GINs) – a recently introduced concept reflecting international collaborative arrangements in science and research.

⁶ SDG Economic Development (2018) *Building the Evidence-Base to Inform ‘connected innovation’ Strategies for Local Enterprise Partnerships: A prototype methodology*. Report commissioned by the UK Smart Specialisation Hub. Manchester, UK.

- This amplification effect stems from the ways in which both GVC and GIN participation acts as pathways for exploiting a range of useful knowledge spillovers via which broader global capabilities and substantial international investments are leveraged.
- Consequently, national investments in innovation that allow contributions to GVCs and GINs can yield amplified returns via the substantial international knowledge spillovers thus enabled. These global leverage opportunities are restricted by national strategies that fail to recognise the long-term significance of this international connectivity (Matthews & Lacy, 2017).

This innovation connectivity-based focus shifts the main emphasis in innovation support away from a 'go it alone' ethos in which the domestic 'means' are treated as the primary way of meeting domestic objectives ('ends') and towards an amplification/leverage-based strategy that develops solutions to domestic goals through internationally engaged approaches.

A 'connected innovation' approach linked to GVC participation facilitates an approach to innovation that recognises the varied ways in which innovation both influences relative prices and is, in turn, stimulated by changes in relative prices. For instance, anticipated rises in the price of production inputs (e.g., water) encourage innovations with the potential to economise on the use of that input and/or create opportunities to substitute new, more cost-effective inputs (e.g., fertilisers that require less energy to produce them).

Similarly, imported inputs to production will become most costly to purchase if the Australian dollar becomes weaker relative to the currencies of the countries from whom these inputs are being imported. This will tend to stimulate efforts to substitute domestic inputs, a process that may require new types of innovation.

The impacts of rural innovation are best understood from the perspective of the inter-twinning of scientific and technological factors and relative prices and associated risks to commercial success.

Using data that can profile changes in the structure of value chain over time, therefore, provides a coherent and comprehensive context for understanding rural innovation.

From this perspective, success in innovation in a national context is reflected in defending, and enhancing, these shares of global value added in production chains. Whilst there are multiple pathways via which innovation impacts upon shares of global value chains, some direct and some indirect, the over-arching principle is that innovation effectiveness correlates with changes in GVC participation. Consequently, many of the metrics used to try to capture innovation outputs and outcomes (patenting etc) are, in effect, intermediate and enabling measures.

In a global economy, the litmus test of innovation effectiveness for both sectors and for national economies is whether shares of the value added in GVCs is increasing or decreasing – and which countries and sectors are either gaining shares at our expense or, more positively, losing shares to us.

Whilst complementarity between different sectoral and national shares of GVCs is inherent in the concept, the sectors and national economies that best exploit this complementarity are those that prevail in global competition.⁷

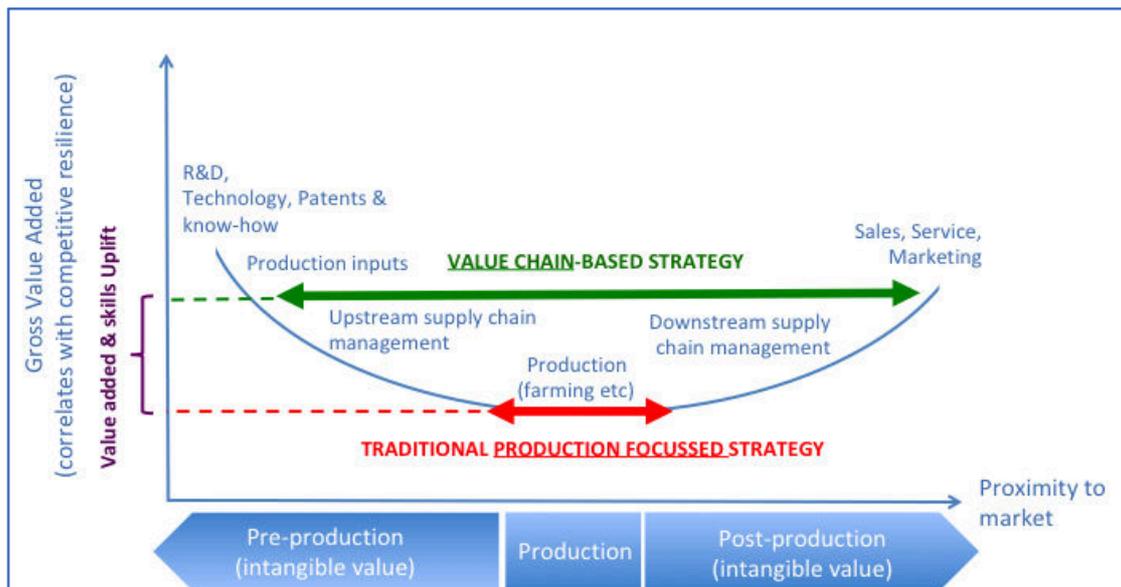
⁷ Howard Partners, via their partnership with SDG Economic Development in the UK, have helped to draw attention to this link between innovation strategies and GVCs – as reflected in the Discussion Paper on 'Innovation Strategies and Global Value Chains' commissioned as part of the process of developing Australia's National Innovation Strategy, see Matthews and Lacy (2018). This work is only possible because of the pioneering efforts of the OECD and other international bodies to produce readily accessible data on the structure and performance of global value chains.

3.5.3 How innovation performance drives participation in GVCs

The following diagrams summarise the main pathways via which innovation performance drives participation in global value chains.

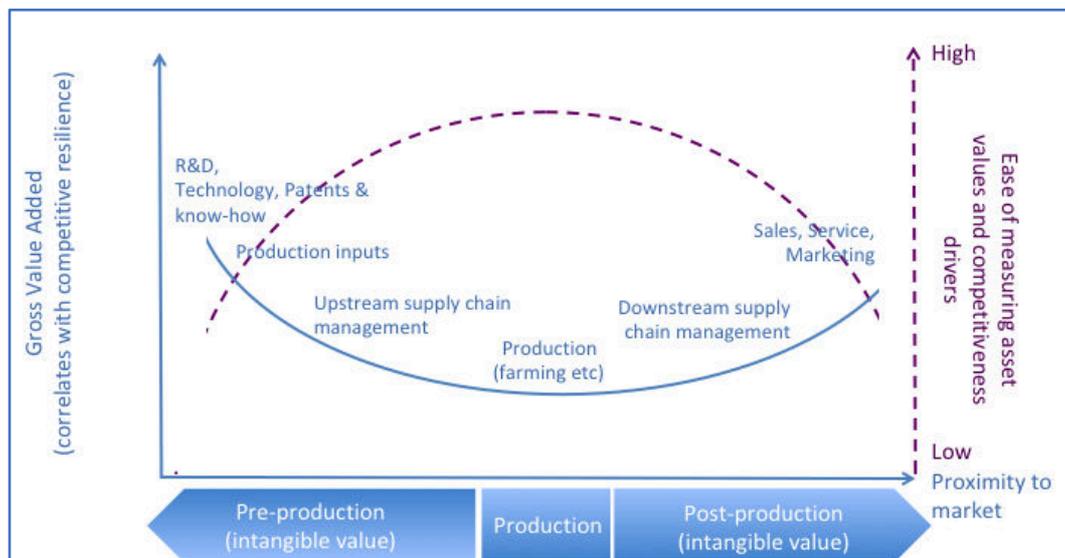
The first, Figure 7 is a version of the well-known 'smiling curve' relationship between position/span in value chains and the level of value added. It highlights the higher value-added associated with activities removed from production per se. The second, Figure 8 highlights the inverse relationship between the value-added curve and ease of measurement.

Figure 7: Production versus Value Chain Approaches to Innovation



Source: Based on Shih (1996), and taken from SDG Economic Development (2018)

Figure 8: Measurement Challenges for Value Chains



Source: SDG Economic Development (2018)

Unless progress is made with measuring and demonstrating how global value chains and configured, and are evolving, innovation strategies risk being too focused on the lower value-added production segments of value

chains whilst neglecting the important higher value-added, but harder to measure segments.

The logical solution is to seek to use data on value added in global value chains – a focus that starts by considering how value added is created via links between activities in different sectors and national economies. Innovation is then treated as one of the drivers for changes in the structure and performance of these global value chains.

The literature on global value chains highlights the way in which upgrading can be achieved by strategies focused on lifting value-added contributions to GVCs that use innovation as part of a broader competitive agenda. Four strategies are identified, as summarised in OECD (OECD, 2013b) these are:

- *Process upgrading* is achieved when firms can undertake tasks with significantly greater efficiency and lower defect rates, and process more complex orders than their rivals. This tends to rely on firm-specific management skills and flexible organisational structures;
- *Product upgrading* is achieved when firms can supply higher value-added products than their rivals owing to their superior technological sophistication and quality and introduce novel products faster than rivals. This tends to rely on introducing advanced production technology, effective quality management and good designs;
- *Functional upgrading* is achieved when firms can provide competitive products or services in new segments or activities of a GVC which are associated with higher value added. For firms previously specialised in production, this means becoming competitive in upstream or downstream activities such as design or marketing. This requires sophisticated technologies and design capabilities together with strong marketing, brand visibility and extensions in retail and collaboration networks; and
- *Chain upgrading* is achieved when firms can participate in new GVCs that produce higher value-added products or services, often leveraging the knowledge and skill acquired in the current chain.

One example of a GVC-focused innovation tactic is the deliberate targeting of 'choke point' technologies, identified by McKinsey & Co, and reported in *Interconnected Economies* (OECD, 2013b).

'Connected innovation' strategies developed in the corporate sector apply in a rural innovation context - but crucially only if innovation is treated as an integral part of a broader GVC upgrading strategy rather than in a more stand-alone framing.

GVC upgrading strategies should also focus on the intangible segments of value chains. For example, developing and exploiting rural innovation intellectual property and know-how as *itself* an export that lifts GVC participation. Technologically sophisticated nations, including Israel have been prioritising this strategy. Consultations for the Review indicated that several RDCs are supporting this approach.

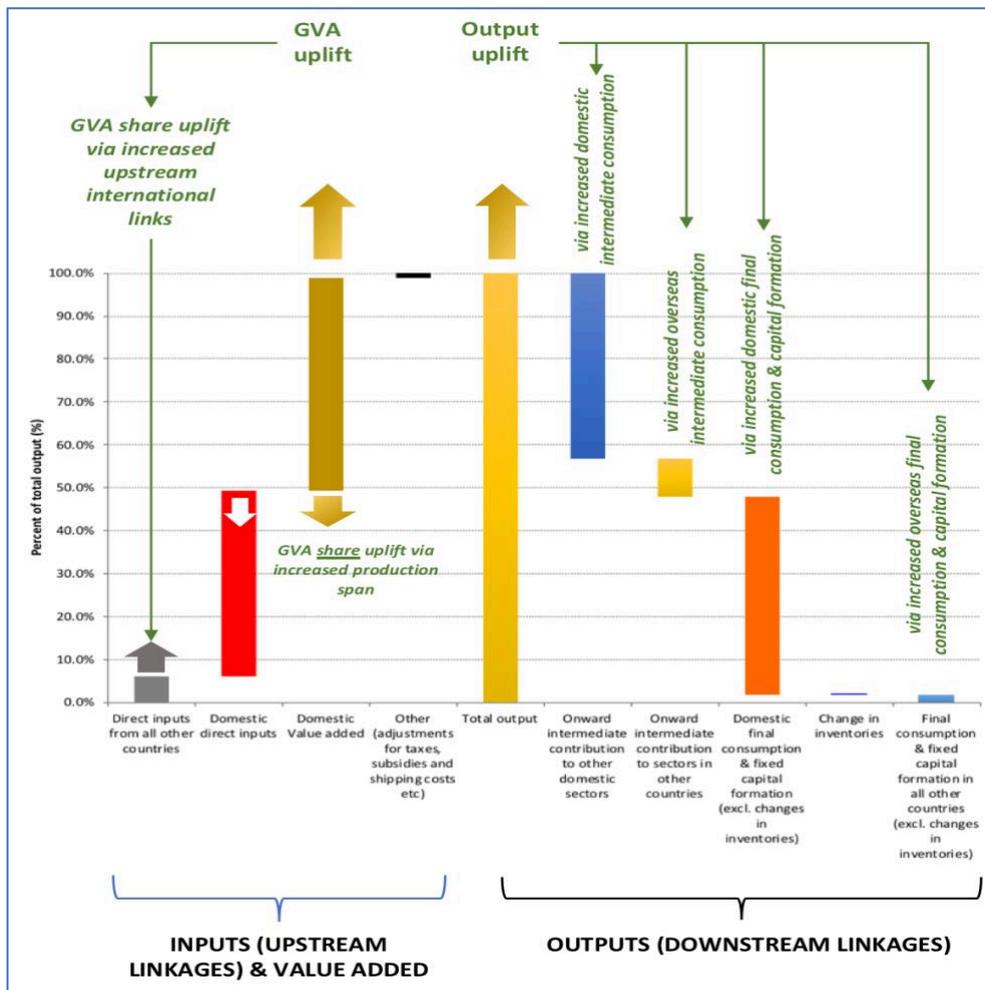
Consultations indicated that the value chain should be seen as the smallest unit of analysis in an innovation context.

3.5.4 Developing a Strategic Investment Framework around GVCs for Australia

From this perspective, a *Strategic Investment Framework* for rural industries can be framed as illustrated in Figure 9 below. This diagram, which is based on the actual GVC profile of the Australian

economy, shows how both output and gross value added (GVA) levels in an industry, or entire economy, can be increased by an effective industrial strategy.

Figure 9: Impact pathways for Industrial strategy



Source: the authors

On the input side, increased upstream international linkages can provide access to embodied technology, IP, and know-how not available domestically. This can, in turn, allow more globally competitive products and production processes to be implemented that increases GVA and/or output by onward 'downstream' sales as illustrated in the diagram. Similarly, improvements in domestic technology, IP and know-how can have the same sort of impact via downstream linkages.

The diagram also highlights the scope for increasing the GVA share of output by increasing the *production span* of an industry – substituting within industry value-added for inputs from upstream industries. This process is the reverse of the 'unbundling' of functions that has played such an important part of the growing prominence of the service sector in modern economies (Hagel & Singer, 1999). Namely, the ways in which functions previously performed within an industry have been outsourced into upstream industries (e.g., a farm procuring service inputs previously provided 'in house').

Whilst innovation can be an important enabler of these Industrial Strategy driven increases in GVA and output, as has been stressed throughout this Review, innovation *can be* a necessary condition but only very rarely a sufficient condition for industrial success.

Consequently, one advantage of this GVC participation-based Industrial Strategy framework is to highlight what innovation can help to achieve in the right sort of broader strategic 'package'.

As Figure 9 makes clear, the purpose of innovation is to help a *globally engaged* Industrial Strategy to deliver increases in value added, and secure the future of that value added, within a national economy by exploiting international linkages and capability.

3.6 Global value chains and distributed ledger technologies (“Blockchains”)

In any value chain, global or domestic, as with all production processes, productivity is strongly influenced by the likelihoods that materials and sub-assemblies will be in the *right place*, at the *right time* and in the *right state* (i.e., processed and quality certified as agreed). Productivity declines as these ‘place-time-state’ likelihoods diminish because error-tracing, troubleshooting, re-work etc are required, and sometimes, in-process and/or production outputs must be scrapped. Not surprisingly, maximising these ‘place-time-state’ likelihoods are a major emphasis in advanced manufacturing techniques and a familiar feature of Japanese high-reliability ‘lean production’ methods.

As production systems become more complex, the productivity consequences of low ‘place-time-state’ likelihoods can become very serious. This is mainly because this complexity in production systems can amplify problems. So too can limitations to the accuracy of the information available on these ‘place-time-state’ likelihoods. Indeed, limitations in the ability for production inputs to achieve high ‘place-time-state’ likelihoods are compounded by errors, inconsistencies, and uncertainties in the information available on the ‘place-time-state’ status. This can be thought of as a multiplicative relationship: a bad situation regarding the status of production inputs is made worse by information imperfections on ‘place-time-state’ status.

A GVC system represents an especially complex challenge due to the large number of participating firms and the profusion of cross-border transactions. Production inputs can be delayed because the import paperwork is missing or not correctly completed, uncertainties over where these production inputs are when in transit and other challenges can all be highly disruptive to industry.

Indeed, when we consider this inter-play of what is happening and what information systems *say is happening* that we can quickly grasp the importance of adopting *systems thinking* for GVCs. As the correlations between information and reality in a GVC system weaken, the damaging consequences of this mismatch tend to be amplified and cascade throughout that system. An ideal GVC has both perfect ‘place-time-state’ likelihoods and perfectly accurate information on actual ‘place-time-state’ status.⁸ A real GVC faces a myriad of challenges that stem from imperfections in both real flows of inputs and the information on the status of these inputs.

These systemic coordination challenges are addressed in the research literature on GVCs via work on value chain *governance* (Gereffi et al., 2005). This work emphasises the importance of the *complexity of transactions*, the how these transactions are *codified* and the differential *competence of suppliers*

⁸ The severe challenges that are emerging as the UK attempts to leave the European Union and new ‘boundary crossing’ arrangements are required that were previously unnecessary are a pertinent reminder of the importance of these issues.

in GVCs. Different modes of GVC governance are associated with specific combinations of transaction complexity, their modes of codification and levels of supplier competence.

Governance, framed in this manner, is critically important to GVC performance for the obvious reason that a complex system prone to generating 'nasty surprises' needs governing. For some GVCs a large multinational corporation (MNC) provides this governance function (setting standards for quality assurance, technical communication etc). But there are many types of GVCs, and their governance can pose a severe collective challenge especially when there is no single MNC GVC 'architect' and 'controller' – distributed authority requires distributed governance.

The severity of the distributed governance challenge in GVCs is driving a growth in interest in the use of what are known as 'distributed ledger' technologies, of which blockchain applications are currently the most well-known.

Distributed ledger technologies seek to provide a computational solution for verifying the accuracy of information on complex systems with distributed governance. They can also be used in MNC controlled GVCs. The aim is to eliminate misinformation via widely distributed and large-scale information validation. In a blockchain, all participants must validate (via complex calculations) new information added to the system. This can reduce fraud by using a form of 'voting' based consensus to validate and permanently record transactions⁹.

There are already significant applications of blockchain methods in agricultural value chains, for instance in 'provenance' certification – providing assurance that food products come from where they purport to come and have been checked as they were supposed to be checked.

As part of this Review we carried out an analysis of the potential importance of distributed ledger technologies to the rural industries by tracing the developmental trajectory of distributed ledger technologies back to the seminal work of Claude Shannon on the 'mathematics of information', (Shannon, 1948), the conceptual foundation for the information age. This work is set out in Research Report 1.

*The adoption of distributed ledger technologies in the rural industries opens potentially important innovation pathways beyond provenance and quality assurance per se. It creates opportunities to drive the evolution of rural industry GVCs **as a system** by fixing system performance limitations using robust information on "what does not add up".*

In summary therefore, distributed ledger technologies are poised to play a major role in lifting the efficiency and the effectiveness of GVC governance in general and will also play an increasingly important role in the future evolution of GVCs involving biologically derived inputs (especially for food and pharmacological products). Consequently, national participation in the developments and use of distributed ledger technologies should be a key feature of an Industrial Strategy for Australia's rural industries.

⁹ For example, IBM and Maersk are developing a blockchain solution for tracking shipping containers. Such systems have the potential to significantly increase the accuracy of real time information on the status of shipments and may result in large reductions in the transaction costs associated with managing the shipping aspect of GVCs.

Distributed ledger technologies are a clear illustration of the importance of intangible assets in global competitiveness.

3.7 Innovation in a framework of a biologically derived economy

An additional feature of this Review, also facilitated by the emergence of better data on global value chains, is that it draws attention to the benefits of considering the overall nature and extent of biologically derived economic activity. Many industries make use of production inputs of a biological nature. Examples are the wooden formwork used in concrete pouring through to fish oils in food supplements, and even animal fats in some 'plastic' banknotes.

3.7.1 Economic significance of the biologically derived economy

The pervasive impact of biological materials (and processes) means that rural innovation plays a current and potential future role in a myriad of ways, often very indirectly and via the ways in which downstream industries use a mix of biologically derived and non-biologically derived inputs.

Biologically derived inputs provide the 'feedstock' for a very wide range of biologically derived value-added downstream in value chains. This covers food production, textiles and a range of forest and wood products. There is also a growing appreciation of the interconnecting between food and nutrition, rural production, and the environment.

This biological feedstock is a national strategic resource. It sets the biologically oriented rural industries apart from other industry sectors that make up the Australian industrial system. In particular, the link between biologically derived economic activity and the 'circular economy' concept is gaining ground in industry policy discussions and initiatives.

Biologically derived economic activity aligns especially well with the circular economy ethos. This is because these processes involve naturally generated and re-cycled bio-chemical pathways that can be further enhanced by innovation and capital investment. This is clearest when it comes to re-cycling and re-purposing biologically derived goods and physical assets.

This approach has the advantage that it combines a familiar focus on the key industry sectors that act as this biological input 'feedstock' (agriculture, forestry, fishing, and aquaculture) and also a systemic appreciation of how this primary production then contributes through multiple pathways in modern economies. Rural innovation plays a key role in driving the productivity of these biological feedstock processes.

Innovation in biological systems now plays an important role throughout modern economies. The cutting-edge of technologies with biological applications now has the potential to create radical transformations both in specific industries and the economy as a whole.

It is becoming possible to use genetic manipulation to change both how familiar products grow (e.g., artificial animal meat) and to create entirely new types of grown products, potentially replacing products that have not been 'grown' in this biological sense. Possibilities here are wood-type cellular structures that can be self-healing and more easily decomposed than non-biological materials.

We are already witnessing a step change in the use of wood and wood products in buildings; hence these more disruptive and transformational technologies could further strengthen this use of biologically derived new materials.

In this context, it is also useful to note that the distinction between biological and non-biological materials and processes is itself a potential emerging area for innovation with non-biological materials adopting some biological characteristics such as self-organisation and replication and biological materials potentially adopting aspects of additive manufacturing/3D printing.

In short, therefore, it is useful that a review of rural innovation carried out in an era of such scientific and technological promise does not overlook this long-term potential. Innovation in this context covers existing familiar sectors (*Horizon 1*) but also more pervasive biologically derived aspects of extended value chains (*Horizon 2*) and, more radical transformational impacts over the longer-term (*Horizon 3*).

Given the relatively small scale of the Australian innovation effort (both overall and in more specifically rural aspects), and the potential for a wide range of cutting-edge science and technology to impact on biological material and processes, it is important to consider how Australia can play a key role in this larger global innovation context.

Restricting how we think about rural innovation to existing industries and overlooking the potential of international cooperation in innovation (with the associated step change in the scale and scope of work this enables), will in combination risk Australia missing out on some major opportunities.

Biologically derived sectors cover the cultivation of animals, plants, fish, fibre, and the environments in which this takes place – land, soils, rivers, and oceans. Biologically derived value-added is particularly important as the feedstock for creating value in several industry sectors –

- Manufacture of food products and beverages.
- Manufacture of textiles, wearing apparel, and leather goods.
- Manufacture of wood products and products of wood.
- Manufacture of paper and paper products.
- Construction.
- Wholesale trade.
- Retail trade.
- Accommodation and food service activities.
- Education.
- Human health.

There is potential for the greater application of Australian biologically derived output and reuse to create additional value in these sectors - and potentially others. Also, as noted above, there is a clear affinity and potential at the nexus between biologically derived economic activity and the circular economy.

3.7.2 Australia's current share of globally biologically derived value added

Given the importance of biologically derived economic activity, especially about strengthening the 'circular economy' in Australia, this Review has piloted new experimental estimates of the proportion of the national and global economy that can be classed as biologically derived.

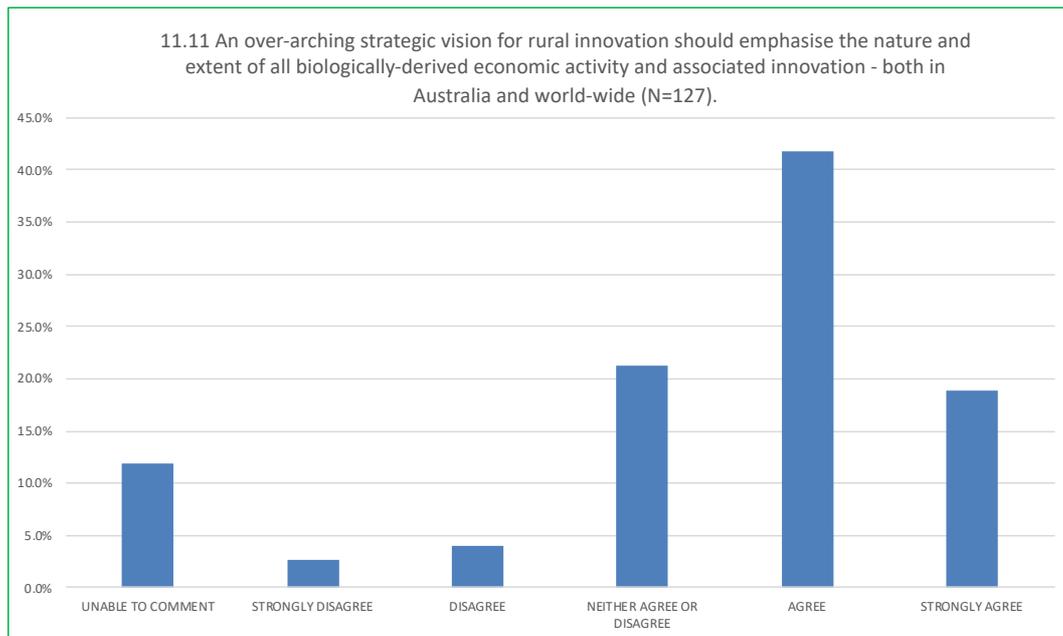
To do this, we analysed the new OECD Trade in Value Added (TiVA) datasets that capture the proportion of value added directly *and indirectly* in global final demand (i.e., 'flowed through' the

3.7.3 Feedback from Consultations and the Expert Opinion Survey

Consultations across the policy and research community, and follow-up in the Expert Opinion Survey, indicated a strong interest in pursuing the biologically derived economy discussion.

The Opinion Survey indicated a high level of agreement and strong agreement to the proposition that “An over-arching strategic vision for rural innovation should emphasise the nature and extent of all biologically-derived economic activity and associated innovation - both in Australia and world-wide”. This is indicated in Figure 11.

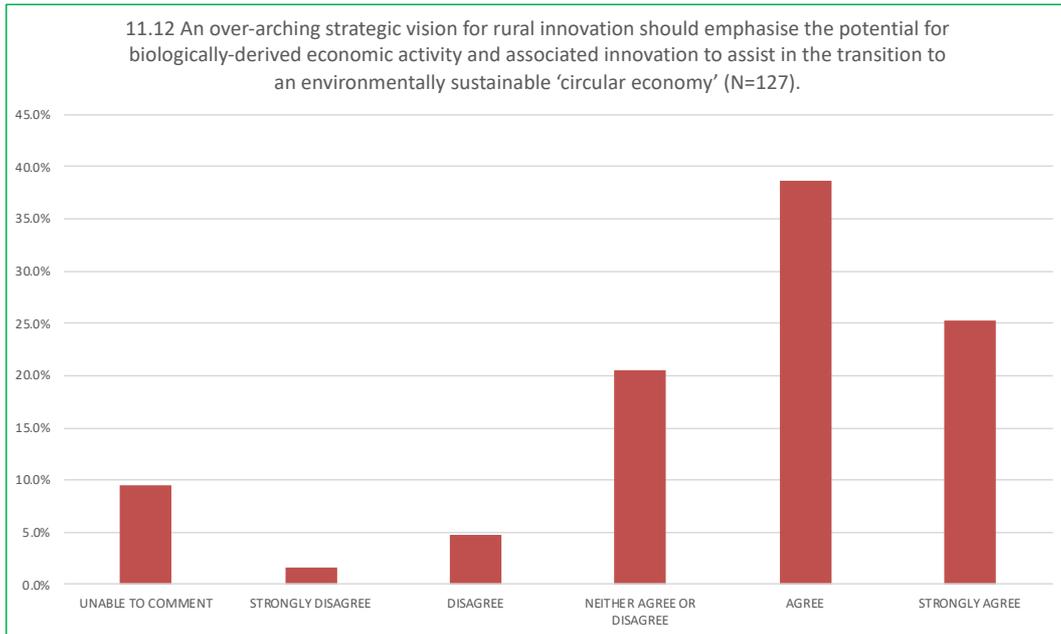
Figure 11: Expert Opinion Survey - Strategic Vision around the Biologically Derived Economy



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

There was also a positive response from Experts to the proposition “An over-arching strategic vision for rural innovation should emphasise the potential for biologically-derived economic activity and associated innovation to assist in the transition to an environmentally sustainable ‘circular economy’”. This is shown in Figure 12.

Figure 12: Expert Opinion Survey – Potential for Biologically Derived Economic Activity to Support an Environmentally Sustainable “Circular Economy”

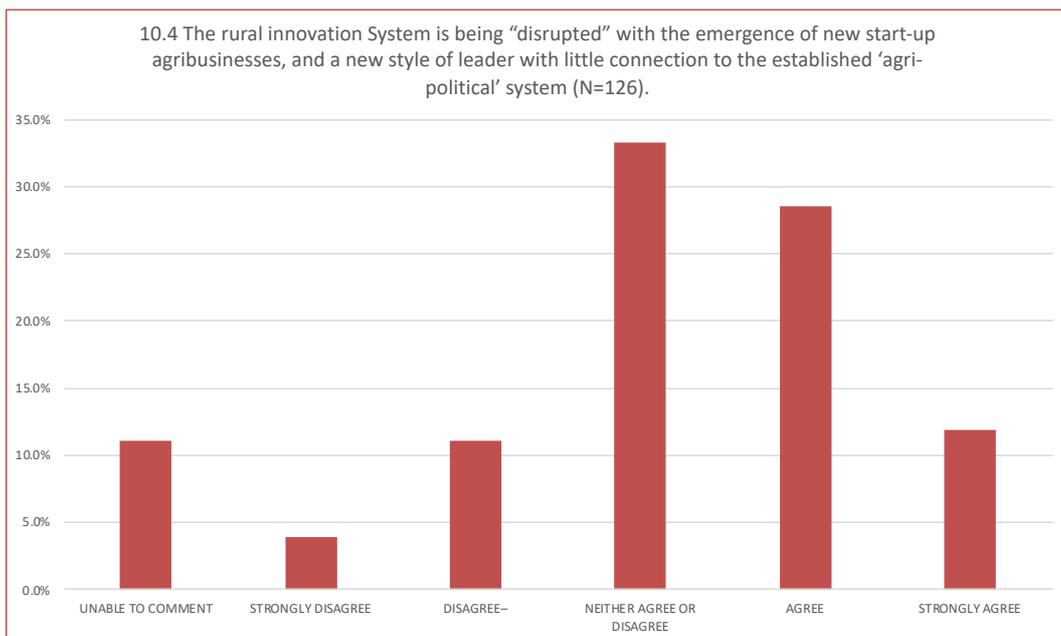


Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

3.8 Impacts of “digital disruption”

It is apparent from the Review that many stakeholders across the rural sector recognise that there is a process of ‘disruption’ taking place through the application of digital technologies, artificial intelligence, and the emergence of start-up firms pursuing a wide range of technology development opportunities, in a wide range of ‘AgTech’ and ‘GeneTech’ businesses. Responses are indicated in Figure 13.

Figure 13: Expert Opinion Survey – Change and Disruption in the Rural Innovation System



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

While 40 per cent of Experts agreed or strongly agreed, 35 per cent were ambivalent and a further ten per cent unable to comment. However, there was very little disagreement. The pattern of response may indicate a low level of awareness about the patterns of disruptive change in the rural innovation system.

3.9 Addressing opportunities and areas for further research

There has been no shortage of advice and analysis about the opportunities for improvement in the performance of Australia's rural RD&I system, and areas for further research. In Research Report 2 summaries of nine contributions from prominent organisations and constituencies over the last five years are provided.

1. The Food Innovation Australia Limited projections, 2017
2. Australian Academy of Science, *The Decadal Plan for Australian Agricultural Sciences: Grow. Make. Prosper*, 2017
3. CSIRO Futures, 2017. Food and Agribusiness: A Roadmap for Unlocking Value-Added Growth Opportunities for Australia.
4. Austrade, Investment Opportunities in Australian Business and Food, 2017.
5. The Australian Council of Learned Academies, *Australia's Agricultural Future*, 2016
6. CSIRO and RIRDC, Rural Industry Futures: Megatrends impacting Australian agriculture over the coming twenty years, 2015.
7. Business Council of Australia, Building Australia's Comparative Advantages: A 21st Century Agri-food Sector, 2015
8. Academy of Technological Sciences and Engineering (ATSE), *Food and Fibre: Australia's Opportunities*, 2014
9. National Farmers Federation, *Blueprint for Australian Agriculture 2013-2020*. 2013.

There is very little cross referencing of the many reports addressing rural innovation and building a cumulative picture of opportunities for performance improvement and step change in the system, and, how these are translated into system goals and objectives.

This matter is addressed further below in Section 5.

Few of the plans referred to above reflect the opportunities in Australia's food service sector, reflected in the statistical category accommodation, cafes, and restaurants. Demand in these areas is strong in the current tourism boom and in changing lifestyles as people move into high density living and small apartments. Flats and units, as small as 60sqm, are being built with small kitchens and limited food preparation facilities. This is combined with a growing interest in healthy eating and meeting demand for speciality foods.

Many legacy food service businesses have attracted the interest of private equity and venture capital investors with expectations of opportunities for turnaround and growth. For example, in September 2016, Pizza Hut in Australia was acquired by a venture investor from US-based parent company Yum! Brands, global owner of the Pizza Hut brand.

Together with technology platforms and opportunities through an increasing number of Apps, on-line ordering from supermarkets, restaurants, and other food preparation areas, has been on the increase. On-line food delivery services are predicted to become a \$4.2 billion industry by 2025. This is, however, placing pressure on returns to restaurants. It may also see a form of disruption to food delivery services. Many of the businesses entering the market commenced with new people and a start-up model.

3.10 Conclusion: Policy implications and next steps

Australia, along with many other nations, has a long history of public support for innovation predicated on the assumption that more innovation translates into higher economic growth (albeit via multiple pathways). Economic growth, in turn generates benefits in terms of social inclusion and wellbeing – mainly via higher levels of workforce participation than would otherwise be the case.

This Section has stressed the importance of ‘braiding’ together science and innovation capability with a range of complementary business capabilities (strategic marketing, knowledge and systems integration, supply chain management etc). The dividend to public and private investment in innovation is maximised when this braiding is effective but is constrained when this braiding is not effective.

The discussion on ‘Rural Innovation Outcomes and Global Value Chains’ has highlighted the ways in which innovation outcomes (or the lack of them) are reflected in participation in Global Value Chains. But that Discussion Paper also highlighted the importance of braiding together science and innovation capability with a range of complementary business capabilities rather than treating innovation *itself* as a driver of economic growth.

There are strong empirical and conceptual grounds for re-framing Australia’s approach to maximising the effectiveness of the rural innovation system as a broader Industrial Strategy challenge. Innovation is a necessary but not a *sufficient* component of an Industrial Strategy. An Industrial Strategy brings together a range of complementary public policy concerns in a way that has a greater likelihood of success than persisting with long-standing support for innovation in a more stand-alone manner.

A major policy implication from this Review is that Australia should re-imagine ‘innovation systems’ (and associated ‘innovation strategies’ intended to lift the effectiveness of these systems) as Industrial Strategy objectives. We do not require strategies for a rural innovation system (per se), rather a more focused and forthright Industrial Strategy for Australia’s rural economy.

This strategy would be most effective if it started by considering how our participation in Global Value Chains could be improved (the ‘ends’) and then moved on to consider how best to deliver on these strategic aspirations (the ‘means’). Other very important dimensions of this strategic approach would be to avoid making risky trade-offs when lifting participation in Global Value Chains: these Industrial Strategy pathways should be environmentally sustainable (crucially not running down our stocks of natural capital in the process).

The easiest way of doing this is to transition from the currently dominating ‘flow’ paradigm (focused on flows of GDP etc) and towards a ‘stock’ paradigm – the contribution of the rural industries to Australia’s national Net Worth. Indeed, Australia is fortunate in playing a world-leading role in producing comprehensive National Balance Sheets as part of the System of National Accounts. Australia is also playing a leading international role in efforts to factor natural resource degradation and depletion into the National Balance Sheet.

This focus on measuring natural capital greatly assists with the complementary emphasis on moving to a ‘circular economy’. A circular economy maintains rather than runs down our stocks of natural capital.

As a nation, we are particularly well placed to develop an Industrial Strategy for the rural economy because we have much better data to draw on than other nations. Our Industrial Strategy for the rural economy should, and can, focus attention on innovations that both lift our participation in Global Value Chains and that do this in an economically and environmentally sustainable manner.

Overall, therefore, this would constitute a world-leading example of public policy.

4. Issues Concerning the Performance of the Rural Innovation System

Key points

- There are many challenges being articulated for the rural sector, including a \$100 billion farm production output by 2030 and a national AgTech initiative
- The contribution of agriculture to GDP has been falling, but when put in a value chain context to include manufacturing and services, the contribution is much greater. A diversified AgTech sector, operating across the value chain is emerging, and attracting interest from investors.
- Farm profitability has been increasing, particularly for larger farm businesses – but the scope for increasing further returns is contingent on reducing *input* costs; anticipating trends in demand, and niche marketing will be a major driver of profitability for many rural businesses.
- Addressing demand side issues, including finding new customers, is fundamental for the future of the rural sector.
- Agility, flexibility, responsiveness, and maintaining the flow of ideas are critical issues for rural innovation and rural production system performance. The two aspects are mutually reinforcing.
- There is a broad understanding that collaboration across the innovation system and the value chain is essential.
- Many opportunities have been identified for a robust rural sector future, including a focus on health and wellness and prospects in food service around platform technologies.

Our starting point has been that the Rural Innovation system cannot be viewed independently from the rural industry economic system, or indeed number of rural social and environmental systems. Innovation is integral to these systems but is not the only factor that impacts on economic, social, and environmental outcomes. Understanding the innovation contribution to those outcomes is the essence of understanding innovation performance.

As outlined in the Introduction, understanding the rural innovation system is a foundation for the development of rural industry strategy. But the system, of itself, cannot develop strategy “organically”.

4.1 Assessing performance: delivering value

Assessing innovation system performance was a front of mind issue in undertaking the Review. Our baseline questions, outlined in the Issues Paper, involved considering the following questions.

The extent to which the rural innovation system is *creating value* for -

- The economy – in terms of jobs generated (or not lost), investment stimulated, and increased exports. In this dimension there is a focus on productivity and competitiveness.
- The rural production sector and sub-sectors – growth in production, processing, services, for example the NFF aim for a \$100 billion industry.
- Small businesses (on farm/off farm) – in terms of generating *satisfactory* returns that support and sustain ongoing operations.
- Investors and shareholders in start-ups and corporate agriculture businesses – indicated by return on investment and creation of shareholder value.
- Universities and research organisations - in terms of research income and progression in international rankings of institutional performance.
- Rural communities – in terms of resilience and viability.
- Consumers - in terms of satisfaction of basic food and fibre needs/wants, reflecting a move from “food as sustenance” to “food as experience”.
- Future generations.

Clearly, there is no one, single measure of value that covers all these dimensions. Our approach has been therefore one of narratives, using data to show performance as appropriate. There are, however, some baseline indicators of value, in both its private and public dimensions:

Value can be indicated by the extent to which the system has been -

- *Effective* in delivering outcomes – indicated by factors such as output quantity, quality, cost, and end user satisfaction.
- *Efficient* in production and distribution – indicated by factors such as productivity, costs per unit of output, cycle times.
- *Economic* in the allocation of scarce resources – indicated by factors such as availability of, and access to, knowledge (RDE, IP, best practice), skills and talent, investment capital, land, markets.
- *Appropriate* – policies and practices that support priority setting, resource allocation, and dealing with external contingencies.

These questions are addressed in our assessment of performance in Section 5 and in subsequent Sections of the Report

4.2 System vision, goals, objectives

Our understanding of the rural innovation system is that it is a *platform* for the development of rural industry strategy.

One of the major concerns expressed during consultations was the absence of a strategy for rural innovation within a framework of a national rural industry policy. There was claimed to be an absence of *national challenges* that could guide innovation and underpin other initiatives that aimed to achieve economic, social, and environmental outcomes.

In a strategic sense, if organisations, or industries, want to achieve a result, there must at the very least be a plan and performance targets that are mutually agreed and committed.

As indicated in Section 2 above, there is, of course, no shortage of plans. CSIRO, State and Territory Governments have developed Food and Agriculture plans that link government, business, and research. The Rural RDCs also have plans. But there is little that connects them. There is no overarching vision or set of challenges for an Australian rural industry strategy centred on innovation.

Governments have a habit of coming up with “funding” programs that identify categories of eligible expenditure that people and organisations can apply for, often on a competitive basis. In this way, funding drives strategy through a “bottom up” process of applications and success in funded projects. In the corporate world, it is done the other way around: strategy drives the distribution and targeting of investment.

Some of the big challenges identified in the consultations included:

- Creating a \$100 billion rural sector (although by some measures we are already there – see Section 4.3.1 below).
- Digitally mapping at a finer resolution Australian soil. It is seen as something that's holding back rural industry and the opportunities in precision agriculture.
- A national AgTech initiative – to capture the potential of AgTech for the sector's innovation and economic future.

Mention was made in Consultations of the New Zealand government challenge to be Chemical Free. The Government has gone to the Crown Research Institutes and said, “this is where you should be investing the majority of your money in the future”.

In Australia, the multiple funding points, and the number of research providers is said to create a “vegemite” problem with resources being spread thinly across a wide range of organisations and capabilities.

There was a broad consensus in the consultations that Australia required a national rural industry strategy, a key element of which would be innovation (ideas), but would also address education and training, rural and regional development, enterprises (new business) development, ecosystems (precincts, innovation districts, clusters and co-working spaces), the natural environment and biodiversity system, the financial system, infrastructure (particularly broadband, energy, water), regulation and certification, energy and the ‘public policy’ system.

A clear requirement for improved rural innovation system performance is the better ‘integration’ and connectedness of the socioeconomic systems towards achieving objectives in a rural industry strategy.

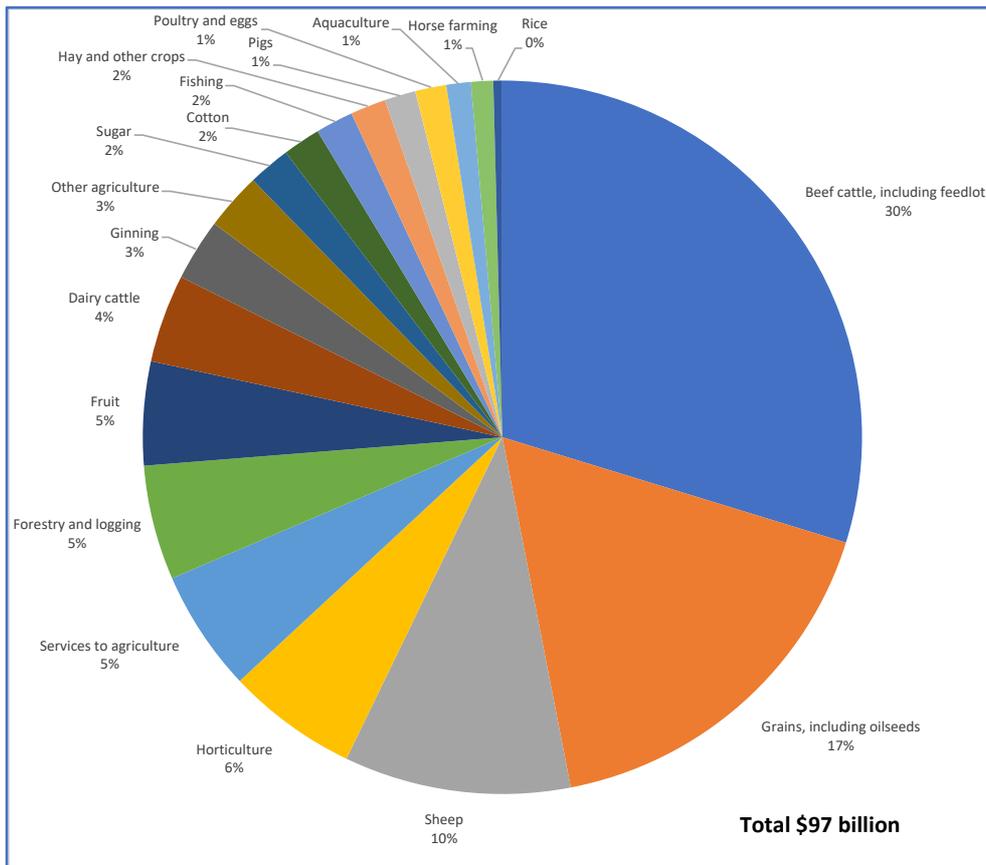
4.3 Production and processing issues

4.3.1 The contribution of rural production to GDP

Agriculture, forestry, and fishing’s share of GDP has fallen by a full percentage point since the late 1970s, to an average of 2.3 per cent in the five years to 2014-15. However, the declining share has more to do with the growth in the shares of other industries, rather than contraction in real terms.

IBIS data, reproduced in Figure 14, shows that Agriculture, forestry, and fishing has a GDP value of \$97 billion, including a service to agriculture component. GDP is dominated by grains, beef cattle, and sheep (57.2 per cent of \$97.0 billion output).

Figure 14: The components of Australia's Agriculture, forestry, and fishing industry



Source: IBIS World, 2017

The significance of beef, grains, sheep, and horticulture carries through to industry levy collections and the Government 'matching' contribution. Meat, grains, wool and horticulture RDCs are in a very strong financial position, accounting for 73 per cent of the \$674.1 billion in net assets held by all RDCs (See Table 18 on page 162 below).

It is becoming apparent that the research and development issues relevant to one industry sector may also be relevant to others. This has become particularly apparent since the *biological innovation wave* of rural innovation took hold (see Figure 115 below). The increased attention being given to "cross sectoral" collaboration has been an important initiative in addressing this commonality of concerns. The larger RDCs have an opportunity to take a lead in these initiatives.

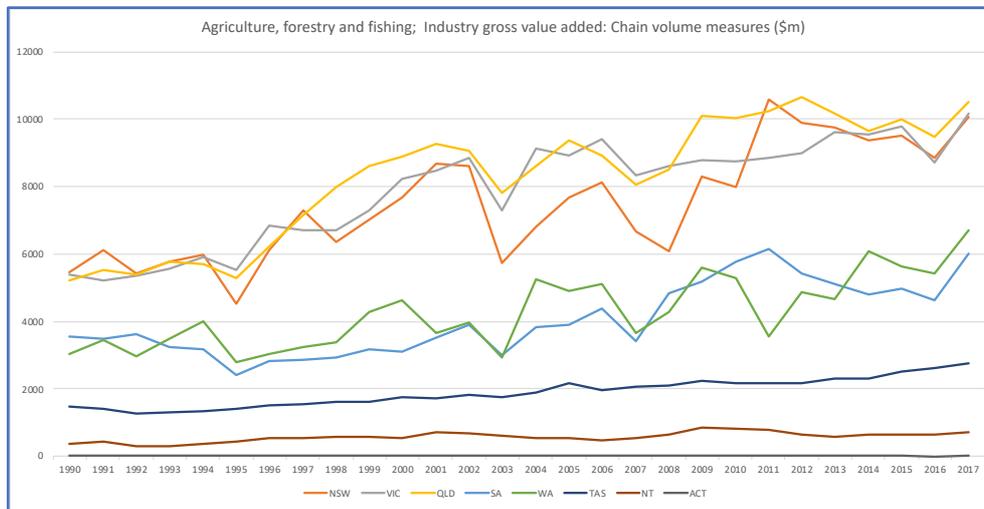
IBIS commented in its report on the economy in 2017 that:

The world still believes that Australia has a resource-based economy, even though that ceased to be true well over 50 years ago. However, given that our exports are more visible to the world than our domestic economy, the perception is understandable. After all, our natural resources currently make up over half of our total exports.

Agriculture makes up 5.6 per cent of Australian exports, but when combined with food processing, food and agriculture makes up 11.7 per cent. There is strong interest in maintaining and accelerating this contribution.

The movement in rural industry gross value added has been flat since 2009, with an uptick recorded in 2017. It has also been uneven across States. This is shown in Figure 15.

Figure 15: Agriculture, Forestry and Fishing – industry GVA 1990-2017 (chain volume measure \$m)



Source: ABS

4.3.2 Productivity improvement

ABARES (Xia, Zhao, & White, 2017) argues that improving productivity is the main way farmers can meet the challenges of competition, declining world prices, uncertain seasonal conditions and other factors beyond their control. The key trends in productivity are:

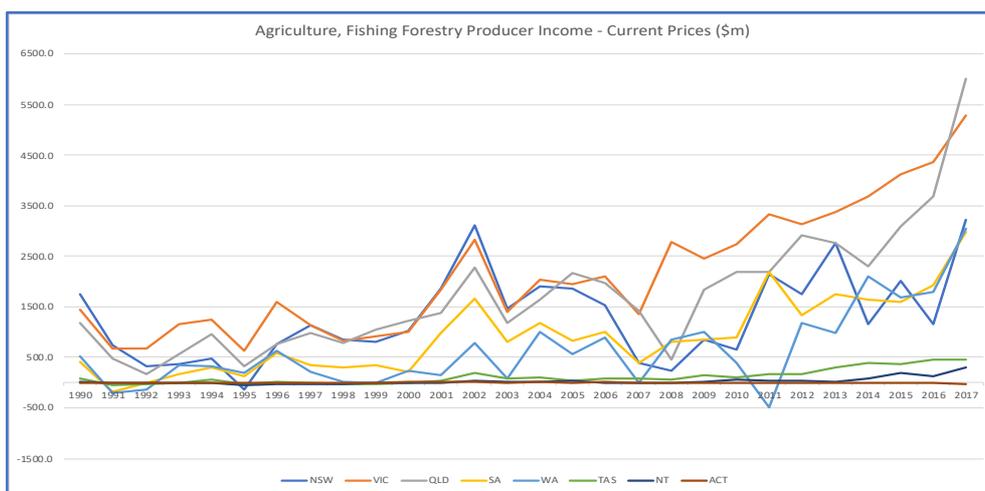
- From 1977–78 to 2014–15, productivity in the broadacre industries grew by 1.1 per cent per year on average because of declining input use (–1 per cent a year) and modest output growth (0.1 per cent a year).
- From 1977–78 to 2014–15 average annual productivity growth in the cropping industry was 1.5 per cent a year, compared with beef (1.3 per cent), sheep (0.3 per cent) and mixed livestock–crops (0.9 per cent).
- Since 2001–02 the sheep industry has exhibited strong annual productivity growth (2.7 per cent a year) compared with the cropping (2.1 per cent), beef (0.5 per cent) and mixed livestock–crops (1.2 per cent) industries.
- Climate conditions have significantly affected the productivity of cropping farms. However, adjusting for the effects of climate, the productivity of cropping farms grew strongly from 1977–78 to 1993–94 (2.5 per cent a year), slowed between 1994–95 and 2006–07 (0.2 per cent) and increased between 2006–07 and 2014–15 (1.7 per cent).
- In the dairy industry, productivity growth averaged 1.5 per cent a year between 1978–79 and 2014–15. This was a result of a 1.3 per cent a year increase in output and a 0.2 per cent a year decline in input use.

There is a real question, however, whether this strategy is sustainable for small farms in the broadacre and dairy sectors.

4.3.3 Profitability and returns to farmers

According to ABS data and indicated in Figure 16, movements in producer income vary widely across States, with income increasing relatively more in Victoria, Queensland, and Western Australia.

Figure 16: Agriculture, Fishing Forestry - Producer Income (Current Prices)



Source: ABS.

ABS data confirms the significant increase in gross value of production since 2010, but it also indicates a squeeze on farm income due to rising intermediate costs, offset by only very moderate increases in compensation costs. This is indicated in Figure 17 below.

Figure 17: Components of Agriculture income (Current prices, \$m)



Source: ABS.

Farm profitability (excluding aquaculture) is reflected in regular surveys undertaken by ABARES (Table 1 below) indicates that the rate of return on capital, a proxy for profitability, is very low for small farms, quite low for medium size farms and barely acceptable for large farms. The situation improved for some industry categories in 2016-17.

Table 1: Rate of return to total capital (excluding capital appreciation) by industry and farm size, Australia, 2010–11 to 2016–17 average per farm

Industry	Business size	Five years ending 2014–15	2015–16p	RSE	2016–17p
		%			%
Wheat and other crops	Small	-0.5	-0.5	(147)	1.1
	Medium	3.2	2.1	(22)	4.9
	Large	5.7	6.0	(7)	6.8
Mixed livestock–crops	Small	-0.4	-0.3	(116)	1.5
	Medium	2.8	1.8	(23)	4.2
	Large	4.5	3.7	(15)	4.8
Sheep	Small	-0.3	-0.9	(50)	0.5
	Medium	2.9	1.8	(40)	4.5
	Large	4.9	4.1	(15)	7.0
Beef	Small	-0.9	0.0	(168)	1.0
	Medium	1.6	2.4	(16)	4.0
	Large	2.0	4.0	(10)	7.6
Sheep–beef	Small	-0.1	0.7	(68)	3.2
	Medium	2.1	2.3	(29)	4.4
	Large	3.5	4.6	(11)	6.7
All Broadacre farms		1.8	2.4	(5)	3.2
Dairy	Small	0.5	-0.9	(147)	-2.5
	Medium	2.8	0.3	(234)	0.2
	Large	4.8	2.9	(11)	1.5
All dairy farms		3.7	1.3	(33)	0.3

Source: ABARES Australian Agricultural and Grazing Industries Survey. p Preliminary estimates.

Overall, these returns would provide little commercial incentive for investment in new productive capability to enhance productivity, including application of new knowledge and practices – even if farmers had the financial resources to make those sorts of investments.

According to the Australian Bureau of Statistics the number of farmers fell by 40 percent between 1981 and 2011, with most students holding ag-related degrees opting for positions as analysts, consultants, and scientists over farming.

The National Farmers Federation (NFF) has a view that Agriculture technology innovation has been slow to develop in Australia, with a few exceptions, despite the huge amounts of research coming out of its universities and public institutions. Many AgTech entrepreneurs have opted to relocate to the US for its larger addressable market and a more developed venture capital and start-up community. The NFF is spearheading initiatives for startups to develop and grow in Australia. These include an incubator for AgTech start-ups (SproutX); an online information portal; and a publicly-available digital big data analysis and farm management tool – the National Farmers' Digital Agriculture Service.

The NFF is rolling out these initiatives alongside several commercial partners including global professional services company Accenture, public accounting firm Crowe Horwath, superannuation fund Prime Super, Commonwealth Bank of Australia, global telecommunications provider Vodafone, and supermarket chain Coles.

The incubator, which is being launched in partnership with financial advisory and accounting firm Findex – the parent company of Crowe Horwath, will identify, foster, and promote innovations in the food and agriculture sector. NFF and Findex have assembled a highly skilled assessment panel to vet innovations and will create relationships with potential investors. The first round of applications for Sprout opened in early 2016.

NFF argues that agriculture is entering a new growth phase and that “new, homegrown agriculture technologies may hold the key to reinvigorating interest in farming while helping Australia’s existing farmers to do more with less.”¹⁰

Review consultations indicated that other incentives are at play, including personal motivation of people to “stay on the land”. These include actions to reduce or cut costs or go without until better times return. Farmers work for value creation – which is not always profit. Value may be in lifestyle, like more time for fishing.

At the same time, rural producers are known to come up with ingenious solutions to problems, involving little financial outlay, but based on many years of farm-based experience and looking for ideas from elsewhere that may work. Examples abound in the rural based trade literature and history of technology.

Given that farm businesses are often “price takers”, determined by movements in commodity prices, production volumes, market demand, and the exchange rate, the returns of productivity improving investments may be captured in other parts of the value chain. For this reason, it is important to look at value creation in an overall value chain framework, as well as ensuring, separately, that buyer power within the chain does not squeeze producer returns unfairly. This has been a matter of recent concern to the ACCC and is reflected in many of the discussions for this Report.

Increasing returns to farmers may have to focus on reducing input costs. Innovations in areas such as food processing, energy, transport, regulatory, and compliance costs may have to have a greater focus on increasing returns to farmers.

4.3.4 Productivity vs. profitability issues

There is a subtle difference between the profitability argument and the productivity argument. Farms can be highly productive (volume of output over costs of production), but they can be unprofitable if the income received from sales is less than overall production costs. Price is determined by a wide range of variables on both the demand and supply sides of a market. In beef, for example -

... producers with Tier 1 and Tier 2 export licences, who are competing on the international stage, have businesses based on economies of scale and mass production. They must do anything to keep their economies going, keep processing works running, and maintain volumes. They will buy cattle from western Victoria and truck them to Dinmore to keep that model going.

The smaller producers, working in niche areas around quality, brand, and reputation, can be more profitable, but possibly less productive. As the larger producers close because they can't keep their economic efficiencies up the smaller ones are benefit.

In several producer segments successful farms are concentrated at the very large and very small endpoints. Small operators can take advantage of niche markets and higher prices for organic and local products, while large farms have economies of scale. In the US, for example, only four per cent of farms have more than \$1m in sales, but they account for 66 per cent of the value of goods sold. Smaller farms tend to be the innovators (Pham and Stack, 2017).

A “commodity” approach driven by economies of scale and lower costs of production is fraught as consumers look for quality and authenticity.

¹⁰ <https://agfundernews.com/australias-nff-to-launch-big-data-management-tool-agtech-incubator-and-online-portal5220.html>

The high value, low volume type models make sense in some sectors such as meat and horticulture, but less so in wheat. In fisheries, for example, businesses may have a goal to continue to catch wild fish “in the absolutely old traditional, authentic, way”. Consumers may pay a premium for that.

Anticipating future trends in demand and in the market, and targeting a niche, will be for many rural businesses a major driver of profitability.

4.3.5 Contracting issues between farmers and processors

During consultations interviewees pointed to an ongoing issue about the unfair way processors were treating their growers, their dairy farmers, wine growers, and fruit growers. This was attributed to national and multinational oligopolies exerting market power, competing on price, and focussed on maximising shareholder value.

The issue has come to attention in the current ACCC inquiry into the dairy industry. An [interim report](#) was released on 30 November 2017.

New producer-processor contracting models are emerging, although it will take some time for execution. These models are vital for the viability of many rural industries.

4.3.6 Emergence of an “AgTech” and “GeneTech” industry sector

Australia is witnessing the emergence of a robust AgTech sector, enabled by start-ups, the availability of early-stage investment, and support from a wide range of organisations and institutions, including banks, large corporates, and Rural RDCs.

AgTech can be seen as the collection of digital technologies that provide the rural industry with the tools, data, and knowledge to make more informed and timely decisions in rural businesses. Writings and commentary tend to have a focus on agriculture, but the development applies to all aspects of the value chain.

Several websites and blogs have emerged around Ag Tech, including [Startup Muster](#) and [AgFunder](#) an online global venture capital platform. A recent report, [Powering Growth: Realising the Potential of AgTech for Australia](#), looks at the potential impact of technology on Australia's agriculture sector. It is co-authored by [KPMG](#) and supported by the [Commonwealth Bank](#) and the [Queensland Government](#). Other major banks, including [NAB](#) and [ANZ](#) have shown interest in the sector.

The [Farming Smarter CRC prospectus](#) involved 72 partners, with the largest component being AgTech. The CRC will focus on cross-sector on-farm issues to drive productivity through solutions that utilise technologies of the digital age. Further discussion of AgTech is covered in later Sections of the Report.

The emergence of AgTech is seen as having a major disruptive influence in rural innovation.

4.3.7 The opportunities in aquaculture

Aquaculture currently only accounts for one per cent of rural production, with fishing making up a further two percent (see Figure 14 above). The Fisheries RDC and many industry analysts and commentators see huge potential for aquaculture to feed the world. However, in Australia aquaculture is highly regulated which places a constraint on opportunities.

Relatively new companies, including Tassal, Huon Aquaculture, are doing well. They employ large numbers of PhDs in the marine sciences. In Tasmania, the fishing and aquaculture salmon industry employs between them and their ancillary suppliers, such as packaging, electricians, around 5 per cent of the population

4.4 Demand-side issues

4.4.1 Satisfying consumer wants

Food has become an *experience good*, reflected in the growth in the foodservice industry, convenience meals, the food delivery sector, the profusion of reality cooking shows, and demand for upmarket cookbooks and diet books. It also now reflects the characteristics of the Fast-Moving Consumer Goods sector, involving rapid churn of products.

There is a stark realisation that *consumers* set demand. They want to be “satisfied” with the experience and enjoyment of eating. In Western economies, food is no longer about basic sustenance.

A senior executive in an RDC commented -

... part of our job is to create demand for innovation which means creating capability, awareness, understanding and absorptive capacity. You've got to work with suppliers of innovations using a design thinking lens on the supply side.

In developing an innovation strategy there is a new mantra “the consumer is at the table”. Innovation must drive to the consumer.

It is essential to understand the nexus between desirability from a customer point of view and technical feasibility, which most researchers focus on, and a viable business model to get that innovation into the marketplace.

4.4.2 Decommoditisation, provenance, traceability

The movement from commodity to the branded product was seen as a critical development in the food and agriculture sector and as a way of differentiation on the market. This relates to the experience or the perceived experience. If someone isn't going to enjoy a meal because they think Angus is better, that is entirely up to them. Marketing plays a critical role.

An interviewee made a comment “if you're thinking about consumers, the brand is what you trust”. There are, however, limitations:

Commoditisation will never disappear. Forty per cent of a beef carcass turns out as manufacturing meat. Now, manufacturing beef, if you've ever been to the US, is 70 per cent Australian beef in that burger. So, American beef is chemically about 50 per cent fat, 50 per cent meat. Ours is 90 per cent meat, 10 per cent fat. If you try to make a burger out of American manufacturing meat, it will be white and fall apart. If you make it, if you bite with Australian meat, it'll be about 25 per cent fat and about 75 per cent meat, then you'll get an excellent brown burger that looks like a burger. So, we're not going to move.

Consultations indicated a solid challenge for developing transparent supply chains, improved production standards, processing, delivery and marketing, and linkages between food production, soil, animals, and human health. These comments support the discussion in Section 2 about Global Value Chains and Distributed Ledger (Blockchain) Technologies.

There is a view within the industry that the idea of being able to give full traceability to the consumer isn't far away. The “holy grail” of objective carcass measurement will lead to the complete digitisation of the beef sector. And we may do it quicker than other industries, which will surprise some people because it's very close. An interviewee observed:

... the most significant thing we can do for customer confidence is provide traceability. Customer confidence is a key issue to driving our consumption. They'll pay more for beef. It's clear. But they'll do it happily if they can be guaranteed of the repeatability of the eating experience. More so if we've dealt with animal welfare type issues and they have something to grasp in the form of traceability rather than eating something they don't know.

“The Butchers shop is moving into the boning room”.

Technology applications are moving to the stage of DNA testing - to have full traceability. Suppose there's a problem with a piece of meat or some scan of what happened. It is what the Japanese wagyu is doing now. They've got full traceability... [Interviewee pointed to a photograph taken in Japan and continued] ... When I was in Japan, I took a photo of this rib set at Isetan in Ginza (which is like the DJ's food hall). That's the rib set; that's its birth certificate. And that's the guy who grew that animal here. And you can see this was 7,000 yen—a hundred grand.

And we don't produce it. But there's the traceability marker right there. That's the whole history of that animal, and you would buy it by the one. In restaurants it will be possible to say, “Here's the certificate of the piece of meat you're going to eat”.

4.4.3 Global connections

Many people consulted indicated that there needs to be much stronger recognition by Government that the direct beneficiaries of rural R&D in agriculture, food and fibre are not only producers and agribusinesses associated with the food production sectors.

It has been estimated that around 35-40 per cent of the direct financial benefits of agricultural R&D accrue directly to food consumers in Australia and overseas through significantly expanded and enhanced export markets and greater value for money, product quality, and/or availability food products¹¹.

Even small producers and processors are globally connected with the Internet, online trading, and secure payments systems.

The Internet and online trading facilitates an orientation towards capturing a niche value chain rather than attempting to transact through multiple buying and selling points.

4.4.4 The emergence of food alternatives

Interviewees made mention of the “inevitable emergence of food alternatives, to meat, dairy etc.” Australia needs to be well-positioned in a very different future market with increasing attention to these issues.

¹¹ Griffith GR, Parnell PF and McKiernan W (2006) The Economic, Environmental and Social Benefits to NSW from Investment in the CRC for Beef Genetic Technologies, Economic Research Report No. 30, NSW Department of Primary Industries. See <http://www.dpi.nsw.gov.au/research/areas/health-science/economicsresearch/reports/err30>

Consumers want to consume different types of food ... as one interviewee pointed out, "Consumers want to eat insects, they want to eat seaweed, they want to eat snacks, they want to eat healthily, they want to eat all sorts of things, they want to eat differently".

A global livestock company has said, "We no longer define ourselves as livestock companies. We define ourselves as a protein company because we see something happening in livestock that we may not want to be part of."

Interviewees commented that there will be many things about the new food economy that will be different to what it looks like now. It might take three, five, ten years, to see substantial change, but "the noises are there now" and particularly outside Australia.

4.5 System issues

4.5.1 Agility, flexibility, and responsiveness

The CEO of Cotton RDC suggested that "we need to build capacity across a wide range of areas to ensure the ongoing, sustainable and smooth growth of the agricultural sector to manage risks to the economy and profitability of agriculture, and to withstand the shocks and disruption of weather and markets that often occur".

Volatility is a big thing for CRDC because we only have one source of revenue which is driven off production. And production has become so dependent upon water availability and drought. So, for us, we probably have the most volatile financial situation trying to operate in that system of constraints. "You can't use your reserves without prior approval." So, it limits your ability to respond. So, we accumulate two years of, two years' worth of reserves, but then we must beg to use them.

I am looking to invest in Main Sequence ventures – the CSIRO Venture Capital Fund. Can we hold shares? Take a week to get an answer on that. Then we must do all the due diligence. it's quite a process. But we need to be in that space where you can have agile response to those opportunities.

Fisheries sees its strength in its flexibility -

If you look at how we've changed our funding model, even over the last three years, we've now started a program, so we have our train tracks, and we've now got a second train having left the station. So, the old train was problem, find a researcher, do the research, extend the written knowledge. We've now got a second train that's looking at fast adoption. And looking at different ways of engaging both in problem, solution, and funding.

So instead of it being us funding the whole train, we've gone, "We're going to help you build your frameset, work out how to pitch for that and look for new business partners." So, this is the FishEx programme that we're running. And you'll see it, SproutEx, all the RDCs are now looking at a range.

Several interviewees saw it important to keep asking new questions, such as:

- What's 3D printing mean to the food industry?
- Where is the future population going to get its protein from?
- What does synthetic chemistry mean?
- What does artificial intelligence mean?"

For R&D strategy this means trying to take that knowledge and thinking through a strategic viewpoint for industry, the rural sector, and the economy.

Many researchers, however, want certainty. For example -

I think a lot of people say, "Well you need to provide a career path. We need a career path." And I go, "Well it's good that people have access to a new career path, if that's what they chose, but equally it shouldn't be the only way for people to feel valued and contribute."

Uncertainty for some is unsettling and creates anxiety. But the rural sector is changing, and the direction is ambiguous. Investors want to know that rural industries are getting the diversity of thinking and talent from wherever it's best placed, rather than getting a message such as "we've got this resource that we have to keep busy, and we need to sustain it".

The system must allow more flexibility, ability to take risks, continually challenge the *status quo*. It may take us "out of an Australia-centric view into a more world view of how we do things". A RDC CEO commented -

And it's not constrained by lack of money. And it's not constrained by people. What it will be constrained by will be narrow thinking. That is what worries me. And they've got to get rid of people like me.

4.5.2 Integrating food, agriculture, environment, and health

Andrew Campbell, former CEO of Land and Water Australia, referred to an op-ed from the *New York Times* that said, "over the last 25 years we've evolved a health system that completely ignores food, and a food system that completely ignores human health." And that's absolutely the case.

Research is now connecting the idea that the food that you eat leads to the strength of your DNA.

... there's a particular study they did of some kids. Some disadvantaged kids in the US that weren't eating red meat. In fact, they were lucky to eat at all and they fed them red meat meals at school and then their cognitive learning went up exponentially. There are too many moving parts for me to invest in that, but the idea that you eat foods and they're good for you, is fast coming through with the idea that you put omega-3 in Tip Top bread... to accentuate some of these vitamin and mineral type benefits.

The trajectory started many years ago with cereal manufacturers talking about niacin and riboflavin and thiamine. While these vitamins weren't well known, people ate them because they sounded good. This sort of development may be more connected with marketing and branding than it is with connecting food and health.

4.5.3 Mindsets

There is a tendency for people to feel comfortable with what they are doing and get locked into it. It is a cultural issue. A RDC CEO observed:

The standard thing of being employed with someone for twenty years, that was maybe an expectation twenty years ago, is no longer the case. So, what you are wanting is people who feel confident and supported that they might be working on cotton today, but they might be working on a social issue tomorrow. So how do we build a system where that sense of agility is promoted and supported? Because it's not tradition now.

Therefore, we can have the best systems in the world, but if our mindset is such that we're stuck in a very conservative frame, it's going to fail.

In terms of the ease of starting companies Australia is comparatively very far down the track. The challenge is to provide the environment where new companies can grow and succeed.

4.5.4 Attracting and retaining talent

Consultations indicated the businesses and research organisations are constrained by immigration rules and government staffing constrains in attracting management and research talent.

We've got to get the younger people in. We need to have pathways that you don't have to have this hierarchical thing where you've got to work your way through to get to somewhere. We need

to be able to pick the smart people and get them into positions faster. We've got to plan our workforce better.

4.5.5 Fast follower strategies

A RDC CEO observed that in an environment where Australia produces two per cent of the world's knowledge and 98 per cent is produced somewhere else, a fast-following strategy can be the most rational.

We often talk about borrowing information, buying information, and the last resort, stealing it before you do anything else. But there's much cheaper ways of doing things sometimes than just going out and doing more research.

An alternative approach is to ensure maxim participation in global value chains to get a "seat at the table"

4.5.6 International connections

Australia performs very poorly at the connecting points. It is good at finding the points, but joining the points is a challenge. So how we engage and bring scientists to Australia is a major issue. An interviewee commented "we're still running some of our exchange programmes, like the Australia French Programme or the Australia Chinese programme like you'd run a programme 30, 40 years ago". An RDC commented:

... we try to work with the EU on programs. Often funding programs are hard to do at an international level. And so, the RDCs must be more like the private sector where they do private sector business rather than constrained by the regulatory frameworks.

The portability of science across borders is not as easy as it should be in Australia. It's harder to bring temporary researchers to Australia under the new 457 visa arrangements. It must be demonstrated that there's not an existing person in an Australian University who can do the research.

4.5.7 System risks

Risk avoidance is seen as a massive problem in the rural innovation systems. An Interviewee commented:

The Uhrig Review said, one of reasons the RDCs should exist and be separate from the government is they're entrepreneurial. The word "entrepreneurial" is important. Everything I see in the government with the PGPA Act and what they're trying to do with funding agreements, is almost to try and create risk avoidance. Not risk of failure. I want to fail. I want to fail more, but I want to fail strategically.

The problem with innovation is that quite often the community sees it as being risky. NGOs see it as a way of driving GMO adoption.

When you take any innovation and step into any new space, there is a risk that someone will not like it. And that risk is driven or can be used to drive outrage in the community. So, it's all well and great to say, "Yes we want to be innovative" and it comes back to the mindset of the community. We have tall poppy syndrome.

There's always a societal backdrop and is always worthwhile keeping in mind that driving innovation is great, but for some sectors, innovation it is "very, very scary". It involves change. But it is also a matter of communicating, honestly, the benefits and the outcomes.

Tasmania has the highest unemployment in Australia. The fishing industry and aquaculture salmon industry employ, we worked out, between them and their ancillary, (suppliers, packaging, electricians etc.), around 5 per cent of the population.

Innovation in fishing and aquaculture is a major development opportunity for Tasmania.

4.5.8 Maintaining the flow of ideas

Innovation is the successful application of new ideas; it is therefore fundamental that the rural innovation system enables and supports a continuous and robust flow of ideas.

Those ideas may come from the community, from practitioners, from ingenious engineers and other professionals, and from scientific research. The [Agrihack Challenge](#) is one of many initiatives around innovation precincts, clusters, and co-working spaces to develop and explore ideas.

Several rural universities run innovation contests involving staff, students, and people from the community as a framework for developing, exploring, and potentially implementing ideas. These may have a commercial or a social outcome.

4.6 Strengthening collaboration

Universities do not have an incentive to collaborate, at least a financial sense. In fact, universities compete, for very small amounts of money. Additional funding, specifically for collaborative projects can stimulate collaboration, such as the Rural R&D for Profit initiative.

Some comments on collaboration that arose during consultations are provided below.

4.6.1 The role of RDCs

In a role as “research brokers” the RDCs have an important role in the growing scale and there is potentially more to be done. Some bigger RDCs have the capacity to make large program investments, but the small RDCs must work very hard at leveraging other people's money's, talent, and ideas to scale.

The Precision to Decision project (Leonard et al., 2017), involving a \$1.8m investment over two years, brought the fifteen RDC's together. It brought in the Data to Decision CRC, the Australian Farm Institute, and some other key organisations into the collaboration. The R&D for Profit program is seen as being powerful at incentivising that cross-sector collaboration.

The National RD&E framework provided some opportunity for discussion and strategising, but in the absence of further financial incentive, there was not a lot of scaling up of collaboration. The R&D for Profit Program has been important in enabling cross sector collaboration. It has been reported that some RDCs have gone from probably 15 per cent investment in cross-sector investment to 40 per cent. A constraint was reported for the statutory RDCs which have reached their Full Time Equivalent staffing cap set by government. As one interviewee reported:

... we were growing already, but then you magnify that by cross sector collaboration. The Australian public sector has a cap on staffing because the government doesn't want to grow the public sector. We get caught in the whole of government. A blunt instrument. So, we've been, feeling the pains of our own success.

But the key point is the scaling up that's possible through that process and bringing together people who have a strategic focus, who can contribute to the cross-sectoral strategy in the National RD&E framework.

Of people that are brokering and connected to end-users, who can see whether we need basic research or applied research or experiential research, collaboration can scale it up at an appropriate level for whoever the partners are. It might say "National", but it might only be with sugar, rice, and cotton, depending on the issue, but we can scale it up. So, I think it's adding a lot of value.

4.6.2 Cooperative Research Centres (CRCs)

CRCs have been performing well with promoting the spirit of collaboration. An RDC CEO commented:

I think it's a valuable model. And I like that the university sector saw that it was valuable for bringing themselves together to collaborate, and provide some additional funds, so they can have,

I guess, more of a sense of a freedom to direct and invest. I don't see it as a bad model; I just don't see it as something for us to participate in, as a partner, as a value-add.

The CRC model now has been creating a concern with high administrative costs and the time needed. Several RDCs are happy to partner in discrete projects and share information and strategy, but not to commit to the full life of the CRC.

A list of currently active and prior CRCs is contained in Research Report 3.

4.6.3 Collaboration with government

Collaboration between the RDCs and the Commonwealth government was identified as a weak point in the Consultation discussions. This may be reflective of the dual role of research investor as well as compliance manager and a weakness in policy development capability that has been driven by many years of fiscal austerity.

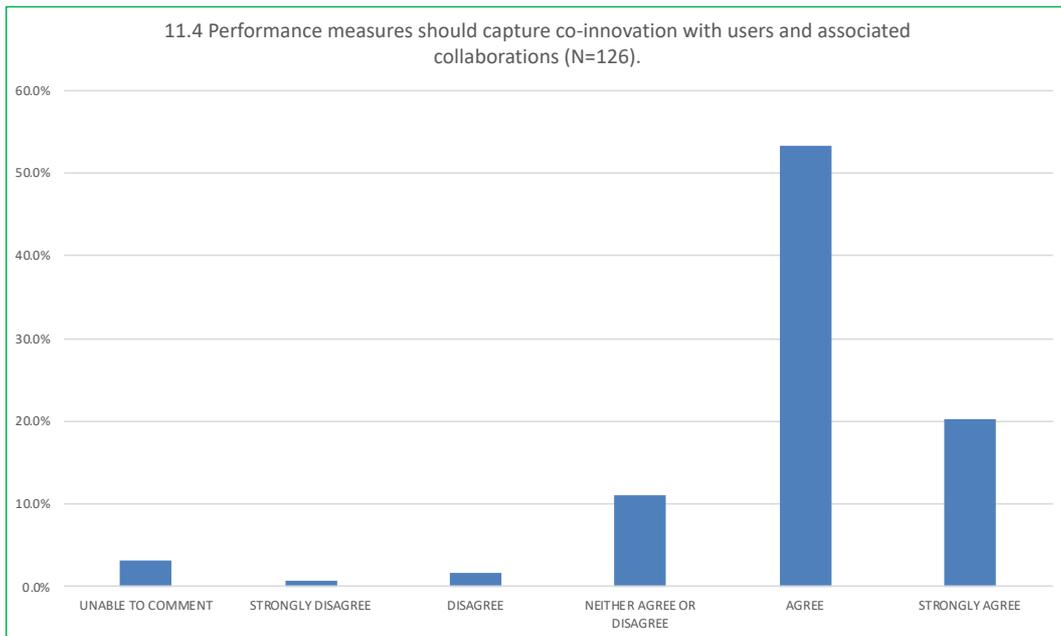
Some interviewees suggested that the Department had “defaulted” its policy work to the RDCs, with the result that policy reflects an aggregation of RDC strategies and plans. To the extent that this may be the case, achieving policy coherence and consistency is a major challenge. As indicated earlier in the report, interviewees across sectors were looking for strategic direction and leadership in rural policy. This is much more, of course, than ‘farm’ policy and ‘research policy’.

There is a need to strengthen collaboration linkages between ‘farm policy’ and ‘food and agriculture’ policy. That is within the remit of Food Innovation Australia Limited (FIAL) - the industry growth centre that operates from the Department of Industry, Innovation and Science.

4.6.4 Assessment of collaboration performance

The scope and extent of collaboration performance is not measured well. Financial transaction data collected in business surveys can only provide a small window on the broad range of interactions that take place on an informal and personal basis. Research reflected in the country profiles in Appendix 5 suggest that these are significant determinants of effective interaction.

Responses from the Expert Opinion Survey indicated support for the development of collaboration metrics

Figure 18: Collaboration Performance

Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

4.7 Institutional and organisational issues

4.7.1 Balancing basic, applied, application and communication research

Research provider and funding organisations are continually looking for balance in their research portfolios between -

- Basic research - discovery, new theories, new explanations. There is a part of the university community that doesn't want the model to change, because "it funds people sitting at benches, and jobs and a whole range of things" (interviewee)
- Applied research - problem solving, using knowledge in new ways; invention - engineering
- Application research - working out ways to adopt and implement – often in collaboration with end users; may not be really research – seeing developments in research organisation incubators
- Communication research – addressing means to achieve attitudinal and behavioural change through various forms of messaging and channels, including, contemporarily, social media platforms

Consultations suggested that the balance was dependent on the issue. If it's an issue "where we need to do basic research, because we don't understand it, well, let's do that first." Another commented "We've been doing basic research and applied research, and extension for twenty years and we haven't solved it. We probably need to rethink the problem". Another said "I've always thought about it, not from an input perspective, but from what we are trying to achieve. ... It's driven by what problem you are trying to solve".

There is a concern about commitment to, and resourcing of, interdisciplinary and integrative research – "in biosecurity you'll need your pathologist, and you'll need your entomologist. Those things that protect the current competitive advantages of industry and biosecurity issues".

Some see knowledge as increasing exponentially. "My problem is getting the knowledge to bear on their problem. Or being able to filter the knowledge from all that other knowledge, so that the

knowledge is bare. So, I ask myself these days, 'Should I be creating more knowledge? Or should I just be developing systems to better use that knowledge?'"

So, I look at my client, like the Fisheries Manager. Should I just create more and more of this, or do I really need to think through how to use knowledge better, which is very different from the old model, where everyone was always trying to create their own knowledge and they had their own little silo. And I think this deregulation of the knowledge market, which is obviously globally affecting new companies, it's globally affecting researchers (Fisheries)

It follows that research investors and managers should have access to a range of capability that can deliver on all aspects of knowledge creation and integration.

4.7.2 Commercialisation and Intellectual Property management issues

Intellectual Property Management was raised as an issue in many consultation sessions. There have been IP issues coming out of collaborations with universities and public research organisations. There is a view that the situation has improved over the last five to ten years, although there have been "some perverse behaviours probably even amongst RDC's and universities". The approach now seems to be moving towards addressing an outcome and then how best managing the IP to deliver and achieve it.

So, I think it's maturing quite well. The ability to commercialise, the skills in doing commercialisation beyond IP management are still not very advanced. That's why I really put a lot of importance on the start-up science and start-up communities to help us grow in that space. Because, even with that, like the track record of those programs is you take the probability of success from a start-up from 7 per cent to 14 per cent.

So, it's still high risk, but the more successful we can be with each of those things then obviously there's dividends in, costs and impacts.

An interviewee referred to the IP on the bull guard, on the genetic engineering and the varietal rights that Cotton Seed Distributors (CSD) and CSIRO developed and are exporting all around the world, which has been very lucrative. The main cotton varieties around the world are Australian, and CSIRO and CSD aggressively pursue the IP and income for that. CSD has just built a \$100m shed. Nonetheless, CSD remains as a grower, membership organisation – a not for profit club – "just like a rugby club and you're a member, it costs you \$50 to be in it".

Many consultations involved some time in addressing the weaknesses of the "hope model" of innovation –

A researcher would have a particular piece of research and you would "hope" that it would lead to a process to get commercialised. So, it had this thing. And we're trying to avoid hope. What we're trying to do is be more modern in saying, "Here's what we need, and let's now go and get all the bits to make it happen from the innovation perspective. And it doesn't necessarily have to have R&D.

Very few things lead through that traditional, linear, transactional model commercialisation. Most of the new things come from the other way – from customers and users.

And that old model, so our book keeps saying, "Oh, you've got to commercialise research," and we keep saying, "Don't know if that works."

Interviewees commented that we have moved on from the linear flow, science push model. Translation funds may assist in commercialisation in some areas of research endeavour, where there is a clear relationship between basic science and application, as in medical research (a drug, treatment, cure), but they are not a general panacea.

Adoption and application call for multidisciplinary and integrative approaches to R&D, user determined requirements, and development of

collaboration and trust-based partnerships that are built up over many years.

4.7.3 Knowledge management

The consultations pointed to a challenge around Knowledge Management (KM). Knowledge Management assumed the status of a discipline in the 1990s, but unfortunately became discredited as a management tool when it became captured by the “techos”, peddling hardware and software products, and was assigned to “fad” status due to concerns with over promising and under delivering¹².

For several RDCs Knowledge Management has been filing and indexing a final report, but this is regarded as being no longer satisfactory. “In fact, I don't really care about the final report. I now want the outputs. I want the data. I want the code”.

We're now saying every time we develop a new model, we want that to be made publicly available, and to make it open access computer code. When we look at the knowledge management, it's not just the old final report, which used to be a textual thing. Probably of more value is the video or the how-to manual or the little app or ... But trying to capture all those things in a knowledge system is a challenge.

And keeping track of previous IP, background IP.

We must have some understanding about where you sit in the world. In most of my industries I sit somewhere with the developed countries but well ahead of developing countries. For some of my industries I sit on number one. And so, my knowledge management system is to protect me being number one. That may mean not sharing anything. Australia is the world's number one pearl producer. We never talk about it.

Australian Rural Research in Progress (ARRIP) was instituted in 1984. It was a research in progress database that covered current and recently completed research and development projects, in the areas of primary production and processing, including agriculture, horticulture, forestry, fisheries, food technology and land, and water and vegetation resources. Many RDCs were enthusiastic investors. It was transferred to another organisation and was discontinued.

Potential opportunities for tracking research and IP (knowledge management) exist by engaging Data61.

4.7.4 Targeting research take up

Research take up, diffusion, or absorption, has been an issue in innovation thinking for many years (Rogers, 1995, 2003). There are well documented differences in commitment to take up, from the leaders to the laggards. MLA has undertaken some analysis of its membership - 76,000 beef and 48,000 sheep members. They have been categorised them into four groups.

- The “ongoing out of business” group.
- The “succession planning” group: “don't bother with me, I'm handing over the farm to the kids and how am I going to do that, but don't bother me”.
- The “everything is fine, we're happy” group: “For god sakes we don't need to be bothered by you, we know what we're doing”.
- The group we are heavily engaged with” - represents 25 per cent, or 20,000 members.

¹² As discussed further in the post knowledge management literature. It is important that “digital agriculture” does not suffer the same fate.

One interviewee commented that the problem with the succession group is that university educated farmers, "aren't going back to farms: they're sitting inside air-conditioned areas in the cities. Succession planning now is why farmers are older, with an average age of 63".

As indicated in Consultations, and noted elsewhere, there is a new cohort of farmers entering the industry, educated in business, and looking to grow the size of farm businesses through acquisitions and leasing, and adopt AgTech innovations.

4.8 Environmental and biosecurity risks

4.8.1 Convergence of issues

In an interview Dr Andrew Campbell, former Managing Director of Land and Water Australia, raised the following issue:

The convergence of agriculture, environment, and health, to me, is just so compelling. And yet, you look at the agricultural innovation system, it's not set up for this in any way, shape, or form.

Where are the CRCs that are bringing together people from Australia's very good biomedical research, you know that whole Parkville Precinct, where's the CRC that's pulling the best out of Parkville and putting it together with the food system?"

This is very much an agenda issue regarding the current performance and future expectations of the rural innovation system. It is a concern that should be built into a Rural Industry strategy.

4.8.2 Climate change

Climate change, exacerbated climate variability, and climate variability in contexts where previously there wasn't any, or perturbed seasonality are significant issues that deliver context for rural innovation. It was commented that climate change -

... gives rise to a considerable research agenda, which is not just "Which crops? Which cultivars? Which agronomic practises?" It's also about policies, institutions, credit, finance, risk, risk-based insurance, etc. Aggregation systems, co-ops, or other ways of ensuring supply for people further down in the value chain.

There is a strong view that rural innovation strategy should reflect the opportunity for innovations in these areas.

4.8.3 Water conservation and use

One of the overarching concerns for rural innovation that emerged during Consultations concerned water use. A point was made that -

Water sensing technologies are critical for us to use every drop of water that we've got, whereas if you've got plenty of it, you don't worry about it; you just let it run through. Then you've got the other problems from leeching and the like with nutrients.

Not only is it possible to use the water more efficiently, but there is also less added nutrient because it's not washing out or adding anything more than is needed. This is, of course, part of a more comprehensive set of policy concerns. But the scope for leveraging innovations from a rural focus should not be overlooked.

4.8.4 Monitoring and baselines

In many areas of research, having monitoring and baseline systems is vital. It was reported that monitoring river flows, and other baselines are becoming harder and harder due to resource constraints. But base data sets are critical. An interviewee commented -

How do you know what you're managing if you haven't got baselines? We talk about biodiversity. I don't know if ... We're great readers of the Department of Environment State of the Environment Report. And so, we always read our chapters very closely because it's always a report card on us.

Shockingly, I think if you read the endangered species list, which is quite large, and if you go and look at some of those species, no one's done any work on some of them for 15 years.

While monitoring and baselines are essential for the environment generally, it is also essential for rural production. There was a view that it was receiving too little attention. It used to be a responsibility of Land and Water Australia, but there is concern that the effort has dropped following its disbandment.

4.9 Resilient rural communities

The flip side of productivity, growth, and technology adoption is that it often replaces labour. This compounds the issue of isolation and lack of resilience in the regional communities.

So, you end up with a more profitable, efficient farm, but no one wants to live or work there because there's no community.

Rural and regional communities have opportunities to develop “smart specialisation strategies” or similar initiatives built around the application of technology and building relationships with knowledge organisations (Schools and TAFEs as well as universities) that will create environments for new business creation and attract skilled, creative, and technologically oriented people.

The poor state of economic and social infrastructure in rural communities was remarked on many occasions during the Consultations. Innovative solutions to essential community services are becoming available, particularly in health.

4.10 Concluding comment

People consulted during the Review see a positive and dynamic outlook for food and agriculture and the rural sector. It is evolving dynamically. There is an expectation of more private investment and greater engagement with start-ups. The evolution of the system is discussed in greater detail in Appendix 5.

5. Detailed System Performance Appraisal

This Section of the Report explicitly addresses the National Research and Innovation (R&I) Committee requirement to describe the performance and impact of Australia's Rural Innovation System. Specifically, the Committee was seeking:

... an analysis of evidence available through which the performance of Australia's rural innovation system can be articulated and understood. This evidence may cover how resources are allocated and utilised, how information flows and various organisations and actors interact, what outcomes are being achieved and what impacts result from the effort.

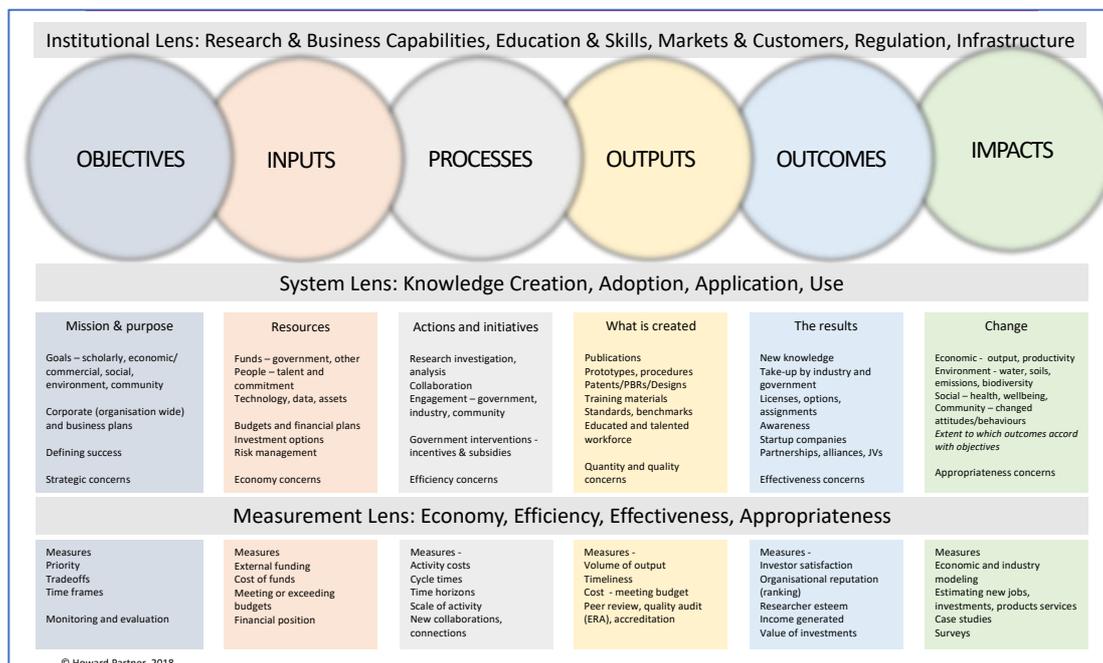
The project brief identified the rural innovation system in the following terms:

... the set of institutions and arrangements which contribute to the development and diffusion of new knowledge, technologies, and practices, and which provide the framework within which governments form and implement policies to influence the innovation process

The Section provides a detailed collation and analysis of evidence across a range of metrics, aiming to present a comprehensive picture of overall system performance, highlighting areas of strength, opportunities for improvement, and gaps in the knowledge base. It also seeks to understand rural research and development in the context of the R&D component of the broader National Innovation System.

This appraisal is presented in terms of a *logical framework* approach to performance review and evaluation, looking at objectives, inputs, processes, outputs, outcomes, and impacts within an institutional and organisational setting. This is represented in Figure 19 below.

Figure 19: Rural Innovation System Performance Review Framework



The Rural Innovation System also operates in several policy, administrative, regulatory, and social domains and contexts that profoundly impact innovation system performance. These are represented in Figure 20 below.

Figure 20: Rural Innovation System Policy Map: Complexity and the “Framing Problem”



This framework, derived from the field of policy analysis (Radin, 2013), points to the existence of “framing” problems that derive from an extensive range of interrelated and often conflicting policy issues and concerns and actors. This report does not specially address these framing problems, except Each element of the performance framework is considered in detail in Sections 5.1-5.6, which follow. It is important to note that the framework representation is not sequential. In public policy, interventions and initiatives often commence with the announcement of “inputs”, such as capped “funding programs” designed to *assist and support* submission-based initiatives and proposals.

The design of ‘funding’ program interventions makes assessing performance against objectives and expected outcomes are particularly challenging – relying in many cases on ex-post rationalisations of what public policy was intending to achieve.

So far, this Report has emphasised that innovation system performance is impacted by the performance and interaction with several other national socio-economic systems. This dimension is addressed further in Section 5.7. Section 5.8 identifies the institutions and organisations that underpin the design and appraises distinctive contributions - although a detailed performance review of each of the 100 or so organisations involved is well beyond the project’s scope.

Section 5.10 summarises the views of the 188 Experts who responded to the Expert Opinion Survey on the performance of system components.

5.1 Objectives of Rural, Research, Development, and Innovation (RD&I) Investment

Key points

- There are multiple objectives across governments, government organisations, and national industry associations
- System objectives reflect an uneasy combination of economy/industry level economic objectives and firm level strategic objectives
- The time frame for achieving objectives is often unclear and there is a mix between short term “horizon 1”, statements, medium term ‘horizon 2’ and game changing ‘horizon 3’ objectives.
- Few statements of objectives are linked to the resource allocation commitments that would be required and even fewer indicate pathways to adoption and how it will be known when success has been achieved.

Objectives for rural, research and innovation investment are set out variously in several reports released over the last five years. These have been referred to above and are summarised in Research Report 2. Objectives identified in the most recent reports are summarised below.

5.1.1 Objectives identified in recent reports and papers

Talking 2030: Growing Agriculture to a \$100 Billion Industry, prepared by the National Farmers' Federation (NFF) and KPMG, lays down a “bold vision” for the agricultural sector: \$100 billion in farm gate output by 2030 (National Farmers Federation & KPMG, 2018).

The paper notes that in 2017 farm gate output will total \$59 billion, meaning a required growth of almost 70 per cent in the coming 12 years. The discussion paper envisages a strategy to capture opportunities and navigate challenges to:

- Respond to changing consumer preferences.
- Harness technology and innovation to boost productivity.
- Reach burgeoning new markets across the globe.
- Access capital to fund this new phase of growth.
- Attract and train the best human talent.
- Lighten our environmental footprint by producing more with less.

Each of these challenges has been canvassed in many recent reports and papers (Academy of Technological Sciences and Engineering (ATSE), 2014; AgriFutures Australia, 2017; Australian Academy of Science, 2016; CSIRO Futures, 2017; Daly et al., 2015; StartupAUS, 2017). The NFF paper brings many of these together. A few reports have focussed on preserving natural capital and resource sustainability in an agribusiness context (National Australia Bank, 2017).

In a press release of 23 March 2018, “Supporting bold vision to grow agriculture into a \$100 billion industry” the Minister for Agriculture and Water Resources “welcomed the release of the National Farmers' Federation (NFF) blueprint” and added:

- The Coalition Government is investing to grow agriculture and supports NFF's ambitious vision for agriculture to become a \$100 billion industry by 2030.
- Nothing worth doing is ever easy and this won't be, but with a clear strategy in place and good policies in place, the sector will be prepared to take on the challenges ahead.
- Agriculture has always been one of the key drivers of the Australian economy and was the largest contributor to national GDP growth in 2016-17, driven by our dedicated, resolute, and innovative farmers.
- We are a trading nation and our future growth in agriculture depends on opening more markets and adapting to consumer preferences.
- More than ever before people are interested in where their food comes from and how it is produced. Australia stands to benefit as a producer of high quality, highly sought-after produce.

- The trade deals we are putting in place in Asia and across the world will be a key driver to reaching this target—70 per cent of our agricultural production is already being exported.
- Asia is expected to be the 2nd largest contributor to future world population growth, growing by 750 million people by 2050, so that's a lot of mouths to feed.
- Our investments in the Inland Rail, water infrastructure, rural R&D, innovation and technology will also help drive the sector over the next decade (Australia. Minister for Agriculture and Water Resources, 2018):

The NFF and KPMG are addressing an important policy gap. Our own consultations for this Review and the Expert Opinion Survey indicated that there is a search among stakeholders for a strategic vision and direction for the rural sector.

In a different context, *Food Innovation Australia Ltd (FIAL)*, published a Sector Competitiveness Plan (Food Innovation Australia Limited, 2017). This was developed in response to the Commonwealth Government identifying the Food and Agribusiness sector, along with five others, as a key priority sectors under the Industry Growth Centres Initiative (Department of Industry and Science, 2015). The Plan outlines a ten-year vision and strategy for the industry.

The Plan recognises that the Australian food and agribusiness industry is highly fragmented and operates in a diverse, dynamic, and complex landscape – spanning growers, raw material producers and manufacturers to packaging, sales, marketing, and retail providers, through to final users or consumers of the sector outputs.

The strategic analysis underpinning the FIAL Food and Agribusiness plan points to misalignment between the federal, state, local and regional levels of government in the provision of services to build the capability and competence of the industry and poor research–industry interaction.

The Plan envisages that growth can be pursued through accessing new markets and by raising competitiveness, but to achieve this change is required. The priority development goals, and the related actions are summarised below:

Figure 21: Food Innovation Australia Limited: Priority Development Goals

Sectoral Development	Priority Actions
<p>Capable firms: Industry players have the confidence and capacity to use their knowledge, resources, skilled workforce, and capabilities to develop innovative, cost-effective, and differentiated offerings for the Australian and international markets.</p>	<ul style="list-style-type: none"> • Identify businesses with a motivation to grow and desire to be a 'business of Tomorrow'. • Build knowledge platforms for collecting and sharing technology, regulatory challenges, and market insights. • Develop capability building programmes to ensure there are more 'boundary speaking gatekeepers' to reduce the industry–research divide. • Develop channel readiness programmes, to up-skill the workforce on innovation, business models, market channels and supply chains. • Support Food and Agribusiness incubators and accelerators
<p>Culture of collaboration: Develop a culture of connected, collaborative industry participants who desire transformational change, and continue to proactively seek and utilise collaborations for national and international market and supply chain success.</p>	<ul style="list-style-type: none"> • Develop collaboration among firms to support investment and innovation. • Establish a network of clusters. • Establish new research and commercialisation metrics, around engagement and collaboration, and outcome driven research to encourage linkages.

Sectoral Development	Priority Actions
Industry leadership: Develop a cohesive and clear voice of industry, influences, and shapes policy, and identifies opportunities for regulatory reform that fosters industry-wide innovation and entrepreneurship, in partnership with government.	<ul style="list-style-type: none"> • Establish effective working relationships and mechanisms for being the voice of industry to government (federal and state), and vice versa. • Encourage and optimise the alignment and effectiveness of government instruments, i.e., policies, free trade agreements and so on.

The FIAL Plan focuses on approaches to build economies of scale in market knowledge, manufacturing, and infrastructure to support those businesses with the desire to develop the confidence to acquire the capabilities and capacity necessary to transition from a 'business of Today into a business of Tomorrow' and that a large number of SMEs (including farm and AgTech businesses), in aggregate, have "the scale and capability to realise significant results through greater capability development, alignment, co-operation and collaboration across the industry, research organisations, and government support programs".

The recent CSIRO Futures, *Food and Agribusiness: A Roadmap* brings together several assessments of future opportunities and requirements for Australia's future in the Food and Agriculture (CSIRO Futures, 2017). It provides a valuable summation and perspective, making a persuasive case for greater innovation, coordination, and collaboration. Among the important perspectives are the following:

- Recently, and for the first time in Australia's history, value-added foods have accounted for the majority (60%) of food export growth (data for the three years to 2016, Austrade).
- However, the sector is traditionally commodity-based, with bulk commodities making up 88% of Australia's food and beverage exports.
- Australia's F&A sector is a minor player in the global food and beverages trade, accounting for only 2.2% of the global food trade in 2014.
- Value-adding typically falls under two categories: Processing (through transformation using manufacturing processes); or Method of production (differentiation, by type of production or type of product, e.g., organic, or selected variety).
- Australia's F&A sector could develop to become a small but significant exporter of sustainable, authentic, healthy, high quality and consistent products – but achieving this will require substantial change in culture, capabilities, and relationships.
- At present, Australia's *clean and green brand* is well regarded - but is not unique and is poorly differentiated.

Several megatrends that are shaping consumer preferences and industry trends are significant for product innovation: *A Less Predictable Planet* (climate change; resistance in pests and diseases), *Health on The Mind* (rising demand for foods providing health benefits), *Choosy Customers* (wealthier consumers demand greater variety and convenience), *One World* (with convergence in markets food value chains are more global and competitive), *Smarter Food Chains* (rising demand and the application of digital technologies is driving leaner, faster, more agile and low waste value chains)

Given this potential, it is a matter of concern that the CSIRO Report suggests that most of the food and agriculture businesses are not oriented to pursuing new markets, investing in building capability and taking managed risks.

The *Rural RD&E Priorities* were also developed through the consultation process that led to the Agricultural Competitiveness White Paper¹³. State and Territory Ministers agreed to the Rural RD&E Priorities at the Agricultural Ministers' Forum on 20 May 2016. The priorities are:

¹³ <http://agwhitepaper.agriculture.gov.au/SiteCollectionDocuments/ag-competitiveness-white-paper.pdf>

- advanced technology, to enhance innovation of products, processes and practices across the food and fibre supply chains through technologies such as robotics, digitisation, big data, genetics, and precision agriculture.
- biosecurity, to improve understanding and evidence of pest and disease pathways to help direct biosecurity resources to their best uses, minimising biosecurity threats and improving market access for primary producers.
- soil, water and managing natural resources, to manage soil health, improve water use efficiency and certainty of supply, sustainably develop new production areas, and improve resilience to climate events and impacts.
- adoption of R&D, focusing on flexible delivery of extension services that meet primary producers' needs and recognising the growing role of private service delivery.

The Rural RD&E Priorities are consistent with the National Science and Research Priorities announced in May 2015.

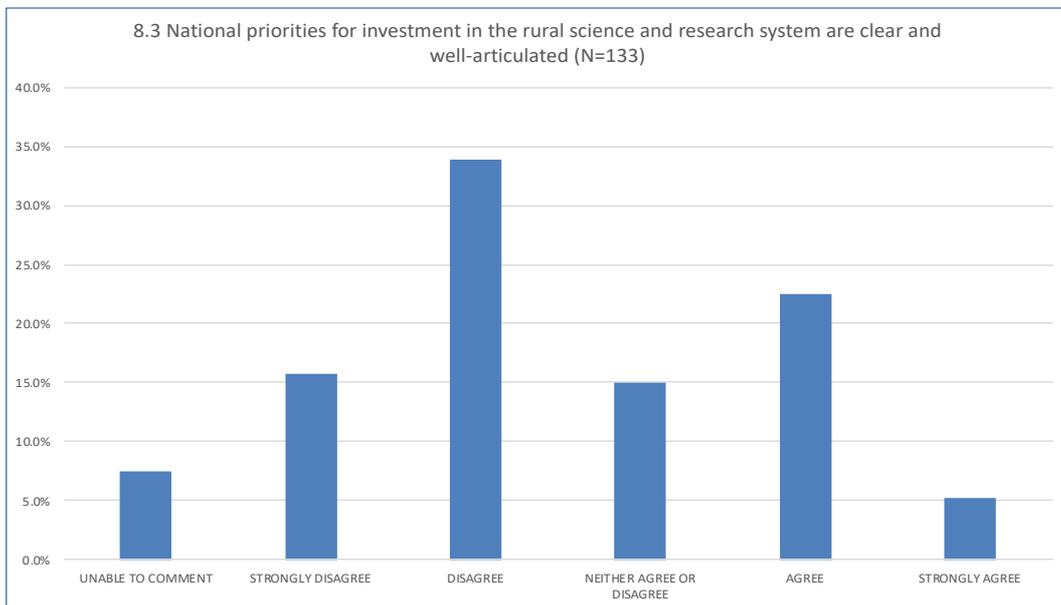
5.1.2 Feedback from the *Expert Opinion Survey*

The Expert Opinion Survey undertaken for the Review provided feedback on objectives. This is reproduced below.

- **Clarity and communication of research investment priorities and directions**

Notwithstanding the existence of *National Primary Industries Research, Development and Extension (RD&E) Priorities*, Rural Innovation Experts were of a view that national priorities for investment in rural science and research are not clear and well-articulated. This is indicated in Figure 22.

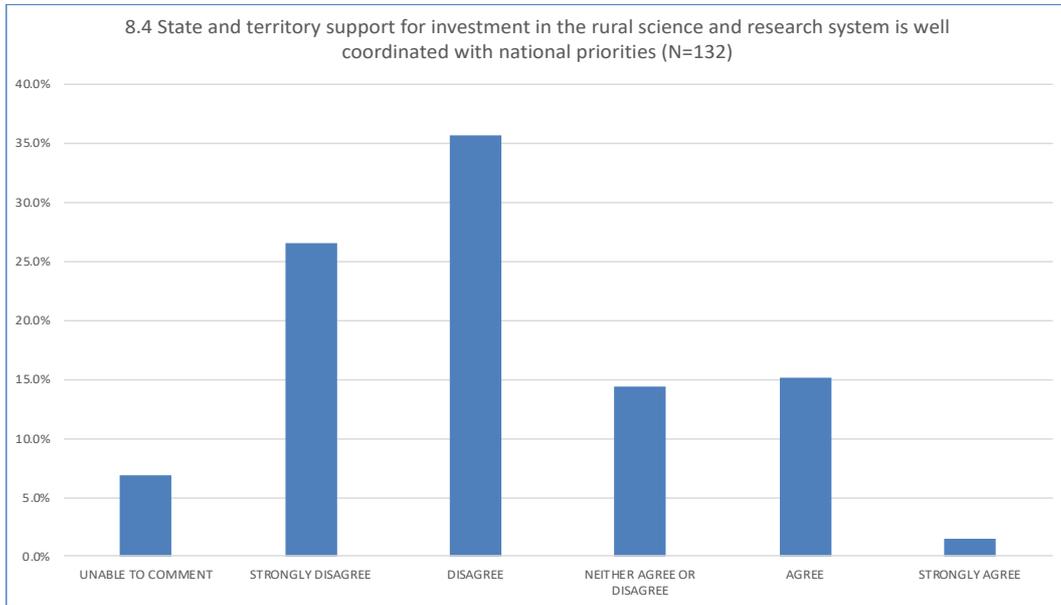
Figure 22: Expert Opinion Survey – Clarity of National priorities for investment in rural Science and Research



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

In a similar vein, Experts did not agree that State and Territory support for investment in rural science and research is well coordinated with national priorities. This is shown in Figure 23.

Figure 23: Expert Opinion Survey – Coordination of State and Territory Support for Investment in Rural Science and Research with National Priorities



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

The perceived absence of priorities and coordination between the Commonwealth and States/Territories in *farm* focused research the situation is exacerbated when looking at research from a value chain perspective.

▪ **Research priorities across the value chain**

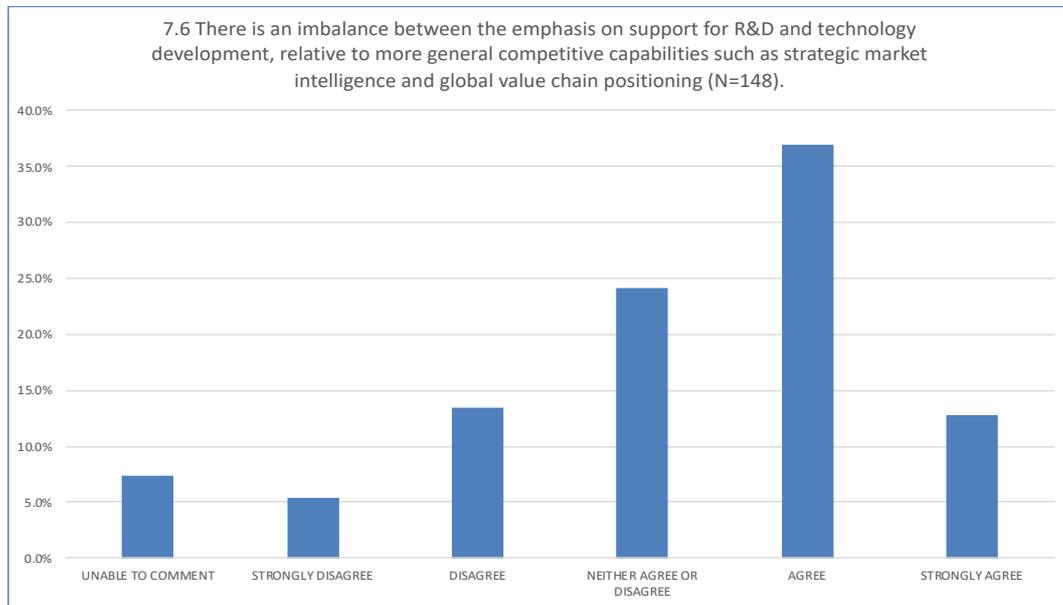
Several interviewees commented that the R&D framework for pre-farm gate and post-farm gate are not connected at all. This disconnect between “pre and post farm gate” in an R&D perspective is seen as a major problem and a major barrier when working in a whole of value chain paradigm.

It was argued that the direct and indirect benefits of a fully integrated, multi-disciplinary, multi-organisational RD&E strategy program designed with industry deliverables and a path to market (to the growing international markets across China, Japan, and Indonesia), and industry uptake in mind would be a major breakthrough in terms of:

- Reduction in time to delivery and increased levels of adoption.
- Strong synergies generated through development of critical mass at RD&E levels.
- Substantially increased flexibility within research programs to ensures maximum benefits to industry.

In support of this position, Consultations, and feedback from the Expert Opinion Survey, indicated a concern about the balance between investment in R&D and technology research on the one hand, and investment in more general competitive capabilities, such as strategic market development and global value chain positioning on the other. This is indicated in Figure 24 below.

Figure 24: Expert Opinion Survey – Balance between support for R&D vs market intelligence and global value chain positioning



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

Differences in approaches among RDCs were also reflected in the Consultations. The connection between the farm-based RD&E effort and the food and agribusiness strategies of FIAL and State Government agencies does not appear strong.

5.1.3 Concluding comment

There has been no shortage of rural industry research, development, and innovation strategies over the last six years. This is apart from the numerous reports and papers released by the Learned Academies, financial institutions, think tanks, and consultants which are detailed in the *Working Papers Report* (Document E).

These strategies exhibit very little cross referencing and a collective accumulation of perspectives about how to capture opportunities and address constraints. Very little mention is made of the resources required to implement strategies, and the challenges in implementation. Few of the reports look at both short term (horizon 1) and 'third horizon' perspectives.

It has almost got to the stage where we know enough about short-term strategies and opportunities based on existing knowledge and turn our thinking to how Australia can realistically position itself in global value chains, as argued in the *Strategic Perspectives* Part of this Report (Document A).

5.2 The Allocation of Resources for Investment in Rural Research, Development, and Innovation

Key points

- The National Primary Industries RD&E Framework aims to provide a shared strategic direction and priorities for national and sector level primary industries RDI in Australia that enhance the productivity and resilience of Australia's primary industries
- There are numerous Rural Research, Development and Innovation investment frameworks adopted by governments, research organisations and universities
- It is estimated that there was \$3.1 billion invested in RDI in 2014-15
- Historically, State governments have invested more in rural RDI than the Commonwealth, although the gap is narrowing
- Business investment in RDI has been increasing over the last five years in both plant and animal production and related products, but there is a view that the private sector commitment should be greater
- Australian businesses maintain a comparatively high level of investment in food products and beverages, but no material investment in textiles or wood and wood products
- Australia maintains strong investment in research facilities and equipment across the public and private sectors
- Experts considered that public RDI investment should target high performing institutions with a view to creating stronger capability, and have a focus on 'national challenges'
- Experts were concerned about low levels of collaboration and would like to see a greater commitment to interdisciplinary research
- Research providers had a concern with investment cycle times and what they saw as an excessive process orientation in grants administration.

The key performance question in this area is the extent to which the scarce resources available for investment in rural research development and innovation have been allocated in most appropriate way among competing demands and uses.

5.2.1 Investment strategy

The principal investment strategy document is the National RD&E Framework. Investment strategies are also reflected in many other documents prepared by other government organisations, universities, and the private sector.

▪ **The National Rural RD&E Strategic Framework**

Through the Primary Industries Ministerial Council (PIMC), the Commonwealth, State and Northern Territory governments, the rural R&D corporations, CSIRO, and universities have developed the *National Primary Industries Research, Development and Extension (RD&E) Framework* to encourage greater collaboration and promote continuous improvement in the investment of RD&E resources nationally. PIMC endorsed the Framework including the overarching statement of intent in *November 2009* (National Primary Industries Research and Development Framework, 2009)

The Purpose of the Framework is set out in the following terms:

Innovation and RD&E are key drivers to improving productivity and Australia's competitiveness in the primary industries sector and making best use of Australia's natural resources under a changing climate and marketplace.

The National RD&E Framework facilitates greater coordination among the Commonwealth, State governments, CSIRO, RDCs, industry and university sectors to better harmonise roles in primary industry RD&E and promotes effective collaboration to maximise benefits to Australia.

Agencies will build capability in fields strategically important to their jurisdictions and industries. Over time, capability will be consolidated into stronger national centres or networks, and it will

become more apparent where prospects in a particular industry or field lie. Agencies may also exit capability in some areas that are not strategically relevant¹⁴.

The Framework outcomes are reproduced below:

National Primary Industries RD&E Framework Outcomes	
1.	To provide shared strategic directions and priorities for national and sector level primary industries RD&E in Australia that enhance the productivity and resilience of Australia's primary industries.
2.	Research capability will more comprehensively and holistically cover the present and future strategic needs of stakeholders nationally.
3.	Public research capability will become more integrated, interdependent, and specialised, and have larger critical mass with less fragmentation across the nation.
4.	Efficiency and effectiveness of RD&E will be improved and consequently returns on investment will improve.
5.	RD&E investment will improve the capability of the national system in priority areas and ensure effective and efficient use of resources, including infrastructure.
6.	The Parties will collaborate to retain and build capability in fields strategically important to their jurisdictions and industries.
7.	The national research capability will be an integral component of a wider innovation agenda, supporting development and extension.
8.	Research undertaken in one location will be developed and extended nationally for primary industries.
https://www.npirdef.org/framework-outcomes	

PIMC has endorsed the following specific RD&E strategies:

- 14 sectoral strategies: beef, cotton, dairy, fishing and aquaculture, forestry, grains, horticulture, new and emerging industries, pork, poultry, sheep meat, sugar, wine, and wool.
- cross-sectoral strategies: animal welfare, biofuels and bioenergy, climate change and water use in Australian agriculture.
- Another four cross-sectoral strategies are underway: animal biosecurity, food and nutrition, plant biosecurity, and soils.

The Framework needs may need updating to reflect a broader rural sector innovation and strategic approach.

▪ **Other investment frameworks**

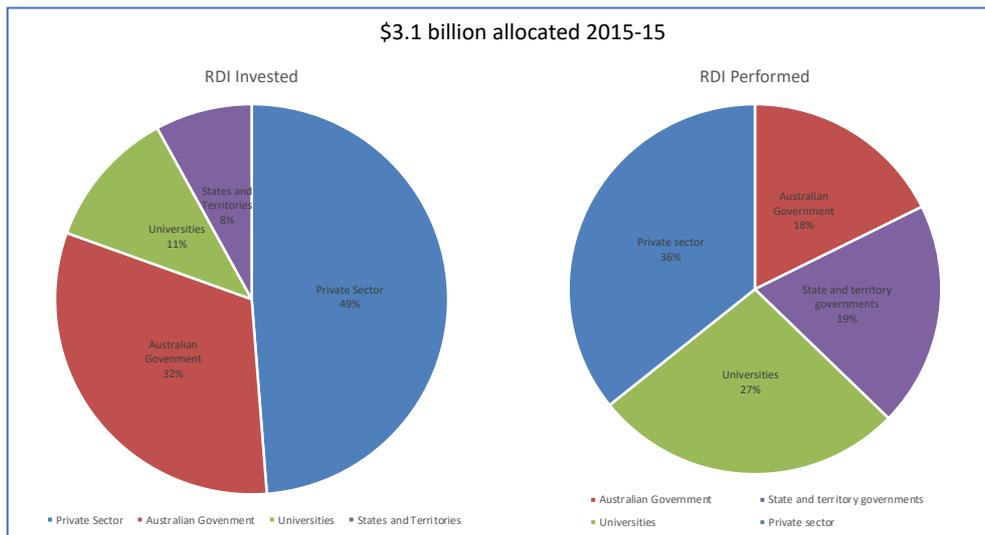
CSIRO, seven State/Territory Governments and up to 20 Universities with rural research centres/institutes, acting independently, have also established investment frameworks in accordance with their own strategic objectives and expected outcomes. In addition to the 14 strategies that fall under the RD&E framework, there are potentially 30 rural investment strategies across Australia.

5.2.2 The funding envelope

Estimates developed by staff at the Australian Bureau of Agricultural Research and Rural Sciences, indicate that \$3.1 billion was invested and undertaken in rural research, development and innovation in 2014-15 (Millist et al., 2017). Information the source of investment and research undertaken is provided in Figure 25.

¹⁴ <https://www.npirdef.org/framework-purpose>

Figure 25: Research Development and Innovation Investment 2014-15



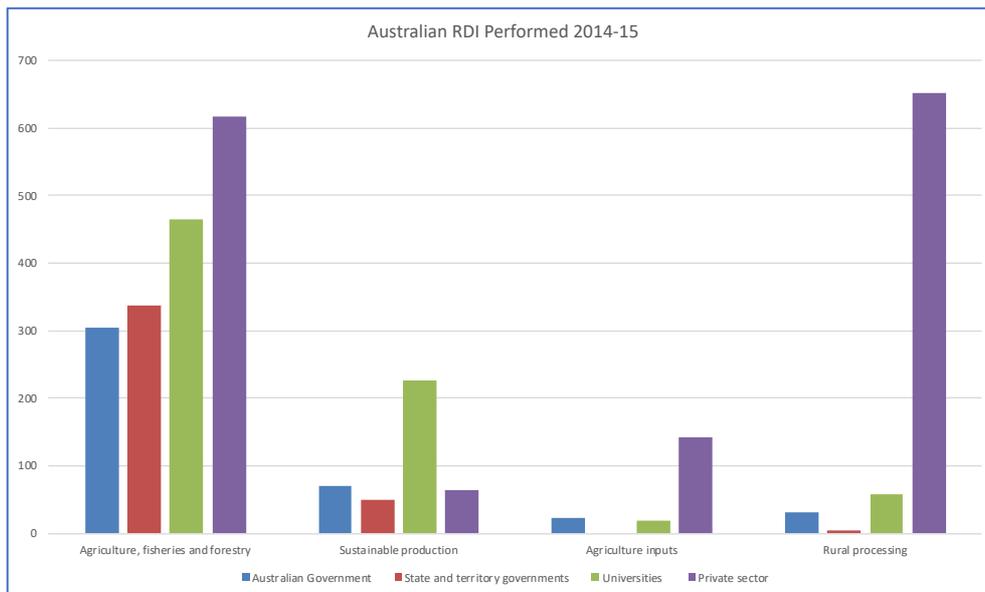
Source: Millist, N., Chancellor, W., & Jackson, T. (2017). Rural research, development, and extension investment in Australia. Research Report 17. 11

The proportion of private sector research funded by the Research and Development Tax Incentive is not provided. The RDTI is only available to incorporated businesses; it is not available to unincorporated businesses. Many farm businesses are run through family trusts.

During the consultations for the Review, many raised the question about the extent to which the annual quantum of RDE investment, amounting to less than 0.2 per cent of GDP, is large enough to make a difference to economic growth. Our analysis in Appendix 3 suggests that there is evidence of cumulative impact over the longer term.

The research undertaken is heavily concentrated in primary production (Agriculture fisheries and forestry) although private sector investment is almost equally distributed between primary production and “rural processing (manufacturing). This is indicated in Figure 26 below.

Figure 26: Australian Rural Research and Innovation Performed



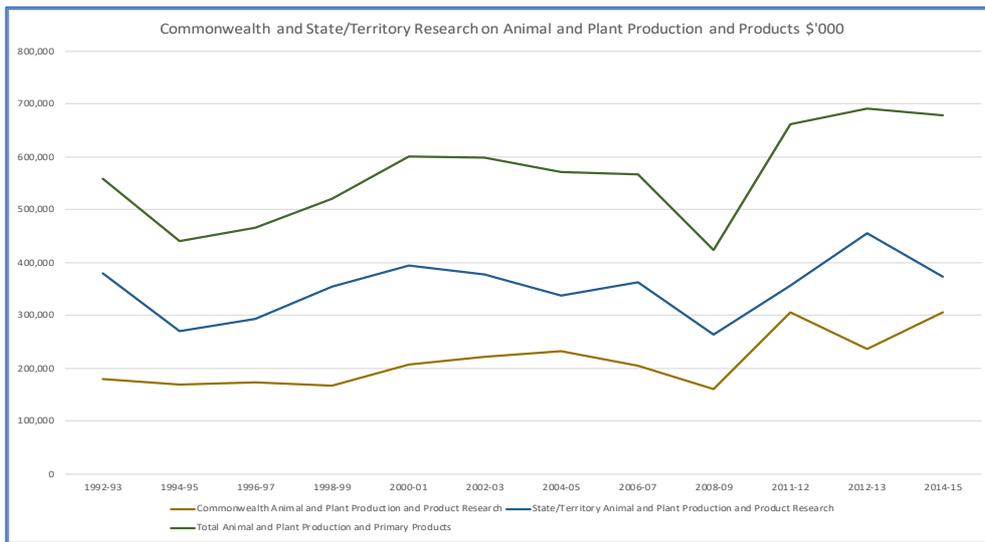
Source: Millist, N., Chancellor, W., & Jackson, T. (2017). Rural research, development, and extension investment in Australia. Research Report 17. 11

Aspects of research investment and performance in government and universities are addressed below.

- **Government investment**

The overall pattern of research expenditure on animal and plant production by Commonwealth and State/Territory Governments is indicated in Figure 27.

Figure 27: Commonwealth and State/Territory Government Research Expenditure on Animal and Plant Production and Related Products



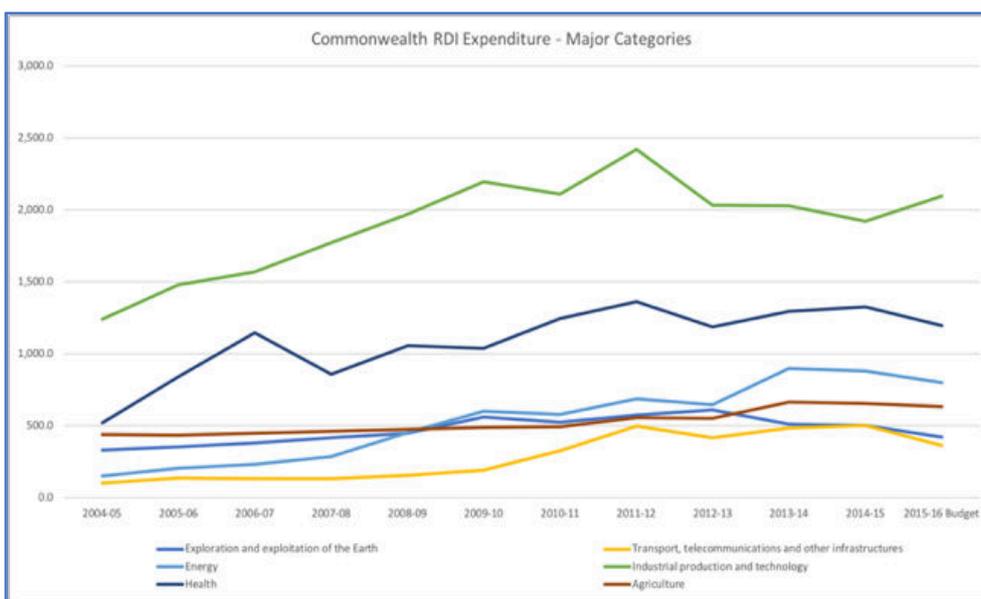
Source: ABS

Figure 27 indicates that State governments, in total, invest more than the Commonwealth, although the gap has been narrowing. There was a significant dip for both levels of government at the time of the GFC in 2009.

Commitment among the States varies, with NSW and Queensland maintaining strong commitments. Commonwealth expenditure is committed through CSIRO, AAHL, the Bureau of Meteorology, and the Australian Institute of Marine Science.

In terms of overall research priorities, Commonwealth RD&I budget tables imply that agricultural research falls a long way behind research into industrial production and technology, and health, as indicated in Figure 28. Of course, in the growing AgTech sector, which has a manufacturing and service component, research may be categorised more generally as industrial.

Figure 28: Commonwealth RD&I Expenditure – Major Categories

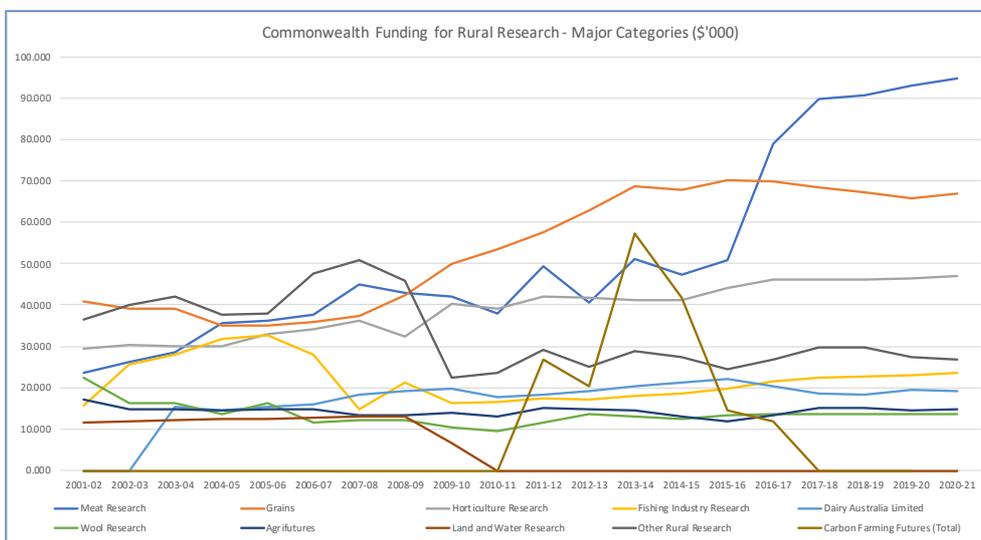


Source: Department of Industry, Innovation, and Science

Research that benefits the rural sector would also be sourced from the health categories, particularly as innovation involves drawing on knowledge developed across many research fields. This is an inherent problem in using international standard classifications of research (socio economic objectives and fields of research) to identify current research commitment.

Data from the Commonwealth RDI Budget tables indicates that the greatest commitments in rural research are made in meat, grains, and horticulture. This is indicated in Figure 29. These investments would be made principally through the RDCs.

Figure 29: Commonwealth Funding for Rural Research: Major categories



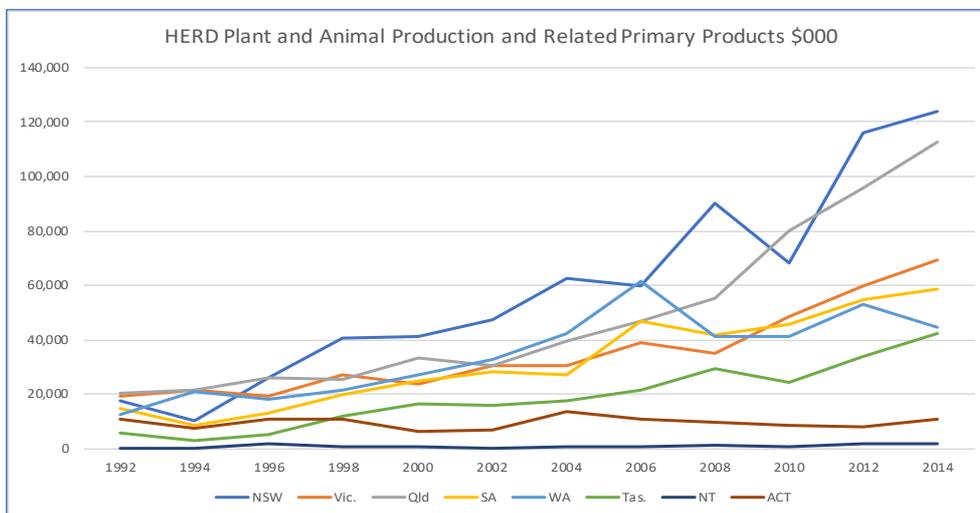
Source: Department of Industry, Innovation, and science

Figure 29 indicates that commitment to land and water research collapsed in 2011-12, following the dissolution of Land and Water Australia. There was a short-lived uptick in environmental focus with the Carbon Farming Futures initiative.

▪ **Higher education investment**

As indicated in Figure 30, ABS data indicate that higher education institutions have been progressively increasing their commitment to research in animal and plant production and related disciplines.

Figure 30: Higher Education Research Expenditure on Plant and Animal Production and Related Primary Products

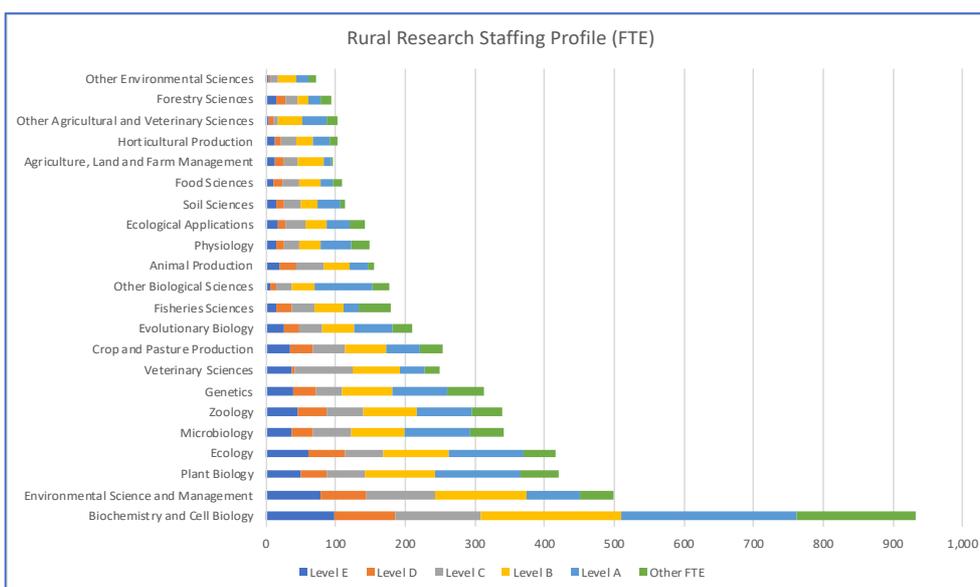


Source: ABS

Higher Education research expenditure is financed from external research income and university own sources. The rate of increase is unevenly spread, with NSW and Queensland showing the strongest trend increases. The trend increase in WA fell away after 2004. From a small base, Tasmania is showing an increased commitment.

Increased funding commitment allows for increases in research staffing. Staffing data, from consolidated ERA returns, classified by Fields of Research, is presented in Figure 31, which includes information from both the agricultural and biological sciences, acknowledging the significance of biology in rural research. It is around biochemistry and cell biology that staffing number increases predominate.

Figure 31: University Rural Research staffing profile (FTE)

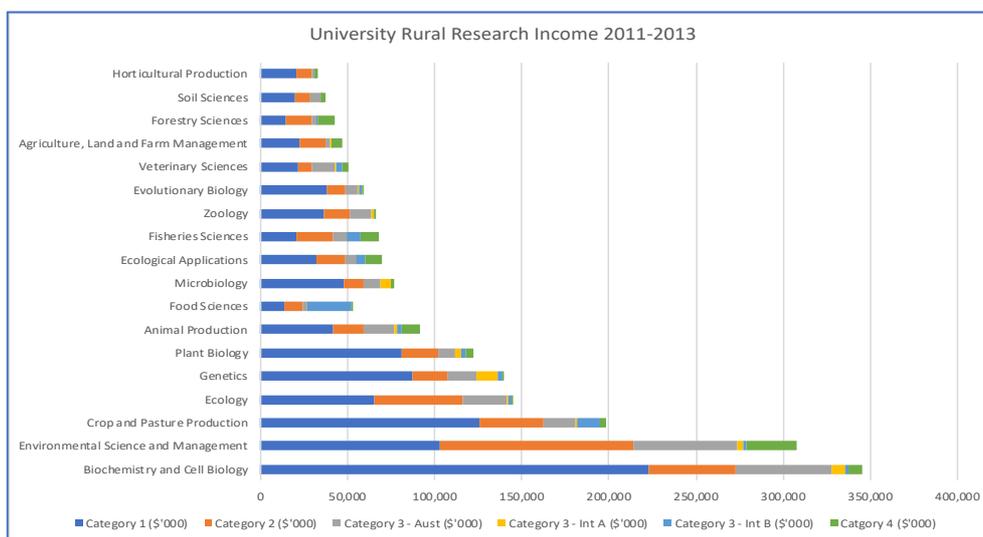


Source: Australian Research Council

Data available from the ERA data files suggests a relatively stable pattern of funding for research in the Agricultural Sciences over the period 2011-2104.

Data from the Higher Education Research Data Collection (HERDC) provides information on university research income (to fund research investment) across fields of research according to income category. Income for the years 2013-2014 in the Agricultural and Biological Sciences Research fields are provided in Figure 32.

Figure 32: University Income for Research in Rural and Related Areas

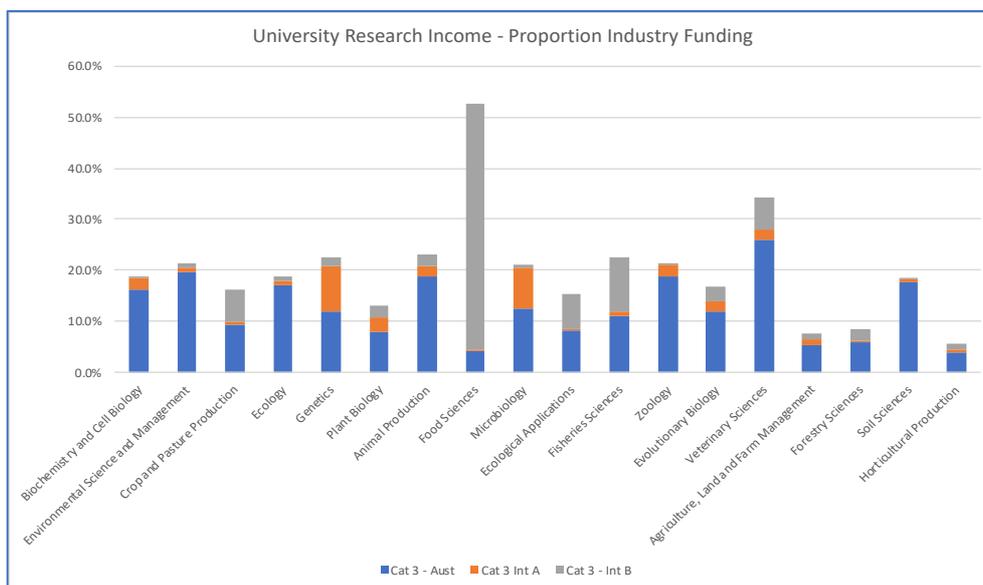


Source: Australian Research Council

Category 1 covers Australian competitive grant income; category 2 covers other government research income; category 3 covers industry income, and category 4 is CRC income, which is very important for regional universities.

Further information on Category 3, income from industry, is provided in Figure 33 below. The data shows some significant international income sources for genetics, microbiology, and plant biology. There is a very strong international commitment to foods sciences, fisheries sciences, ecology, and crop and pasture protection.

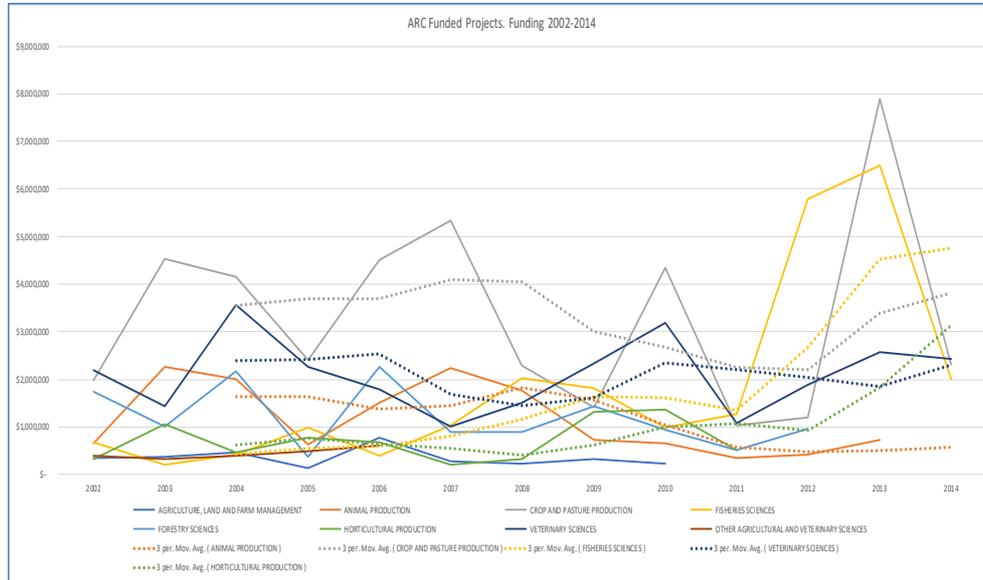
Figure 33: University Category 3 Research Income – Proportions Australia and International Sources



Source: Australian Research Council

Figure 34 gives an indication of ARC research investment across agricultural science fields. The information is sourced on a 'project approval' basis, rather than annual allocations. It therefore picks up successes (or failures) across the timing of funding rounds.

Figure 34: ARC funding for Research in Agricultural Sciences - Project Approval Basis, 2002-2014



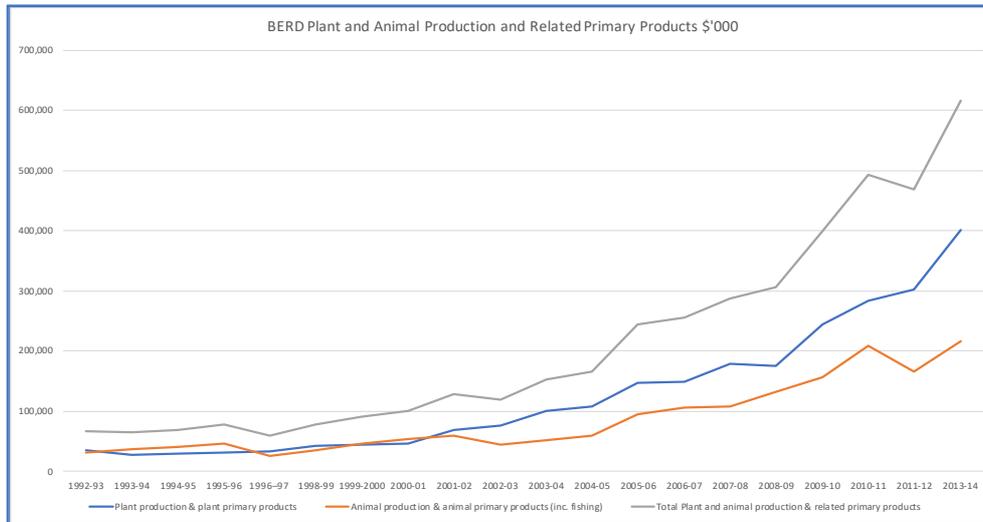
Source: Australian Research Council

The peaks and troughs may be an indicator of the short-term duration of ARC grants (mainly three years) and an absence of long-term continuity in investment commitment, that many researchers were concerned about, as expressed in the consultations¹⁵.

▪ **Business investment**

Business expenditure on research and development has been increasing sharply since 2004-05, possibly reflecting the impact of the R&D tax incentive and changing ownership of rural enterprises (including farms) as they move from trustee business models (which cannot claim the R&D incentive) to corporate business models (which can).

¹⁵ The ARC has not been consulted on the interpretation of this data.

Figure 35: Business expenditure on Plant and Animal Production and related Primary Products

Source: ABS

In the OECD Report, *Research and Development Expenditure Industry, 2008-2015*, (OECD, 2017) comparative data is provided for private investment in food products, beverages and tobacco. The most significant investors are the USA and China, although Australia has been among the leaders in a longer tail.

Table 2: Comparative international business investment in food products, beverages, tobacco (\$US, PPP)

	2008	2009	2010	2011	2012	2013	2014
Australia	319.3	346.5	401.3	357.5	373.2	443.6	..
New Zealand	61.5	56.2	64.5	74.7	59.0	55.3	..
Canada	163.8	169.3	158.9	134.0	123.8	109.2	114.3
UK	..	376.8	330.7	388.2	378.5	446.2	438.8
USA	2937.3	4726.0	4544.7	4983.0	4675.6	5543.3	5777.8
China	3587.7	4876.0	5713.9	6707.0	8800.3	10048.8	11341.6
Germany	350.6	398.7	408.9	379.2	381.9	374.3	371.8
Italy	208.2	203.1	212.8	191.9	216.2	234.4	234.4

Source: OECD, Research and Development Expenditure Industry, 2008-2015,

Lifting Australia's performance in food processing is a challenge being taken up by Food Innovation Australia Limited (FIAL) and its predecessor entities.

Notwithstanding Australia's high level of wool and cotton production, and its quality, there has been a very low level of private investment in textile manufacture. This is in stark contrast to Chinese investment. Conversations in the Review, referred to earlier, suggested that Australia was missing opportunities in this area with the emergence of automation and "digital factories".

Table 3: Comparative international business investment in textiles (\$US, PPP)

	2008	2009	2010	2011	2012	2013	2014
Australia	15.3	11.8	14.6	16.6	..	..	..
New Zealand	..	..	..	..	..	..	..
Canada	39.5	39.6	36.0	34.4	25.1	20.1	22.7
UK	..	15.1	15.4	35.5	43.9	29.7	29.8
USA *	831.2	433.2	489.0	621.2	538.7	626.8	586.9
China	1969.5	2623.8	3016.1	3801.4	3767.3	4231.6	4705.4
Germany	121.9	88.7	54.6	76.5	78.1	66.8	64.7
Italy	98.9	117.8	149.7	127.8	129.4	137.8	156.1

Source: OECD, Research and Development Expenditure Industry, 2008-2015, *includes wearing apparel, leather, and related products

Old models of textile production, involving mass production and labour-intensive factories have largely disappeared. New models using fully automated technology are potentially an opportunity for Australian entrepreneurs and investors. But there is investor resistance:

The Man and the Dog Model of Cotton Textile production

We produce so much energy and we have all these very well educated and highly skilled people in our society and we grow these wonderful, wonderful raw materials and we cannot value add to them any less than we currently do. We cannot add any less value to what we ... We put it in a bale, and we ship it offshore. There is no commercial scale anyway in cotton spinning in Australia.

I tried to buy the Bonds spinning mill out here in Western Sydney years ago, 6 million bucks they wanted for it. It was owned by Pacific Dunlop and my plan was that we would buy it and run it for a couple of years, and we would transfer it out to Narrabri, and we would build a brand new, state of the art, man and dog mill it was going to be. The dog was for security and the man was to feed the dog because that was the only thing we hadn't yet worked out how to automate.

So yeah, you just turn the lights on to service it, hire skilled technical and mechanical and electrical engineers, you know, keeping these things going, producing really, high-quality shirting fibre, 40-50 count yarn. Which I was one of the first to spin, I spun it in Indonesia. I went to the market and said, I want to raise \$6m to buy this factory in western Sydney and I did not raise a cent.

We make the ideal cotton. You know the highest value product made from cotton per kilogram is a men's business shirt, in any quantity there are smaller items, but you know, it might be medical things or there is higher value uses but a 40-50 count yarn into a men's business shirt, which is what we can grow and spin, we could make the best men's business shirts in the world and export them all around the world.

The Chinese too have worked out that automation is better than people and these systems that they are developing, the mill I wanted to build was basically built in Germany and these people are bloody good, the Schussler and Schlafhorst companies and they are just ever, every improving and you know, changing and getting better and innovating.

These factories need to be serviced and they still need to be installed and the mechanical engineers, the electricians and the electronics and there is some serious intellectual stuff going on in there.

Mike Logan, Interview, 1 November, 2017

Such factories can be set up in rural communities. But they require the supporting public infrastructure in areas such as digital communications and connectivity.

At the Huon Aquaculture new processing facility in Northern Tasmania, all the jobs are high-end, and people are being paid a lot of money. They're not menial labour jobs. They are high-end technical jobs. They're the people who can fast track that computer phase or that sensor to make sure the machines will work. And surely that is where we want to go.

A similar picture emerges in relation to wood and paper products

Table 4: Comparative international business investment in wood and wood products, except furniture (\$US, PPP)

	2008	2009	2010	2011	2012	2013	2014
Australia	40.8	40.6	41.5	24.9	..	..	..
New Zealand	..	..	..	..	..	..	..
Canada	180.3	86.8	71.2	69.8	69.0	59.4	56.8
UK	..	4.1	5.1	2.0	3.9	8.9	8.2
USA	278.4	518.3	247.0	206.7	443.5	208.3	336.7
China	261.7	334.6	334.5	404.4	511.1	725.1	866.3
Germany	25.9	25.2	28.5	27.8	24.0	23.7	22.8
Italy	18.8	21.2	18.1	17.4	17.3	16.9	16.7

Source: OECD, Research and Development Expenditure Industry, 2008-2015,

Data from AusIndustry indicate that there in 2013-14 there were 514 agriculture, forestry and fishing entities registered to receive the R&D tax incentive, amounting to 3.7 per cent of all entities. There were 4,386 entities registered in manufacturing, although the proportion of food and fibre companies is not published. The value of rural R&D expenditure supported by the incentive amounted to \$469.7m, representing 2.4 per cent of all R&D expenditure. Manufacturing made up 32.3 per cent of all expenditure.

5.2.3 Balance between discovery, applied, and implementation research

Departing from the usual distinction between pure and applied research and experimental development, and drawing on Ernest Boyer's *Scholarship Reconsidered* (Boyer, 1997), four categories of research relating to innovation can be identified:

- Discovery, investigator driven, curiosity research
- Integrative research

- Applicable research
- Implementation and adoption (translation research).

Each is addressed briefly below.

▪ ***Discovery, investigator driven, curiosity research***

This area of research creates new knowledge and is judged based on excellence and eminence and strong international research connections. This is the principal focus of the Excellence in Research Australia (ERA) assessment. It is also relevant to furthering research collaboration.

As argued in the *Strategic Perspectives Report* (Document A), the performance of the innovation system rests on a strong base of new knowledge flowing from this area of research endeavour.

Global corporates will go to a university and say, "We're interested in your basic research. What are you doing? What do you have down the pipeline? We're not really too fussed about however you apply it because we will do it ourselves."

Interestingly, "excellent" researchers are also sometimes the best industry collaborators.

▪ ***Integrative research***

Integrative research creates new perspectives that emerge from inter/cross disciplinary approaches to the resolution of problems, issues, and opportunities.

As Australian university faculties tend to function as specialised "business units" defined by disciplinary boundaries, and there is little external public funding for this type of research, and it tends not to be done in the absence of an external investor or stream of investor income. Yet it is a form of research that external partners are interested in, although they won't invest unless they can see the capability. It is a catch 22 situation and may partly explain the low level of interaction between universities and businesses in Australia.

Integrative research is conducted in specially constituted and independent (from faculty structures) research centres and institutes, under university rules for "recognised research centres", and are positioned to attract philanthropy and industry investment through long term partnership arrangements. Some may be established as not-for-profit companies with external equity.

This institutional form is common in the US, but less so in Australia (although medical research institutes tend to be structured in this way). There are some leading examples in Australian rural research.

Autonomous or "university recognised" independent research centres and institutes in universities can be expensive to operate and must demonstrate financial viability. They rely on commissioned research and consultancy to subsidise loss making discovery research that earns them esteem. Otherwise, they lose their independence and become folded back into faculty structures.

Integrative research does not receive a great deal of attention or priority in the Australian research investment system. This may be because research investment is focussed on fields of research rather than bringing fields together to create new and novel approaches to address new and evolving research and innovation horizons. This is a matter to address in future rural research and investment strategies.

- ***Applicable research***

This form of research covers investigation, inquiry and analysis that brings new knowledge and perspectives into use. It focuses on how research results can be brought into practice. This research tends to be strategic, and market focussed on approach and can cover investments that reduce business risk.

CSIRO, State Agricultural Research Institutes, and the CRC program tend to be positioned in this area.

- ***Research that addresses implementation and adoption (translation research)***

Research that looks at ways to implement and adopt and communicate findings and practices to end users who may not have an academic background. This is sometimes referred to as 'translational' research. The Medical Research Translation Fund is an example of a major investment commitment in this category.

During the Consultations for the Review there were many advocates for an Agricultural Research Translation fund modelled on the Medical Research Translation Fund. Of course, the greater is the extent to which research is conducted in partnership with users, the lesser is the translation problem.

The main issue concerning implementation research is addressing the technical and other risks associated with implementation.

5.2.4 Investments in facilities and equipment

In addition to supporting operational expenditure on research and development activity, investments are also allocated to the creation of infrastructure assets.

The Australian Government has invested in rural research and development infrastructure through several schemes, including:

- The National Collaborative Research Infrastructure Strategy (NCRIS)
- The Super Science Initiative
- The Education Investment Fund (EIF)
- The Collaborative Research Infrastructure Scheme (CRIS)
- The Australian Research Council's (ARC) Linkage Infrastructure, Equipment and Facilities (LIEF) scheme.

Significant investments by the Commonwealth in rural research facilities cover -

- Facilities owned and operated by the CSIRO, including the Australian Animal Health Laboratory (AAHL)
- Australian Plant Phenomics Facility - measures the phenotype (physical attributes) of plants leading to the development of new and improved crops, healthier food, more sustainable agricultural practices, improved maintenance and regeneration of biodiversity and the use of crops to develop pharmaceuticals.
- National Imaging Facility (NIF) - national network that provides state of the art imaging of animals, plants, and materials for the Australian research community.

State Governments have major investments in research facilities through State Agricultural Research Institutes, often in collaboration with universities. Universities have also developed strong facilities for research and problem solving through the creation of research infrastructure. The infrastructure is very extensive, although capabilities and performance are not well known outside the research sector and the organisations that invest in them.

Many of these facilities have been developed over an extended period through investments from State Government capital budgets and the Rural Research and Development Corporations. The existence of these facilities has enabled Australian scientists to build capability to undertake world class research in a range of agricultural, biological, and environmental science research fields.

Information on Government, University and privately-owned infrastructure recorded during 2013 and sourced from the *National food and nutrition research and development and technology transfer strategy* (CSIRO et al., 2013) is listed in Table 5 below.

Table 5: Australian Agriculture and Food Infrastructure

Distinctive Infrastructure	Organisation Location
Pilot plants and processing laboratories	
Extensive pilot plants (molecule - kg)	CSIRO Brisbane, Melbourne
Small pilot scale processing equipment	University of Queensland Brisbane
Extensive pilot plant	DAFFQ Brisbane
Fermentation lab (micro to pilot scale)	Provisor Adelaide
Brewing plant	SARDI Adelaide
Distilling plant	SARDI Adelaide
Malting pilot plant	Edith Cowan University, Perth
Cheesemaking facility	SARDI Adelaide
Ultra-High Temperature processing units	University of Newcastle, University of Western Sydney
Food Technology laboratory	DAFFQ Brisbane
Live seafood laboratory	DAFFQ Brisbane
Pilot facilities for training and product development, bakery, confectionary	William Angliss TAFE Melbourne
Horsham Grains Innovation Park (Small scale grain quality testing instrumentation and laboratory;	DEPI Vic Horsham
Free Air Carbon Dioxide Enrichment (FACE) array - for assessing quality under higher carbon dioxide field conditions,	DEPI Vic Horsham
Agribio – Bundoora (molecular technologies for crop protection, soil health, quality, pre-breeding, and structure function analysis at molecular scale)	DEPI Vic Bundoora
Hamilton and Attwood (Red meat innovation centre - quality testing lab. facilities to support on farm trials)	DEPI Vic Hamilton, Attwood
Ellinbank (Laboratory and paddock and field facilities to support GHG abatement and mitigation)	DEPI Vic Ellinbank
Ration packs, freeze-drying production line	DSTO Scottsdale, Tasmania
ISO 9001 accredited Whole grain assessment, micro malting, milling, test baking, yellow alkaline noodle evaluation facilities	DAFFQ Toowoomba
NATA Accredited Microbiological Food Safety Lab	DAFFQ Cairns
Non-invasive pre-processing and in-line assessment technologies facility	DAFFQ/James Cook University, Cairns
Human and animal studies facilities	
Consumer/Sensory Laboratory and Focus Group units	DAFFQ Brisbane
Product development kitchen	SARDI, TAFE SA Adelaide
Food-based clinical labs for human trials	University of Wollongong Wollongong
Human Clinic	CSIRO Adelaide Flinders
Large scale clinical lab for human trials	Adelaide University Adelaide
Animal house	Flinders University, CSIRO Adelaide, Sydney
Nutrition and Health facilities	
Nutrition substantiation, glycaemic measurement equipment and nutrigenomics laboratories	CSIRO Adelaide
Analytical Facilities	
National centre for durum wheat and pasta lab	NSW Trade and Investment Tamworth
Synchrotron, accelerator, and neutron scattering Facility	Australian Synchrotron Melbourne
Rheology and polymer testing lab	RMIT University Melbourne
Flavour analysis lab	University of NSW Sydney
Lipid analysis lab	Adelaide University Adelaide
Packaging stability lab	University of NSW Sydney
Sustainable packaging systems lab	Victoria University Melbourne
Neutron scattering instrumentation facility	ANSTO Sydney
Chemical, nutritional, microbiological instrumentation laboratories	NMI Sydney, Melbourne
Food safety microbiology and genomics research lab	University of Tasmania
Pilot flour milling and baking facilities	Grain Growers Sydney
Australian Export Grains Innovation Centre (AEGIC), with capability for grain quality, grain economic analysis, market intelligence, grain quality genetics, processing and product functionality, and storage and product integrity	DAFWA, GRDC Perth, WA
Food testing laboratory	DTS Food laboratories Kensington, Vic
National Association of Testing Authorities labs	Food Laboratories Australia Abbotsford, Vic
Spectroscopic rapid analytical laboratory	The Australian wine research institute South Australia
Fully equipped training kitchens and bakeries, Coffee Academy, Wine sensory evaluation centre, meat processing rooms, Confectionery training meat processing rooms, Confectionery training centre	William Angliss Institute of TAFE, Melbourne
Bakery test kitchens	Box Hill Institute of TAFE Box Hill, Vic
Dairy processing facilities (UHT, dryers, sterilisers)	Shepparton TAFE Shepparton, Vic

Source: <https://www.npirdef.org/content/33/8700b4c8/Food-and-Nutrition-RDIT-Strategy.pdf>

It is not clear whether this portfolio of facilities has been updated since 2013.

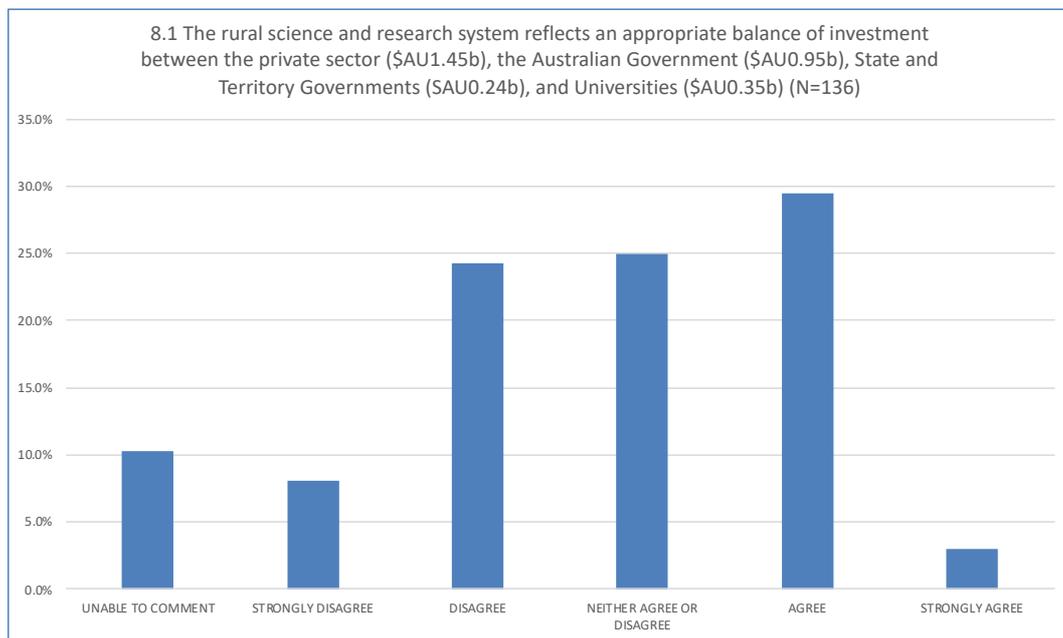
There is also capability embedded in long standing rural research institutes and centres not listed above. Profiles of Commonwealth, State and University rural research Institutes and facilities are in the *Working Documents* that accompany this Report.

5.2.5 Feedback from the Expert Opinion Survey

▪ *Allocation between public and private investment*

The Expert Opinion Survey asked whether this investment in Science and Research reflected an appropriate balance between the private sector, government, and universities. The overall responses were ambivalent, although tending towards disagreement, as reflected in Responses are provided in Figure 36.

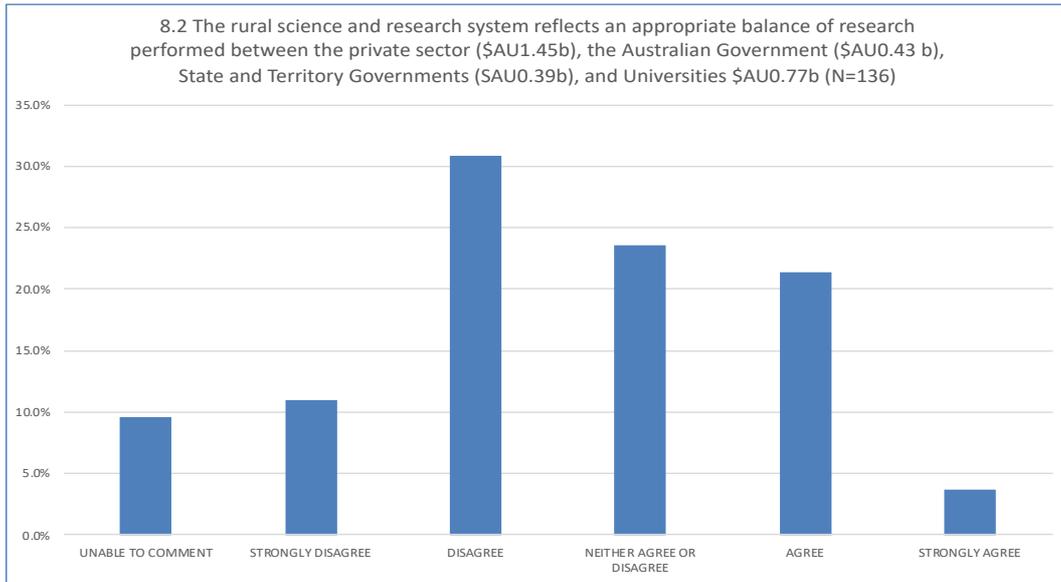
Figure 36: Expert Opinion Survey – Balance between private, government and university investment in research



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey. 2018

In terms of research performance, Experts indicated more disagreement about the extent to which there was an appropriate balance between private, government and university research. This is indicated in Figure 18.

Figure 37: Expert Opinion Survey - Balance between private, government and university research performed



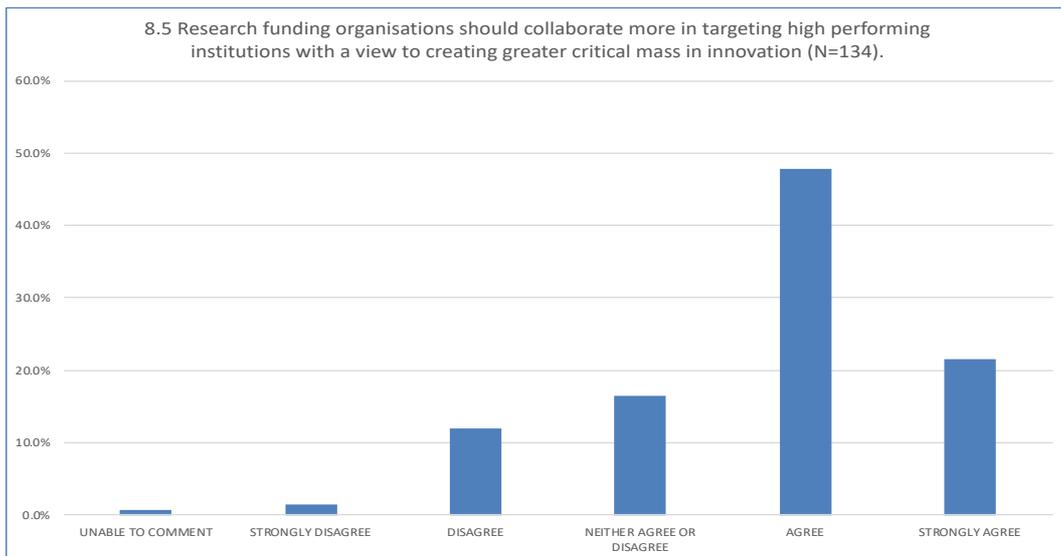
Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

Consultations found that most experts considered that the private sector in Australia should make a greater commitment to research.

▪ **Supporting high performance institutions to create “critical mass”**

The subject of “critical mass” in research was a consistent theme during Review Consultations. Figure 38 shows Experts responses to the proposition “Research funding organisations should collaborate more in targeting high performing institutions with a view to creating greater critical mass in innovation”.

Figure 38: Expert Opinion Survey - Targeting high performing institutions with a view to creating greater critical mass in innovation



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

The response should not be interpreted as an argument for re-distributing the currently available research investment funds among existing institutions. It should be seen as part of an argument to consolidate and build capability in rural research and development.

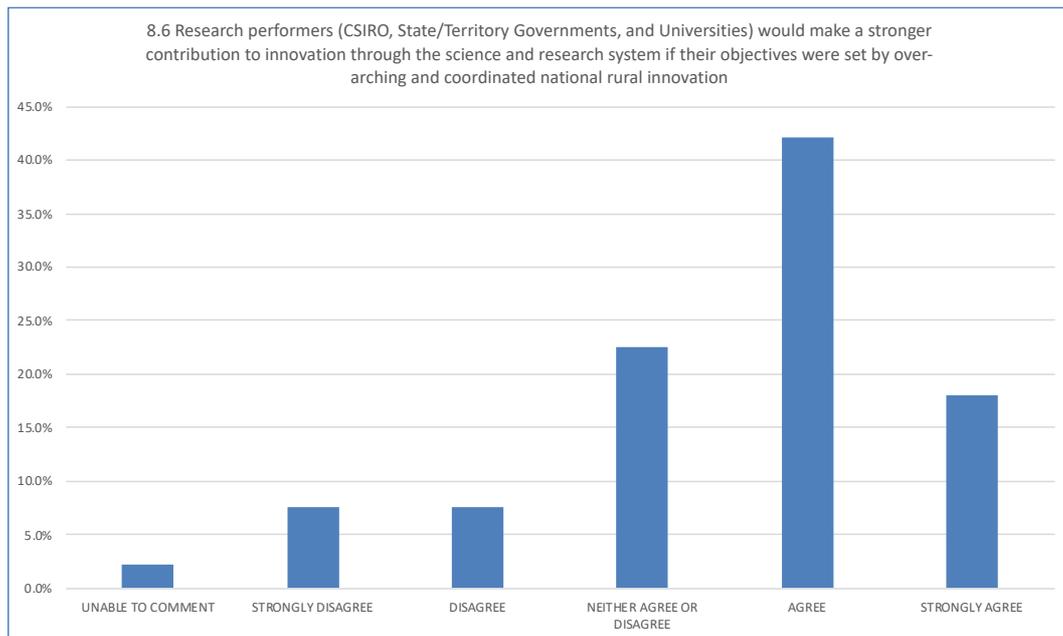
- **Research that targets “National Challenges”**

Innovation Science Australia, in the *Australia 2030 Prosperity Through Innovation* strategy gives a focus to investing in national missions and challenges. In that context, the Expert Opinion Survey included the proposition that:

Research performers (CSIRO, State/Territory Governments, and Universities) would make a stronger contribution to innovation through the science and research system if their objectives were set by over-arching and coordinated national rural innovation challenges

Experts indicated a high level of agreement, in the region of 60 per cent for this idea, as shown in Figure 39.

Figure 39: Expert Opinion Survey – Research investment focussed on national challenges



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

This response supports arguments for a strong strategic, and goal oriented, approach for towards rural research and innovation investment. An interviewee commented:

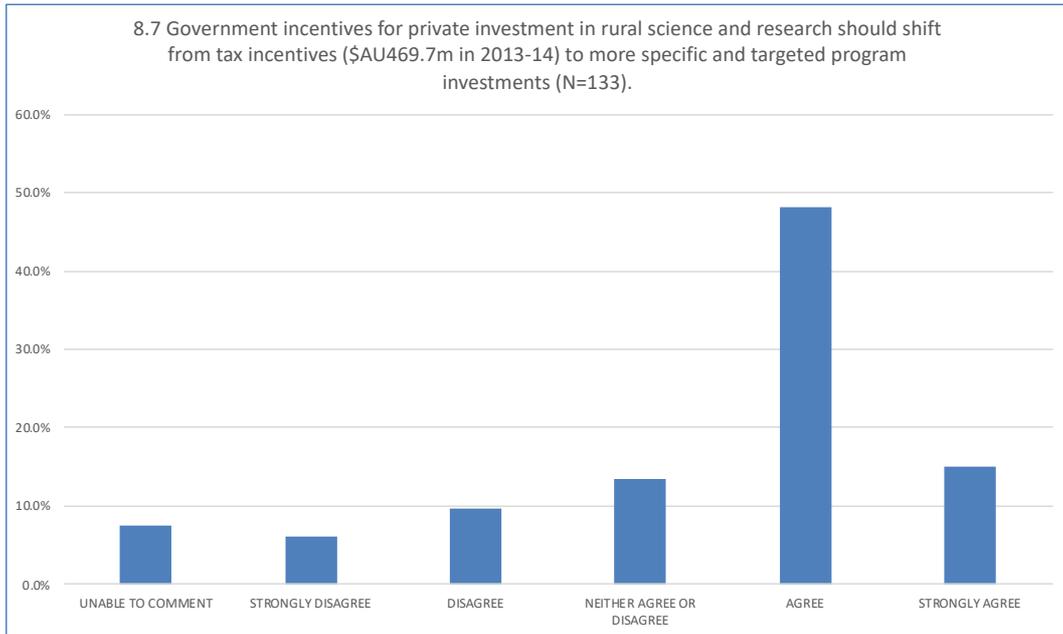
One might ask “where is the next national challenge for Australian Rural Innovation.

During Consultations national challenges around Soils and AgTech were mentioned.

- **Research investment options**

Experts were asked whether “Government incentives for private investment in rural science and research should shift from tax incentives (\$AU469.7m in 2013-14) to more specific and targeted program investments”. Responses are provided in Figure 40, which shows a high level of agreement and a modest level of strong agreement.

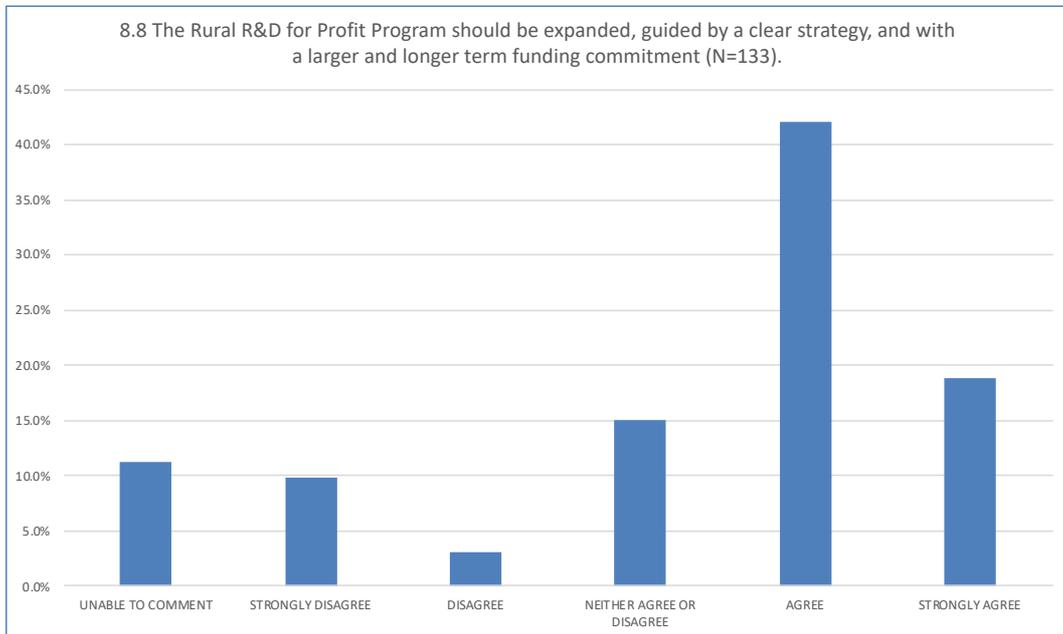
Figure 40: Expert Opinion Survey – Shifting research incentives for private research from tax incentives to targeted program investments



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

Experts also indicated, in Figure 41, a high level of agreement for expansion of the R&D for Profit Program, based on a clear strategy and a longer-term funding commitment.

Figure 41: Expert Opinion Survey – Expansion and extension of the R&D for Profit Program

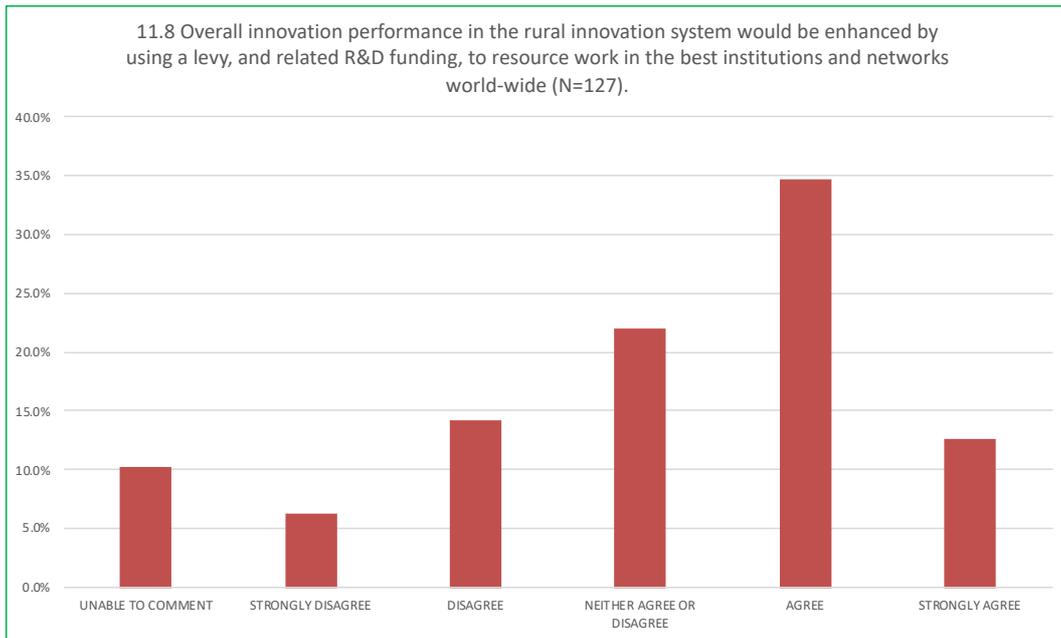


Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

It is understood that the R&D for Profit Program is currently being evaluated.

During Consultations the idea of using a levy system as a basis for research in the best research institutions and networks, in Australia and internationally was floated. As shown in Figure 42, only 40 percent of Experts agreed or strongly agreed with this proposition.

Figure 42: Expert Opinion Survey – Adopting a levy to invest in the best institutions and networks worldwide



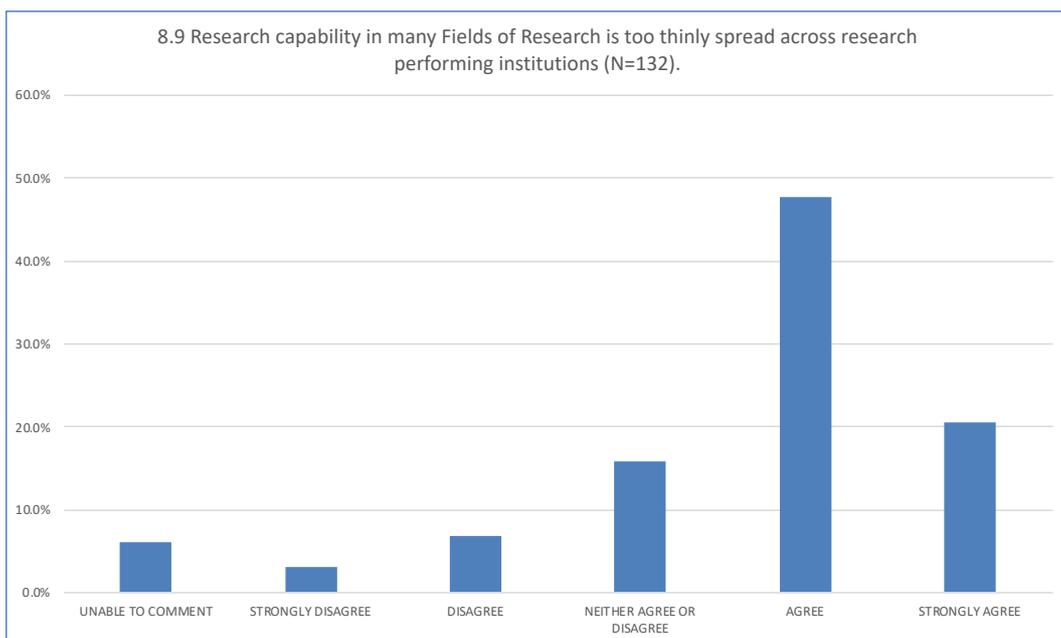
Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

▪ ***The “spread” of research investment***

During the Consultations program there was discussion about the extent to which limited funding available for research investment was too thinly spread across Fields of Research. This it is argued, would work against the development of strong fields of excellence and depth in capability. Experts’ views are captured in Figure 43.

Bibliographic data on research performance and impact for agricultural sciences, biological sciences, and Environmental sciences, provided by Clarivate Analytics InCites is provided in Section 5.5.2 below.

Figure 43: Expert Opinion Survey – Is research capability across FoRs too thinly spread?



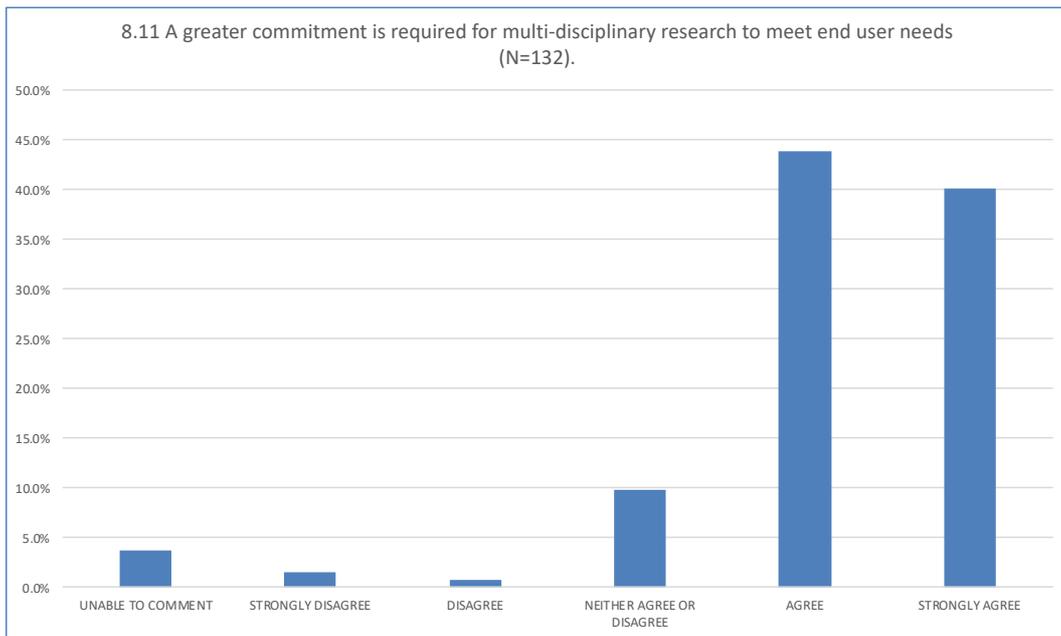
Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

▪ **Cross disciplinary research investments**

It is widely appreciated that innovation draws on multidisciplinary approaches to research to meet end user needs in business and government.

This is often a challenge for research organisations, and particularly universities where faculties are designated, organised, and resourced around disciplinary specialisations defined largely by Fields of Research. Nonetheless, Consultations and Expert feedback, reflected in Figure 44, indicates very high levels of agreement and strong agreement for a greater commitment to interdisciplinary research.

Figure 44: Expert Opinion Survey – Commitment to interdisciplinary research to meet end user needs



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

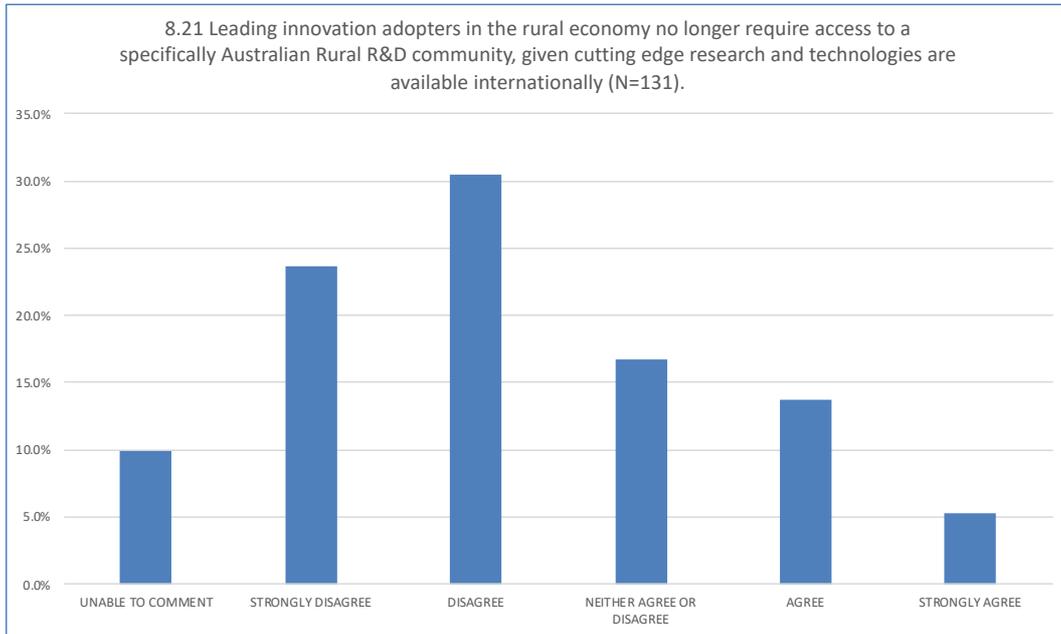
▪ **Continuing commitment to public sector research**

There was little support in the Expert Opinion Survey for the proposition that:

Leading innovation adopters in the rural economy no longer require access to a specifically Australian Rural R&D community, given cutting edge research and technologies are available internationally.

This is indicated in Figure 45, suggesting that, on balance, a focus and commitment to rural innovation should continue.

Figure 45: Expert Opinion Survey – Leading Innovation adopters no longer require access to an Australian R&D community



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

5.2.6 Feedback from Consultations

The following sub-sections report feedback, in a general sense, from the Consultations. While many concerns are raised in discussions they often tend to be of an anecdotal nature, and it has not been possible in the time available to validate the generality of the issues or the underlying factors that give rise to them. Quite often concerns are contingent on the situation. Concerns covered:

- Allocation principles and criteria: there was some concern about transparency in the way research investment decisions are made.
- Size of investments tends to be small, causing research providers to continually scout for more funds to support their projects.
- An overemphasis on specific project-based allocations rather than broad program investments linked to a clear investment strategy.
- Cycle times tend to be short, generally three years, which limits capacity to commit to longer term “breakthrough” research?
- Only CRCs and large businesses invest for the longer term; otherwise, a “transactional” focus on funding highly specified projects.

Interviews indicated that emphasis in information and communications research was growing; this tends to take pace outside agriculture faculties. Hence the importance of cross disciplinary research institutes and centres.

5.2.7 Concluding comment

Funds available for and allocated to research, development and innovation should be regarded as being available for investment in programs that are expected to achieve results, however defined – over the short, medium, and longer term.

Research investments should be guided by research providers having a clear and well-articulated strategic plan. Investments should be made in organisations with a strong strategic plan. In other words, providers should allocate a substantial amount of time to ensuring that their projects and programs are ‘investible’ when investment opportunities arise.

5.3 Programs, processes, and collaboration

Key points

- Processes can be highly structured, for the purposes of accountability and control, or relatively unstructured where there is a propriety on agility, flexibility, and responsiveness to meet requirements for innovation.
- Research investment processes are multifaceted and vary across agencies and research fields
- There is concern about what appears to be an excessive concern with compliance and control
- There should be scope for achieving consistency across research organisations in legal and contracting documents and approaches
- There is scope for better use to be made of Customer Relationship Management (CRM) Systems to improve industry, business, and government engagement processes
- Design thinking offers opportunities to improve and redesign a range of processes.

A characteristic of Australian Public Administration is that we are very good at developing policy and strategy, but less adept at implementation and execution. In the Canberra environment particularly, policy and strategic capabilities are highly regarded, but management skills and capabilities are less highly prized - and rewarded.

5.3.1 The importance of process

Even in the private sector, it is acknowledged that only a very few strategies achieve the results intended (Bossidy et al., 2002; Govindarajan & Trimble, 2010; Kambil, 2002). In the public sector, it is surprising how often strategies fail to adequately address execution and implementation challenges and requirements. These are essentially *management* issues, and Australia's capability for management excellence has long been a matter of concern (Australia. Industry Task Force on Leadership and Management Skills, 1995; Green, 2013; Green et al., 2009; Green et al., 2012).

Objectives and resource inputs come together in the form of programs, processes, routines, and projects, designed to deliver the planned and intended results. These instruments are also a way of dividing work to set responsibilities, accountabilities, and ways to measure performance.

Programs can be highly structured (bureaucratic) with multiple steps and tightly set routines. The primary focus of structured approaches is *control* and predictability – applying what is known to work. Contracting and procurement tend to be highly bureaucratic in orientation. The scientific method is also a process, built around hypothesis testing and deduction based on evidence and data.

In contrast to the learning and adaptability central to the scientific method, government funding programs are criticised for lacking in flexibility, agility, and responsiveness to changing situations and circumstances.

This inflexibility can limit the efficiency and the effectiveness of government interventions.

In response, there is now developing interest in some governments and inter-governmental organisations in basing *ex ante* programme appraisal and in-process and *ex post* impact evaluation on scientific hypothesis testing principles. This approach can be faster and cheaper to implement than current approaches with the added advantage that (being scientifically based) it is better at dealing with ambiguities and uncertainties faced when evidence is analysed. This is addressed by the OECD in *Evaluation of Industrial Policy* (OECD, 2015).

This emerging work has an explicit focus on how policy interventions can be treated as experimental hypotheses being tested via practical implementation. If the approach were to be implemented in Australia it could provide a cutting-edge *combined* program appraisal and evaluation method for support provided to the rural industries.

At the other end of the spectrum, innovative approaches involve elements of unstructured creativity, co-creation, and *design thinking* (Brown, 2013; Bucolo, 2014; Tom Kelley & Littman, 2001; Thomas Kelley & Littman, 2005; R. Martin, 2009; Plattner et al., 2012). Design thinking involves bringing methodologies and approaches from the arts and creative practice to create products and services around the needs (or wants) of a customer or user, whilst still drawing on scientific and technological excellence (Howard, 2008).

In many areas of program and process management the default management approach is *control* and risk minimisation.

Governments initiate programs, sometimes of substantial scale, such as the R&D for Profit Program, and research organisations also divide their work into identifiable programs that relate to achieving objectives. Each RDC may have five or more programs.

Comments on some key processes in the Rural Innovation System Framework are provided below.

5.3.2 Research investment processes

The Australian rural research investment processes are diverse and open. It involves numerous funding organisations, over 100 research performing organisations, and several thousand researchers (see Figure 31 on page 70).

Australian research investment is generally accessible and highly competitive, with 151 Commonwealth, State and Not for Profit grants listed on the [Commonwealth Competitive Grants Register](#). Apart from the ARC and RDC programs, the grants included on the register are predominantly for health-related research investments, and particularly cancer research. The availability of this funding would naturally slant research commitment in universities towards health and medical research. This is reflected in Higher Education Research and Development data. Agriculture-related biological science may also connect with health-related programs, however.

Each grant funding agency has its own processes and procedures for investment. University Research and Technology Transfer Offices have a responsibility for sorting through this material to inform staff of “research funding opportunities.” The implicit message is for research staff to position “funding applications” to secure funds for their pre-existing research interests.

Many people pointed out in consultations for the Review that submitting different grant applications for multiple grant schemes is time consuming and expensive.

The alternative to open competitive processes is a process for *strategic investments* to known researchers who have demonstrated capability and experience and for processes aimed at building research capabilities and opportunities for mid-career researchers. In consultations many people pointed to the ageing of the rural research workforce and the limited opportunities to develop new talent. On the other hand, as the material in Table 12 on page 104 indicates, there are very high levels of collaboration with international research organisations and private sector organisations.

There are, in addition, hundreds of arrangements under which businesses and industry seek to commission research and consultancy. These are frequently one-off, and each university has

developed their own processes and procedures for responding through their Research Offices or Technology Transfer Offices. During consultations businesses expressed some concern about differences in approach between universities and the level of the contribution to university overheads for commissioned research and consultancy projects – often in the range of 30 per cent or more.

Research organisations may find it useful to commit to a process of comprehending shifts in demand for commissioned research and consultancy, and aligning capability to meet demand, as well as foresighting future demand.

5.3.3 Collaboration

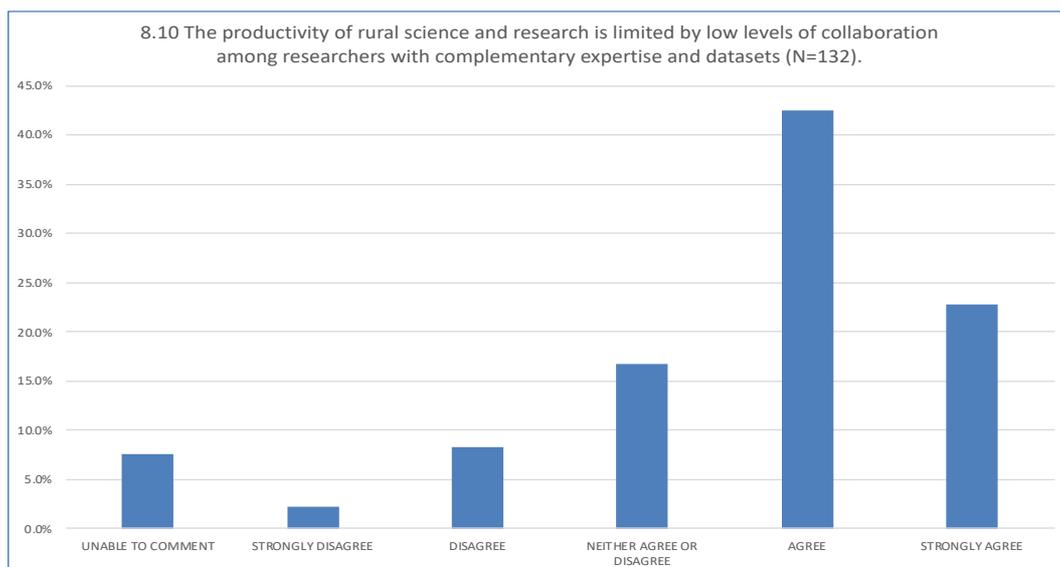
Securing collaboration in research and research-industry engagement is a critical process and is an important area for discussion across the science and research system. There has been a tendency to regard collaboration as a transactional process (buying and selling knowledge and capability) but in practice it involves developing partnerships based on long term commitment and high levels of trust. A comprehensive discussion of collaboration is provided in Appendix 5 (from page 216).

Financial support under the Cooperative Research Centres Program (CRC) established in 1992, has provided a major incentive for collaboration between universities, business, and government. As indicated in Research Report 3, it has been important for rural innovation. Compared to other Commonwealth Program initiatives it has been remarkably resilient, with the major purpose in place for more than 25 years. The CRC program is a premium program and is being supported by more recent initiatives such as the CRC-P program.

Collaboration is supported by Government through ARC-Linkage grants and initiatives of RDCs and State Government industry, innovation, and rural production agency programs. Government is often seen as the 'glue' that brings collaborators together.

Nonetheless, the Expert Opinion Survey reported a high level of agreement for the Proposition that "productivity of rural science and research is limited by low levels of collaboration among researchers with complementary expertise and datasets": This is indicated in Figure 46.

Figure 46: Expert Opinion Survey – Productivity impact of low levels of collaboration among researchers

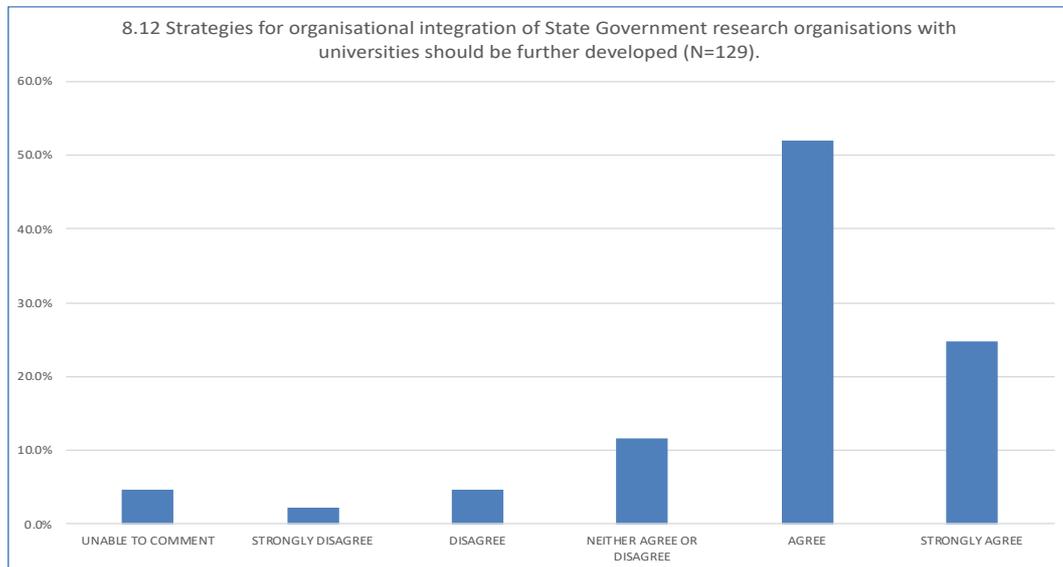


Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

In several States, Government research organisations and universities are developing closer collaboration, and in some cases, such as with the Tasmanian Institute of Agriculture, are moving

towards full integration. Based on feedback from the Expert Opinion Survey, reflected in Figure 47, support for this sort of initiatives appears to be strong.

Figure 47: Strategies for integration of State Government research organisations with universities



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

Building these collaborations takes many years, and encounters some risks, particularly if State Governments lose critical capability – for example, around biosecurity monitoring and response.

5.3.4 Business and industry engagement

Everyone thinks that research around business and industry engagement is a good idea. As mentioned in other parts of this Report, engagement processes are often transactions-based. The Review did not allow time to identify research organisations which have developed *client relationship management* (CRM) systems that are adopted as standard practice in business.

One hears about individual researchers from different faculties and schools in the same institution making multiple contracts with the same organisation – quite often overlooking the opportunities for larger, longer-term relationships.

Long-term relationships must be built around engagement at the most senior executive levels in both research organisations and business.

However, the processes to achieve conformance in expectations and value to be created for all parties are often challenging. On one side, individual researchers may be looking for money to support a research project or program, whilst on the other side businesses may be looking for return on investment that is consistent with corporate mission and purpose. It is also the case, however, that middle and junior officers in business may cold call universities and research organisations looking for low-cost research support. Most universities channel these queries to a Technology Transfer Office.

Researchers must spend time “researching” their value proposition and *investment business case*, and how it will help the businesses and industry they are targeting.

This may involve changing and repositioning a research program. Businesses must also spend time “researching” what a research organisation has to offer. This will not necessarily come from a process

of trying to find experts through online databases, such as [D61+Expert Connect](#), which is currently in Beta version.

Several universities have developed processes for entering *Memoranda of Understanding* and *Affiliation Agreements* for engaging with business. These instruments set a pathway for engagement by starting a journey that will deliver reciprocal value, generate returns, and engender trust.

5.3.5 Towards “Design Thinking”

At least one RDC has developed a “very simple supply-demand model,” or process, to match demand and supply for innovation around design thinking:

Part of our job is to create *demand* for innovation which means creating capability, awareness, understanding and the capacity to be absorbed, or absorptive capacity, and then on the *supply* side, you've got to work with suppliers of innovations using a design thinking lens.

That means that innovators must understand that nexus between *desirability* from a customer point of view, *feasibility* which is what most researchers focus on which is technically, they will deliver what it says it's going to deliver, and *viability* which is that there is a viable business model to get that innovation into the marketplace.

We apply a whole systems view, a whole supply chain view, a design thinking view around what we do, and my fundamental belief is if you're working with customers, you have to get customers engaged in that process and the best way to get customers engaged, not the only way but one of the best and most fundamental ways in which you can test strength of your engagement is that they will contribute to it. Why we have 40% of our co-investments with industry is that we're always making sure, we have our customers of innovation totally tied into this whole strategy and they're tied in because they're putting 50% of the money on the table or 25% in some cases.

Establishing effective processes for customer and end-user engagement can be a major challenge for research organisations.

5.3.6 Accountability, compliance, and control

Where research investments involve the allocation of public expenditure there is a community expectation that decision-making and resource allocation processes will be open, transparent, and accountable. Ministers, Department and Agencies are called upon to explain and justify expenditure to scrutiny agencies for a range of input and process costs.

There was a concern, nonetheless, conveyed many times in the consultations that Government had an “obsessive” concern with compliance. Although there was a sound understanding of the need for accountability. A RDC CEO commented

One of the fatiguing issues for me is the culture of the department, because they have all these objectives for agriculture and what they are they going to deliver but, but. Their relationship with their agency is all about principally about compliance.

And I keep saying to them, “What are the opportunities for partnering in delivering outcomes that are, you know, mutual?” “You know we are the biggest cost line in your budget, we're also your biggest asset.” They don't see funding as an investment, more than as a cost.

A compliance and control culture can drive out innovation.

There is no time to be innovative if you're constantly writing compliance reports, and you don't have time to do the futures thinking or the "Where next?" or the collaboration to grow the sales.

The solution is getting that balance right. In the first instance Government could rely upon the fact that it has appointed skill-based boards, and let that board fulfil its governance responsibilities rather than impose all of government directions.

At the moment RDCS cannot issue financial instruments or access reserves without pre-approval. You can't increase your staff because there's a cap on the whole sector. You can't increase remuneration by more than 2 per cent. You can't ...

You couldn't run a business on that basis, could you? So, at the same time, we're expected to deliver these outcomes for government and industry. And we focus on the cost side, rather than the impact.

Guidance on corporate governance requires that Boards address both compliance and innovation through the development and implementation of strategy. Where Boards are not fulfilling their governance responsibilities, then is the time to exert controls – rather than controls in anticipation of governance failures.

5.3.7 Legal and contracting issues

A concern was raised during consultations that RDCs, collectively, could not agree on a single set of legal instruments that could be placed in common use, to make it easier for organisations to contract and partner. Negotiating contracts was reported to have very high transaction costs. A RDC CEO commented -

I'm not a big supporter of R&D for Profit. But one of the big breakthroughs has been for things like *Precision to Decision*, the RDCs are on the cusp of developing an agreement system for working better together, a legal framework. And it's going to be important. We're now having transaction costs of 12 months to get things across.

It is acknowledged that collaboration and cooperation are critical, and an element of the criticality is developing workable agreements to enable this.

The legal instruments that we have are not evolved enough. We're still doing things on single agreements. We don't have multi-party agreements. We're not moving modern legal instruments for cooperation. And what we do is, we end up with a million lawyers sitting at each party's table and we don't end up with an ideal cooperative model. And I think that's a failure.

This concern was echoed by research providers in discussions and interviews.

Contractual agreements vary not only between organisations, but also when occupants of Chief Legal Officer (or equivalent) change.

In the business sector innovative professional services businesses have developed a suit of legal templates, such as [Business in a Box](#), to cover a broad range of legal issues. A parallel approach could achieve significant benefits of time and cost in research contracting.

The scope for achieving economies and efficiencies in 'back office' processing has been addressed by RDCs many times over the years. The scope for economies in universities and research organisations through benchmarking and best practice remains a challenge.

5.3.8 Timeliness

The time taken to reach agreement on a research "business deal" was raised on many occasions. During consultations interviewees mentioned that businesses have walked away for potential deals due to extended time frames in negotiation.

5.3.9 Reporting

During consultations concerns were raised about the processes for making research reports accessible and searchable. This is of concern not only to research investors and research performers, but also to business and government wanting to source research capability and expertise.

It is not simply a matter of putting text and numerical material on websites – it is an opportunity for intermediaries to make connections between researchers and end users – business, whether “on-farm” or “off farm.” Fee for service models are emerging in agribusiness consulting firms.

Research organisations and RDCs might consider collaborating to put the baseline data into meaningful searchable formats. This takes the investment further than trying to connect mountains of administrative data.

It is a matter that should be addressed by research organisations and RDCs working collaboratively.

5.4 Outputs: The way resources are used

Key points

- ARC/ERA information indicates that research outputs from universities have grown strongly over the five years 2008-2015, and particularly since 2015.
- Patenting and commercialisation income has been quite modest, except for biochemistry and cell biology
- According to Clarivate Analytics InCites data there has been strong secular growth in publications across all research fields since 1993, particular by universities in the biological and environmental sciences.
- CSIRO and The Universities of Queensland and Sydney have maintained a strong commitment to publication in Agricultural sciences

This Section provides information on research outputs in Agricultural, Biological and Environmental Sciences and related fields. It provides a profile of research “production” rather than impact. However, it does provide a picture of where research effort is concentrated.

Output is generally measured in terms of quantity and is a key metric in assessing individual and organisation performance. It is essentially an efficiency indicator. Considerations of timeliness and ‘cost per unit’ (‘cost per paper’) may also be of interest.

Outputs may or may not be of a certain quality and may or may not lead to impacts (or change). That will depend on levels of adoption, take-up, and ultimately, how outputs are used. Measure of output are often, incorrectly, used as proxies for measure of impact.

5.4.1 Government

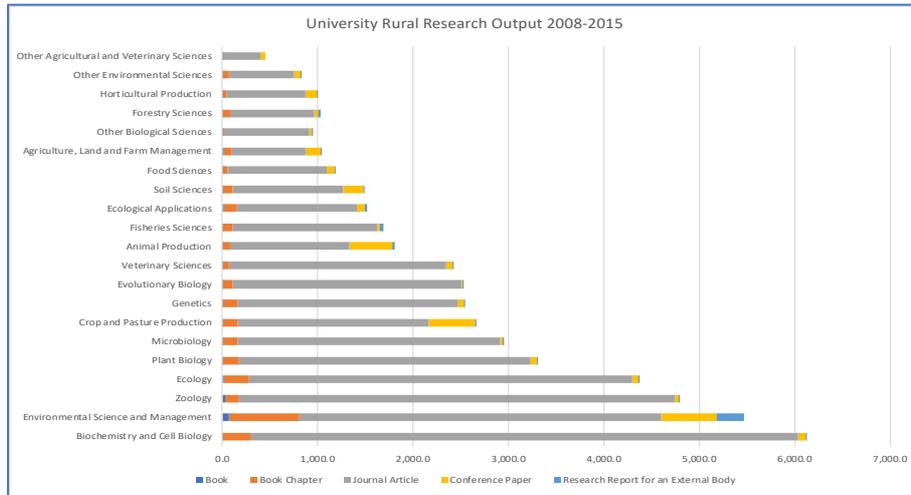
Data for CSIRO and other Commonwealth Research Institutes and State Research Institutes is not readily available in a consolidated form.

5.4.2 Universities

University sector research output data in research fields relevant to rural production and over the years 2008 to 2015 is contained in the following charts

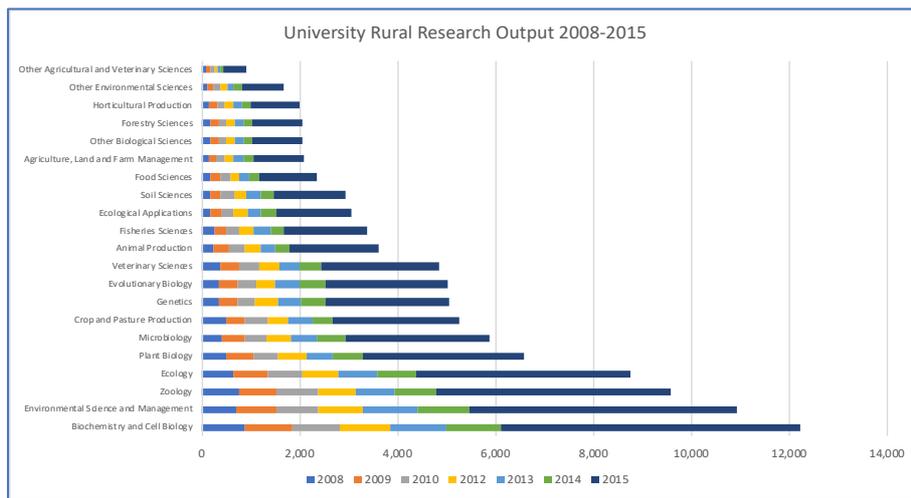
▪ **Research outputs – publications**

Figure 48: University Rural Related Research Outputs – Form of Publication



Source: ARC, ERA data

Figure 49: University Rural Related Research Output 2008-2015 – Number of Publications

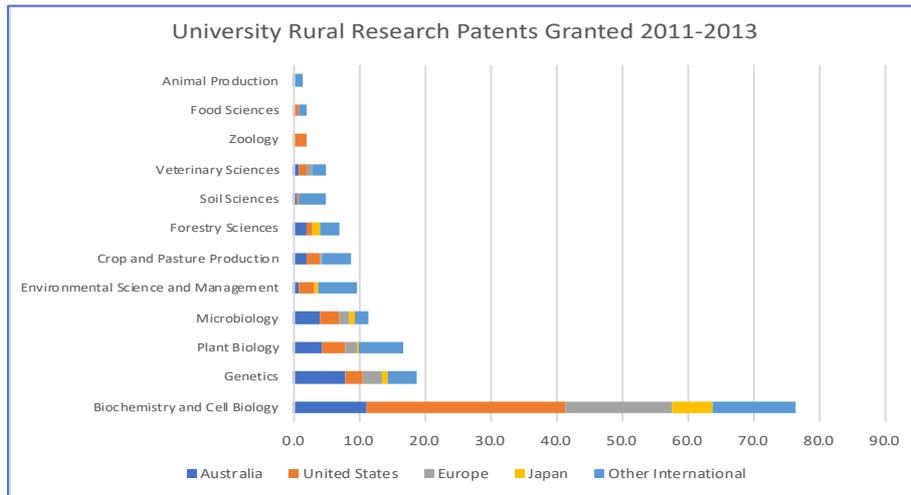


Source: ARC, ERA data

▪ **Research outputs – patents**

Figure 50 provides information on university rural research related patents granted. By far the most significant patenting area is Biochemistry and Cell Biology.

Figure 50: University Rural Research Patents Granted



Source: ARC, ERA data

The National Survey of Research Commercialisation (Australia. Department of Industry and Science, 2015; Australia. Department of Innovation Industry Science and Research, 2011, 2012) collects patenting data by research organisation, but it is not disaggregated across research fields.

▪ **Research outputs – plant breeder rights**

Information from the ERA data collection shows the total number of plant breeder rights issued between 2011 and 2013. This is reproduced in Table 6 below.

Table 6: Plant Breeder Rights granted 2011-2013

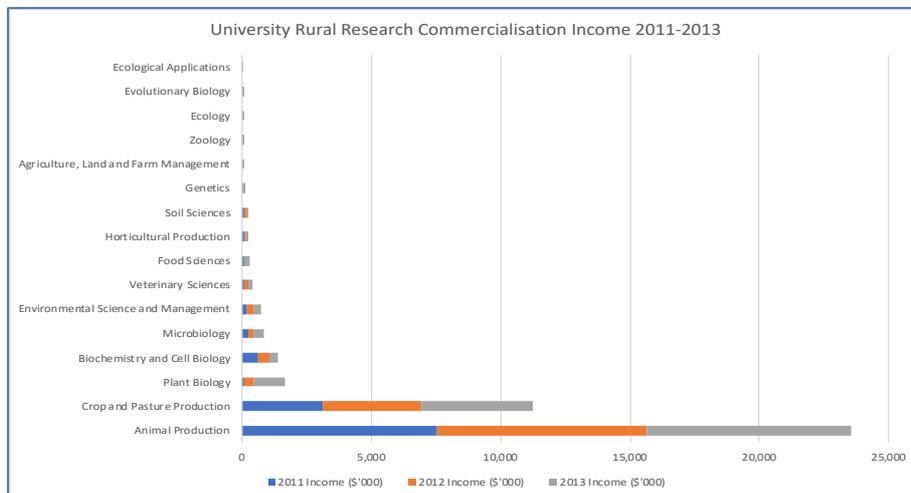
Code	FoR Name	Plant Breeder's Rights	% Of Total
0703	Crop and Pasture Production	23.5	78.3
0705	Forestry Sciences		
0706	Horticultural Production	4.9	16.3
	Agricultural and Veterinary Sciences	28.4	94.7

Source: ARC, ERA data

▪ **Commercialisation income**

ERA data shows that university commercialisation income is concentrated in the fields of Animal Production and Crop and Pasture Production, as show in Figure 51.

Figure 51: University Rural Research Commercialisation Income



Source: ARC, ERA data

Data on research commercialisation income covering all research organisations is also collected in the National Survey of Research Commercialisation, including CSIRO. But the data is not reported by Field of Research.

5.4.3 Research output – long-term trends

This Section brings together material regarding research performance using research publication and citation data from the Clarivate Analytics' InCites platform (using Web of Science data).

The material looks at the volume of output in agricultural science, biological science, and environmental science across research fields (as defined by the Australian Government's Field of Research (FOR) Codes) and organisations from journal articles, books, book chapters and conference proceedings.

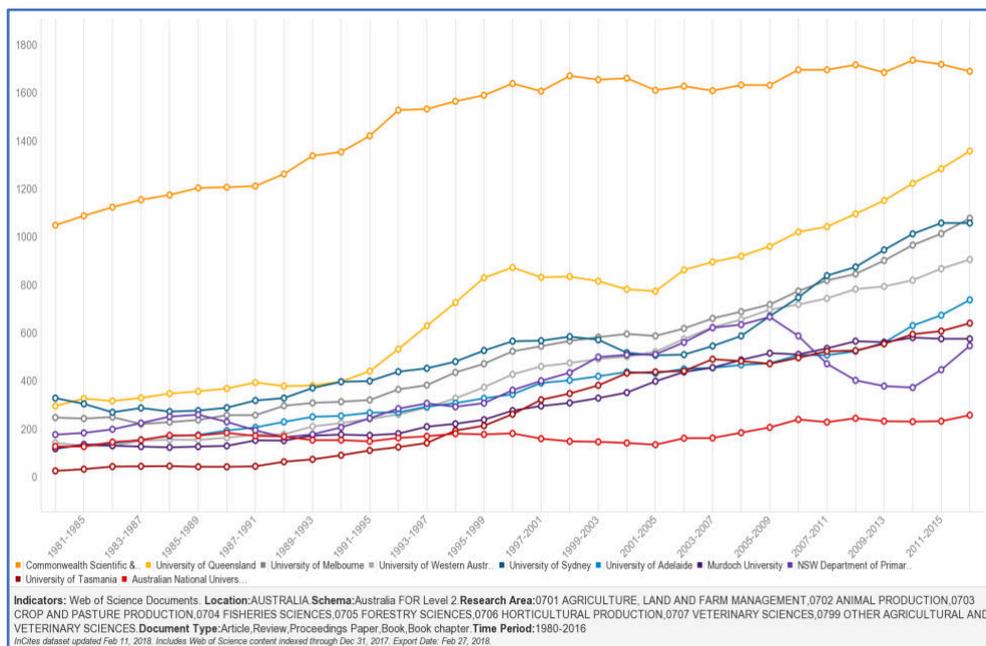
In Section 5 (addressing impacts) outputs are compared using normalised citation metrics across the fields to identify performance and impact to Australian and global baselines (global metrics are normalised =1.0 so values better than this suggest Australian impact is better than the global average in these research areas).

The material points to concentration, and dispersion, across fields and organisations. Australia performs very strongly in some key rural related FoRs, reflecting an evolution of the Innovation System into biology and biotech.

- **Agricultural sciences**

Information on publications in Field of Research codes that begin with 07 (Agricultural Sciences) is provided in Figure 52. It shows trends in publications output, by the 10 most prolific publishing organisations.

Figure 52: Trend in Number of Publications, Agricultural Sciences, by Organisation

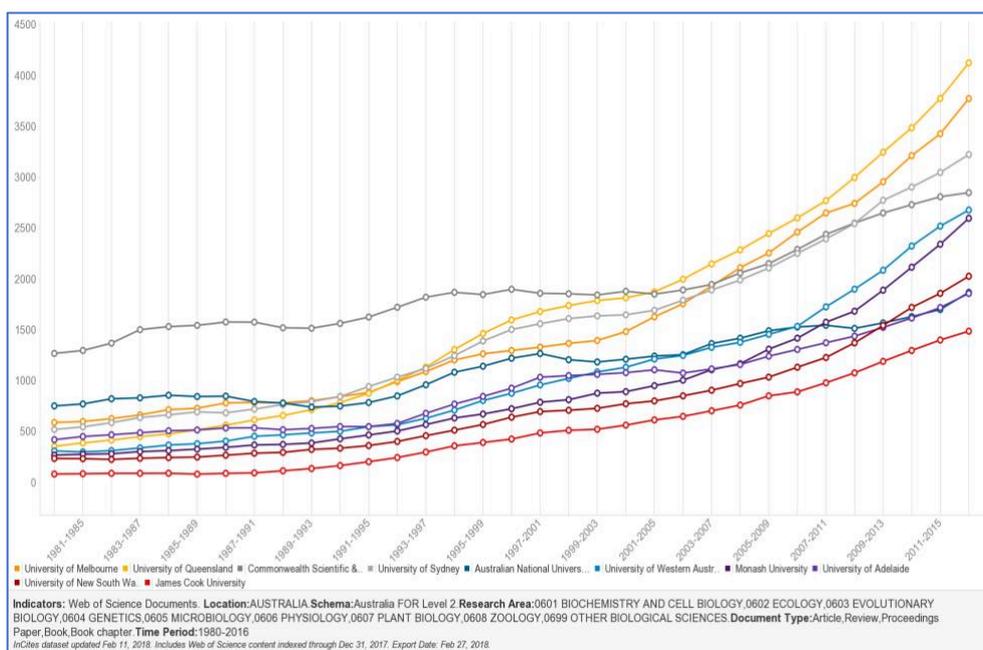


Source: Clarivate Analytics InCites

- **Biological sciences**

Figure 53 identifies the research organisations particularly strong in biological sciences, and the growth in output at the Universities of Queensland and Melbourne.

Figure 53: Trend in Number of Publications, Biological Sciences, by Organisation

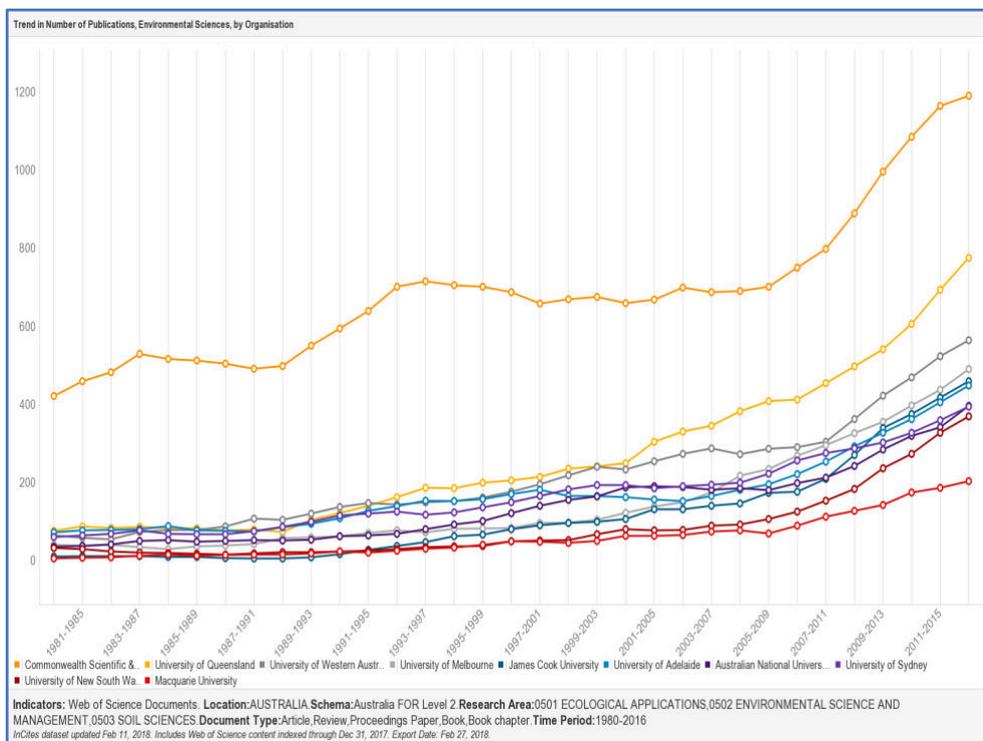


Source: Clarivate Analytics InCites

■ **Environmental sciences**

Figure 54 identifies trends in publications among the 10 most active research organisations. The increasing commitment and output of the CSIRO is of interest.

Figure 54: Trend in Number of Publications, Environmental Sciences, by Organisation



Source: Clarivate Analytics InCites

5.4.4 Concluding comment

There is a vast amount of information about output quantity. As the system incentivises a focus on output and production in scholarly journals this type of output is booming. Alan Finkel, in *The Conversation*, 18 April 2018, addressed this issue in the following terms.

The future of the scientific paper

Earlier this month The Atlantic magazine published a [provocative essay](#) headlined “The scientific paper is obsolete”. The scientific paper has done great things since it was [developed in the 1600s](#). Today we could certainly say that production is booming.

But the peer-review system is critically overloaded. The irony is, we’re working so hard to generate papers, we don’t have time to read anybody else’s. One must ask, have we hit Peak Paper?

My tentative response is “no”. The scientific paper has endured for a reason, and it still holds. It’s an efficient way to structure and communicate information.

The pressure to publish

I think we would all agree that commitment to quality over quantity is the ideal. Authors could invest more time in their papers, and peer reviewers could invest more time in their critique.

In the real world, we know that the incentives often skew the other way. But where do you intervene to break the cycle?

I recently [came across a radical suggestion](#): a lifetime word limit for researchers. I suspect it would be very difficult to enforce but what about a variation: change the focus from publications to CVs.

For starters, let’s contemplate a rule that you can only list a maximum of five papers for any given year when applying for grants or promotions. Your CV would have to list retractions, with an explanation.

On the [recommendation of Jeffrey Flier](#), the former Dean of the Harvard Medical School, candidates for promotion would have to critically assess their own work, including unanswered questions, controversies and uncertainties.

Could we have an “ethical journal” stamp, building on the excellent work of the [Committee on Publication Ethics](#)?

<http://www.chiefscientist.gov.au/2018/04/opinion-science-isnt-broken-but-we-can-do-better/>

It is unlikely that the issue will be resolved soon. But in addition to the science quality implications, there are resource implications of a too heavy focus on quantity. Time spent on producing large numbers of papers of uneven quality could be better spent elsewhere, such as in teaching or engagement with industry.

The bibliometric data appear to indicate a shift of emphasis in publication from the agricultural to the biological sciences, which is probably consistent with the waves of innovation approach referred to earlier in the Report.

In many of the fields of research and organisation performance, organisations like CSIRO, University of Queensland, University of Melbourne, the University of Western Australia, and University of Adelaide tend to produce most of the material in the research areas of interest. There are several organisations with comparatively less capacity. This may reflect a set a specific and strategic focus on a narrow range of research areas.

Despite the vast amount of information on the quantum of output, very little is known about the cost of producing output outside the research organisations. In the clinical area information about cost according to Diagnostic Related Groups (DRGs) has been collected for many years. This information assists in allocating resources to areas of clinical practice. Research organisations may have their own productivity indicators which may be used in performance appraisals and internal reporting.

From system wide perspective baseline efficiency and productivity data may assist in determining the extent to which resources are being allocated to the most ‘productive’ areas of research and to inform future resource allocation decisions accordingly.

5.5 Outcomes: Effectiveness in Achieving Intended Results

Key points

- Australian universities have world class research capability in most research fields relating to Agricultural Sciences and in many fields relating to biological sciences, particularly genetics, plant biology, zoology, and ecology.
- Researchers have recorded high levels of esteem in biochemistry and cell biology, plant biology, genetic and environmental science, and management.
- According to Clarivate Analytics and InCites data there are some indications of a shift in research emphasis and impact from the Agricultural sciences to the biological sciences.
- Although commercialisation income is small, there have been several successful start-ups in the AgTech and GeneTech areas (including CropLogic and Nexgen Plants).
- The “extension” space has become highly contested: intermediaries that survive will produce unique value, adding value to a transaction or relationship that is not easily replicable.

Performance in relation to outcomes concerns the extent to which resources achieve the results intended. These results may be expressed in terms of quality, timeliness (particularly if research is urgent and essential in relation to a particular issue), the level of stakeholder satisfaction, the reputation and esteem of researchers and the research organisation, and the extent to which research is commercialised.

5.5.1 Research quality: Excellence in Research Australia (ERA) data

Research quality is the effectiveness metric that receives the most attention. It relates to effectiveness in achieving results relating to the research enterprise, including publication, commercialisation, and other forms of knowledge transfer. Research quality does not assess impacts associated with the *adoption, application, and use of research* in industrial, social, and environmental contexts. Uptake is determined by a range of factors and investments beyond the control of the research enterprise. This is addressed in Section 6 below.

▪ *Excellence in Research Australia (ERA) institutional assessment*

ERA utilises a five–point rating scale that is broadly consistent with the approach taken in research evaluation processes in other countries to allow for international comparison.

Table 7: ERA Assessment Scale

Rating	Rating Descriptor
5	The Unit of Evaluation profile is characterised by evidence of outstanding performance well above world standard presented by the suite of indicators used for evaluation.
4	The Unit of Evaluation profile is characterised by evidence of performance above world standard presented by the suite of indicators used for evaluation.
3	The Unit of Evaluation profile is characterised by evidence of average performance at world standard presented by the suite of indicators used for evaluation.
2	The Unit of Evaluation profile is characterised by evidence of performance below world standard presented by the suite of indicators used for evaluation.
1	The Unit of Evaluation profile is characterised by evidence of performance well below world standard presented by the suite of indicators used for evaluation.
n/a	Not assessed due to low volume. The number of research outputs does not meet the volume threshold standard for evaluation in ERA.

Source: http://www.arc.gov.au/sites/default/files/filedepot/Public/ERA/ERA%202015/ERA_2015_National_Report/ERA2015_Introduction.pdf

Summaries of ratings by for university research in the fields of research relevant to rural research and development (agricultural sciences, biological sciences, and environmental sciences) are provides in the following tables.

Table 8: ERA Assessments, Fields of Research (FoRs) relevant to rural research and development, 2-digit codes

Institution	07 Agricultural and Veterinary Sciences	05 Environmental Sciences	06 Biological Sciences
Australian National University	4	5	5
Central Queensland University	4	4	2
Charles Darwin University	3	4	3
Charles Sturt University	3	3	2
Curtin University of Technology	4	3	3
Deakin University	4	4	3
Edith Cowan University		4	4
Federation University Australia		1	3
Flinders University	3	3	3
Griffith University	3	5	4
James Cook University	3	5	5
La Trobe University	5	3	4
Macquarie University	5	5	4
Monash University		4	3
Murdoch University	3	3	3
Queensland University of Technology		4	2
RMIT University		4	3
Southern Cross University	5	4	3
University of Adelaide	4	4	4
University of Canberra		5	2
University of Melbourne	4	5	4
University of New England	5	4	4
University of New South Wales		4	4
University of Newcastle		2	4
University of Queensland	4	5	5
University of South Australia		4	4
University of Southern Queensland	3	4	
University of Sydney	4	4	4
University of Tasmania (inc. Australian Maritime College)	4	4	4
University of Technology, Sydney	5	5	4
University of the Sunshine Coast	4	4	4
University of Western Australia	4	5	5
Western Sydney University	4	4	4
University of Wollongong		3	3
Total UoEs evaluated	24	34	33
No 4-5	17	26	19

The ERA data indicates that there are five universities performing well above world standard in agricultural and veterinary sciences, nine in environmental sciences, and four in biological sciences. Within the headline research fields there are also some very high levels of performance, as indicated in the tables that follow.

Table 9: ERA Assessments, Agricultural Sciences, 4-digit codes

Institution	0701 Agriculture, Land and Farm Management	0702 Animal Production	0703 Crop and Pasture Production	0704 Fisheries Sciences	0705 Forestry Sciences	0706 Horticultural Production	0707 Veterinary Sciences	0503 Soil Sciences
Australian National University			5		5			
Charles Sturt University		3	3			5	3	
Curtin University of Technology			5					
Deakin University				4				
Flinders University				3				
Griffith University								4
James Cook University				4			4	
La Trobe University		5	5				5	4
Murdoch University		3	4	3	4		3	
Southern Cross University			5	4	5			4
University of Adelaide		3	4			5	5	5
University of Melbourne	4	5	3		4		4	4
University of New England	5	5						5
University of Queensland		3	4	4	4	5	4	4

University of Southern Queensland			4					
University of Sydney		3	3				5	5
University of Tasmania	5		3	5	4	5		
University of the Sunshine Coast				4	3			
University of Western Australia	5	3	4	4				5
Western Sydney University					5			5
Total UoEs evaluated	5	9	13	9	8	4	8	10
No 3-5	5	3	9	7	6	4	6	10

Table 10: ERA Assessments, Biological Sciences, 4-digit codes

Institution	0601 Biochemistry and Cell Biology	0602 Ecology	0603 Evolutionary Biology	0604 Genetics	0605 Microbiology	0606 Physiology	0607 Plant Biology	0608 Zoology
Australian National University	4	5	5	5	5		5	5
Charles Darwin University		4						3
Charles Sturt University	2							
Curtin University of Technology							4	4
Deakin University	3	3	4					5
Edith Cowan University	3	5						
Flinders University	3	2	3		3		4	3
Griffith University	3	5	3		3			
James Cook University	3	5	3		3		5	3
La Trobe University	5	5		4	5	5	5	5
Macquarie University	3	5	5	5	4		5	4
Monash University	4	5	4	4	4	4	5	5
Murdoch University		3	4	4	3		3	3
Queensland University of Technology			4		3			
Southern Cross University		4						5
Swinburne University of Technology					3			
University of Adelaide	4	5	4	5	3		5	3
University of Canberra				4				
University of Melbourne	4	5	4	5	4	3	4	4
University of New England		5	4					5
University of New South Wales	4	4	3	4	5			3
University of Newcastle	5			5		4	5	4
University of Queensland	4	5	5	5	5	4	5	5
University of South Australia	5							
University of Sydney	3	4	4	4	3	4	5	4
University of Tasmania		5	4				5	5
University of Technology, Sydney	3	3		5	4		4	
University of the Sunshine Coast		4						5
University of Western Australia	4	5	4	5			5	5
Western Sydney University	3	5			4		5	3
University of Wollongong	n/r	3						
Total UoEs evaluated	21	24	17	14	17	6	17	22
No 4-5	10	20	13	14	9	5	16	15

The strengths in several of these areas could be attributed to long term and ongoing investments in rural research centres and institutes by RDCs and State Governments. Although RDCs tend to invest on a sectoral basis, many research institutes have a cross sectoral focus and draw on investments from several RDCs. At this stage it is not possible to track RDC investments to specific research institutes and centres over an extended period.

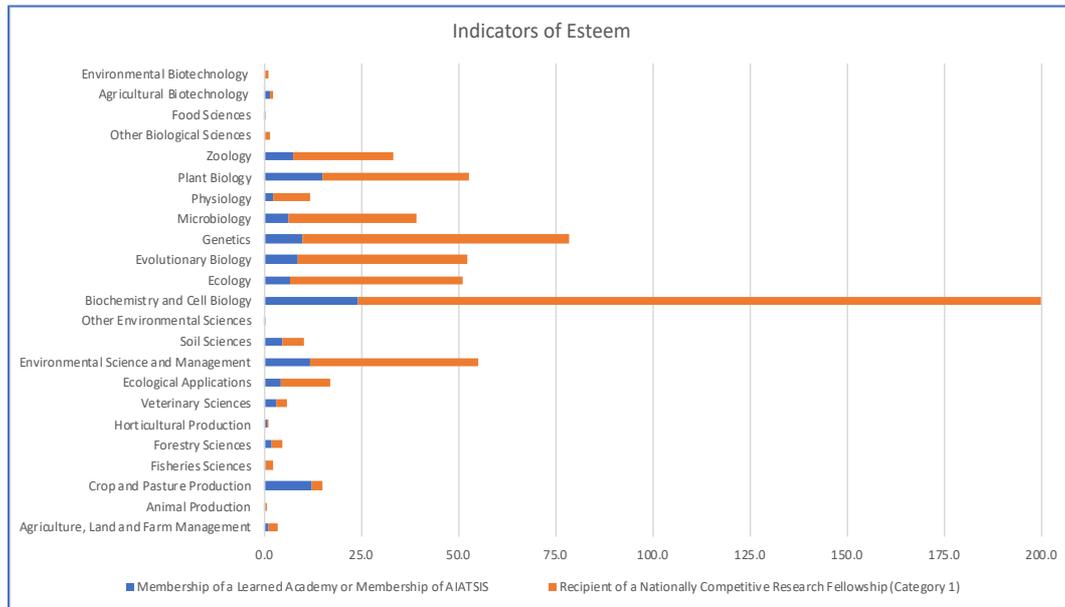
Profiles of Government and University research centres and institutes are in the *Working Documents Report*.

- ***Excellence in Research Australia (ERA) reputation and esteem***

Universities compete based on esteem. Esteem is reflected in global university rankings. High levels of esteem among individual scholars are important for continuing to attract top faculty, research students and research income. Esteem is also important for attracting international undergraduate students.

The ARC collected indicators of esteem in the 2015 ERA assessment. Summary data are in Figure 55. The highest levels of esteem are recorded in biochemistry and cell biology, genetics, environmental science and management, and plant biology. These areas feature very highly in the citation data referred to in the next sub-section.

Figure 55: Indicators of Esteem



Source: ARC, ERA

5.5.2 Research Quality: Clarivate Analytics InCites citation data

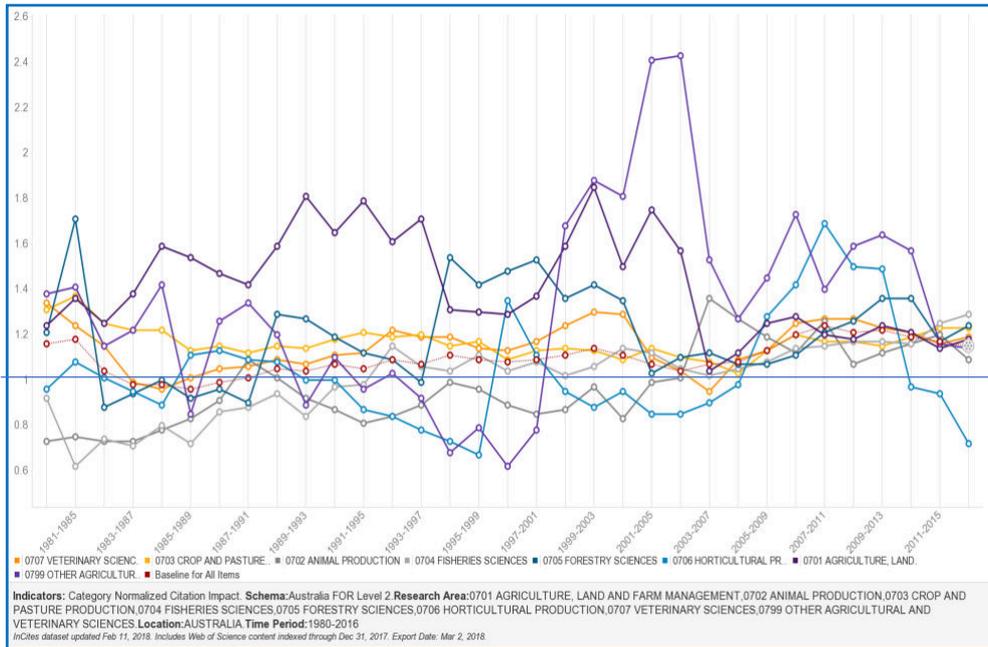
This Section uses research publication and citation data from the Clarivate Analytics' InCites platform (using Web of Science data) using normalised citation metrics across research fields to compare the performance and impact to Australian and global baselines (global metrics are normalised = 1.0 so values better than this suggest Australian impact is better than the global average in these research areas).

The material points to concentration, and dispersion, across fields and organisations. Australia performs very strongly in some key rural related FoRs, reflecting an evolution of the Innovation System into biology and biotech.

a) *Agricultural sciences*

Information on normalised citations in Field of Research codes that begin with 07 (Agricultural Sciences) is provided in Figure 56.

Figure 56: Trend in Normalised Citations (5 year rolling window), Agricultural Research FoR codes from Australia.



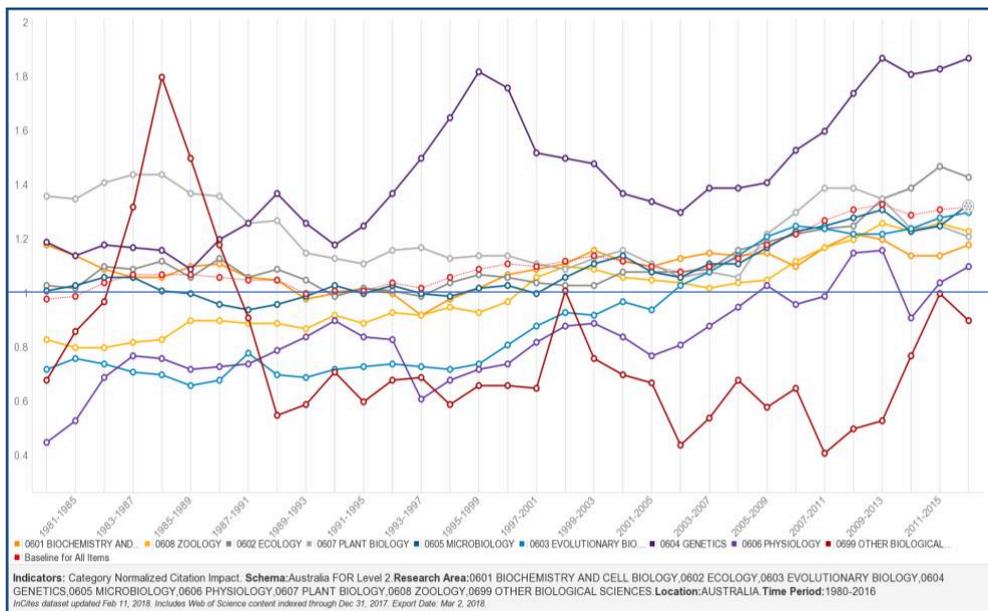
Source: Clarivate Analytics InCites

Currently Australia is ahead of the world in all FoRs except horticulture.

b) Biological sciences

Figure 57 provides a profile of normalised citations in the biological sciences and related areas. It points to a strength in genetics.

Figure 57: Trend in Normalised Citations (5 year rolling window), Biological Sciences FoR codes from Australia.



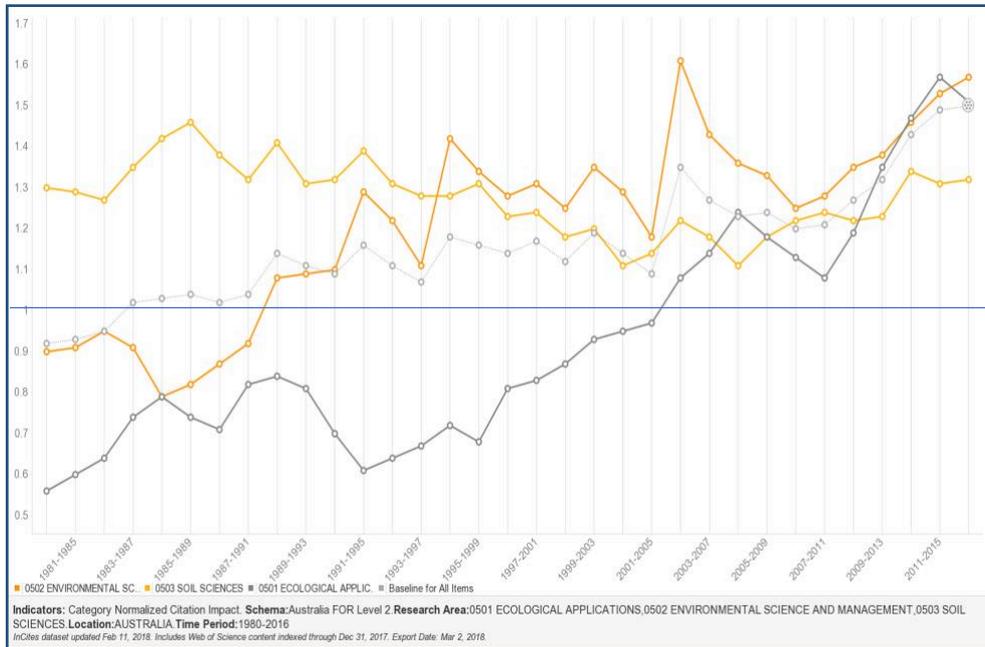
Source: Clarivate Analytics InCites

The strength in genetics sits behind the potential for growth in GeneTech applications. There is also a major strength in plant biology.

c) Environmental sciences

For trends for Environmental sciences are shown in Figure 58

Figure 58: Trend in Normalised Citations (5 year rolling window), Environmental Sciences FoR codes from Australia.



Source: Clarivate Analytics InCites

The data indicate that Australia is ahead of the average in all FoRs included above.

d) Research impact of RDC investments

Analysis of the InCites dataset in Table 11 provides a profile of the quality impact of RDC investments for the 56 FoRs in which research has been performed.

Table 11: Research Quality Impact of RDC Investments 2008-2017

Name	Web of Science Documents	Category Normalized Citation Impact	Times Cited	% Docs Cited	% Industry Collaborations	% International Collaborations	International Collaborations	Journal Normalized Citation Impact
1107 Immunology	9	5.92	687	100.00	11.11	88.89	8	3.38
1199 Other Medical & Health Sciences	1	2.48	20	100.00	0	0.00	0	2.90
0503 Soil Sciences	17	1.71	217	94.12	0	17.65	3	2.36
0203 Classical Physics	1	1.99	1	100.00	0	100.00	1	2.28
0702 Animal Production	119	1.98	1162	85.71	0	10.92	13	2.10
1116 Medical Physiology	1	2.56	6	100.00	100	100.00	1	1.97
1114 Paediatrics & Reproductive Medicine	5	1.58	147	80.00	0	60.00	3	1.89
0406 Physical Geography & Environmental Geoscience	4	2.01	23	100.00	0	50.00	2	1.82
1701 Psychology	2	0.35	6	50.00	0	0.00	0	1.82
1702 Cognitive Science	2	0.35	6	50.00	0	0.00	0	1.82
1115 Pharmacology & Pharmaceutical Sciences	3	1.18	27	100.00	0	33.33	1	1.72
0909 Geomatic Engineering	4	1.69	20	100.00	0	50.00	2	1.69
1103 Clinical Sciences	6	1.27	52	83.33	0	50.00	3	1.62
1108 Medical Microbiology	6	1.31	137	83.33	0	16.67	1	1.60
0299 Other Physical Sciences	4	1.42	13	50.00	0	25.00	1	1.55

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Name	Web of Science Documents	Category Normalized Citation Impact	Times Cited	% Docs Cited	% Industry Collaborations	% International Collaborations	International Collaborations	Journal Normalized Citation Impact
1117 Public Health & Health Services	6	1.22	65	83.33	0	33.33	2	1.51
0304 Medicinal & Biomolecular Chemistry	5	1.73	99	100.00	0	0.00	0	1.48
0914 Resources Engineering & Extractive Metallurgy	2	0.63	11	100.00	0	0.00	0	1.45
0102 Applied Mathematics	2	0.96	20	100.00	0	100.00	2	1.44
1106 Human Movement & Sports Science	4	1.45	29	75.00	25	25.00	1	1.33
0601 Biochemistry & Cell Biology	17	1.31	150	88.24	0	35.29	6	1.28
0703 Crop & Pasture Production	135	0.85	1009	87.41	0	22.22	30	1.25
0607 Plant Biology	129	0.89	640	75.19	0	30.23	39	1.17
0501 Ecological Applications	27	0.83	237	85.19	0	14.81	4	1.17
0908 Food Sciences	30	1.27	420	93.33	0	16.67	5	1.15
0604 Genetics	26	1.16	476	100.00	0	46.15	12	1.12
0707 Veterinary Sciences	58	1.19	491	94.83	0	25.86	15	1.10
1111 Nutrition & Dietetics	18	1.17	217	83.33	0	22.22	4	1.10
1203 Design Practice & Management	2	0.58	10	100.00	0	0.00	0	1.10
0701 Agriculture, Land & Farm Management	9	1.04	89	88.89	0	11.11	1	1.08
0706 Horticultural Production	79	0.94	236	68.35	0	25.32	20	1.02
0608 Zoology	61	0.87	483	81.97	0	19.67	12	1.02
1003 Industrial Biotechnology	2	0.67	26	100.00	0	0.00	0	1.02
0204 Condensed Matter Physics	1	0.67	9	100.00	0	0.00	0	1.00
0904 Chemical Engineering	16	0.78	174	93.75	0	25.00	4	0.98
0605 Microbiology	82	0.74	716	86.59	0	25.61	21	0.94
0602 Ecology	15	0.97	130	100.00	0	46.67	7	0.94
0905 Civil Engineering	3	1.23	29	100.00	0	0.00	0	0.93
0912 Materials Engineering	6	0.39	40	100.00	0	16.67	1	0.90
0704 Fisheries Sciences	5	1.09	50	100.00	0	20.00	1	0.89
0913 Mechanical Engineering	4	0.89	22	100.00	0	0.00	0	0.89
0705 Forestry Sciences	31	1.00	271	83.87	0	41.94	13	0.87
0799 Other Agricultural & Veterinary Sciences	1	1.45	15	100.00	0	0.00	0	0.87
0606 Physiology	8	0.84	45	87.50	12.5	50.00	4	0.83
0603 Evolutionary Biology	17	0.56	159	88.24	0	11.76	2	0.79
0305 Organic Chemistry	1	0.83	16	100.00	0	0.00	0	0.79
0907 Environmental Engineering	5	0.96	43	100.00	0	20.00	1	0.76
0906 Electrical & Electronic Engineering	2	1.20	12	100.00	0	0.00	0	0.67
1605 Policy & Administration	2	0.53	5	100.00	0	50.00	1	0.66
0104 Statistics	2	0.94	27	100.00	0	50.00	1	0.66
0401 Atmospheric Sciences	2	0.94	27	100.00	0	50.00	1	0.66
1001 Agricultural Biotechnology	9	0.58	46	77.78	0	66.67	6	0.64
0910 Manufacturing Engineering	5	0.46	17	100.00	0	20.00	1	0.64
0502 Environmental Science & Management	10	0.77	47	80.00	0	60.00	6	0.63
0801 Artificial Intelligence & Image Processing	5	0.73	29	80.00	0	20.00	1	0.62

Australia's Rural Innovation System

Name	Web of Science Documents	Category Normalized Citation Impact	Times Cited	% Docs Cited	% Industry Collaborations	% International Collaborations	International Collaborations	Journal Normalized Citation Impact
0915 Interdisciplinary Engineering	1	0.86	3	100.00	0	0.00	0	0.61
0999 Other Engineering	5	0.43	27	100.00	0	20.00	1	0.57
0301 Analytical Chemistry	3	0.18	7	100.00	0	66.67	2	0.53
1606 Political Science	1	0.78	1	100.00	0	100.00	1	0.52
0903 Biomedical Engineering	4	0.42	21	100.00	0	25.00	1	0.49
1801 Law	2	0.62	4	100.00	0	50.00	1	0.49
1205 Urban & Regional Planning	1	0.46	3	100.00	0	0.00	0	0.45
1202 Building	1	0.55	4	100.00	0	0.00	0	0.42
0306 Physical Chemistry (Incl. Structural)	4	0.13	7	75.00	0	75.00	3	0.40
0303 Macromolecular & Materials Chemistry	3	0.17	9	66.67	0	33.33	1	0.27
1604 Human Geography	1	0.00	0	0.00	0	0.00	0	0.00

Dataset: InCites Database. Schema: Australia FOR Level 2. Funding Agency: [SUGAR AUSTRALIA, AUSTRALIAN EGG CORP LTD., GRAPE & WINE RESEARCH & DEVELOPMENT CORPORATION IN AUSTRALIA, AMPC (AUSTRALIAN MEAT PROCESSING CORPORATION), AUSTRALIAN WOOL INNOVATION, COTTON AUSTRALIA, DAIRY AUSTRALIA (AUSTRALIA), FISHERIES RESEARCH AND DEVELOPMENT CORPORATION (FRDC), GRDC (AUSTRALIA), MLA (MEAT AND LIVESTOCK, AUSTRALIA), RIRDC (AUSTRALIA), HORTICULTURE AUSTRALIA LIMITED, AUSTRALIAN PORK LIMITED, FOREST AND WOOD PRODUCTS AUSTRALIA] Time Period: [2008, 2017]. Document Type: [Article, Book, Book chapter, Proceedings Paper]. Location: [AUSTRALIA]

Table 12 shows the research quality impact of RDC collaborations with private and public sector organisations.

Table 12: Research Quality Impact of RDC Collaborations 2008-2017

Name	Web of Science Documents	Times Cited	% Docs Cited	Category Normalized Citation Impact
Human Frontier Science Program	1	4	100.00	8.39
Sanofi-Aventis	1	114	100.00	7.99
Servier	1	114	100.00	7.99
Private Sector, Turkey	2	185	100.00	5.99
Merck & Company	2	122	100.00	4.34
Royal Society	1	87	100.00	4.34
AstraZeneca	1	71	100.00	3.98
Novo Nordisk	1	71	100.00	3.98
Pfizer	1	71	100.00	3.98
GlaxoSmithKline	1	71	100.00	3.98
Bristol Myers Squibb	1	71	100.00	3.98
Ministry of Science and Innovation (MICINN)	1	34	100.00	2.90
University of California System	4	46	100.00	2.76
Cooperative Research Centres (CRC) Programme	59	709	88.14	2.64
NIH National Centre for Research Resources (NCRR)	1	34	100.00	2.58
Lawrence Ellison Foundation	1	34	100.00	2.58
Australian National University	11	154	90.91	2.46
European Union (EU)	1	25	100.00	2.44
National Institutes of Health (NIH) - USA	7	78	100.00	2.43
Australian Research Council	32	840	87.50	2.42
United States Department of Homeland Security (DHS)	1	10	100.00	2.39
Australian Renewable Energy Agency (ARENA)	1	10	100.00	2.37
Australian Wool Innovation	75	548	88.00	2.30
Monash University	5	111	80.00	2.03
Agriculture & Agri Food Canada	2	23	100.00	1.97
University of Alberta	2	6	100.00	1.75
Consejo Interinstitucional de Ciencia y Tecnologia (CICYT)	1	22	100.00	1.69
Cancer Research UK	1	8	100.00	1.68
Centers for Disease Control & Prevention - USA	1	42	100.00	1.67
Commonwealth Scientific & Industrial Research Organisation (CSIRO)	170	2859	94.71	1.63
National Health and Medical Research Council of Australia	29	628	79.31	1.60
BBSRC	1	23	100.00	1.57
Tehran University of Medical Sciences	1	36	100.00	1.55
Australian Government	70	578	87.14	1.54
University of Melbourne	81	1007	96.30	1.47
New Zealand Foundation for Research, Science and Technology	1	14	100.00	1.43
National Science Foundation (NSF)	3	66	100.00	1.39
University of Queensland	86	793	87.21	1.35
NIH Eunice Kennedy Shriver National Institute of Child Health & Human Development (NICHD)	4	21	100.00	1.32
Dairy Australia	48	635	95.83	1.20
United States Environmental Protection Agency	1	24	100.00	1.12
Australian Meat Processor Corp	11	67	100.00	1.11
University of Sydney	97	1191	84.54	1.00
Chinese Academy of Sciences	2	5	100.00	0.91
National Heart Foundation of Australia	2	14	100.00	0.88
CAPEs	2	9	50.00	0.87
Rural Development Administration, Republic of Korea	2	31	100.00	0.82
National University of Singapore	2	35	100.00	0.79
NIH National Institute of Allergy & Infectious Diseases (NIAID)	1	19	100.00	0.78
Australian Pork Limited	6	26	100.00	0.76

Name	Web of Science Documents	Times Cited	% Docs Cited	Category Normalized Citation Impact
Australian Livestock Export Corporation Ltd (LiveCorp)	7	14	71.43	0.69
University of Liege	1	4	100.00	0.68
Institut National de la Recherche Agronomique (INRA)	7	52	100.00	0.67
Australian Eggs	3	5	100.00	0.65
Centre National de la Recherche Scientifique (CNRS)	6	42	100.00	0.58
China Scholarship Council	2	5	100.00	0.52
Department for Environment, Food & Rural Affairs (DEFRA)	1	3	100.00	0.51
United States Department of Agriculture (USDA)	5	32	100.00	0.37
University of Toronto	1	1	100.00	0.36
Natural Sciences and Engineering Research Council of Canada (NSERC)	1	1	100.00	0.36
National Natural Science Foundation of China	1	1	100.00	0.34
Ohio State University	2	10	100.00	0.32
Howard Hughes Medical Institute	1	6	100.00	0.22
Grains R&D Corp	1	3	100.00	0.20
City University of Hong Kong	1	0	0.00	0.00

InCites Dataset. Schema: Australia FOR Level 2 Funding Agency: [SUGAR AUSTRALIA, AUSTRALIAN EGG CORP LTD, GRAPE & WINE RESEARCH & DEVELOPMENT CORPORATION IN AUSTRALIA, AMPC (AUSTRALIAN MEAT PROCESSING CORPORATION), AUSTRALIAN WOOL INNOVATION, COTTON AUSTRALIA, DAIRY AUSTRALIA (AUSTRALIA), FISHERIES RESEARCH AND DEVELOPMENT CORPORATION (FRDC), GRDC (AUSTRALIA), MLA (MEAT AND LIVESTOCK, AUSTRALIA), RIRDC (AUSTRALIA), HORTICULTURE AUSTRALIA LIMITED, AUSTRALIAN PORK LIMITED, FOREST AND WOOD PRODUCTS AUSTRALIA]. Time Period: [2008, 2017] Document Type: [Article, Book, Book chapter, Proceedings Paper]. Location: [AUSTRALIA]. Exported date 2018-02-13.

e) Concluding comment

The data appear to indicate a shift of emphasis and impact from the agricultural to the biological sciences and environmental sciences, which is probably consistent with the waves of innovation approach referred to in the *Strategic Analysis, Options and Recommendations Report* (Document B). The increase of publications in basic research areas may also reflect increased investment from ARC/NHMRC in these enabling technologies, the interest of research providers looking for new twists on old problems. This is important for building the knowledge base.

During consultations there was a view put forward, however, that small universities may be in too many fields. This view cannot be evaluated based on the data available, as small universities can be very focused (i.e., USQ and biopolymers) and their papers are spread across many journal categories. Nonetheless, critical mass is likely to remain an issue, indicated in terms of capability and visibility (low citations counts).

We were advised in consultations that RDCs will go to where the best capability is; for example, The University of Sydney for Field Robotics; others will find it difficult to get into this space. SCU has some specific capabilities in analysis and testing, and UNE is known globally for animal genetics.

Consultations also indicated that the smaller regional universities were much more collaborative in their approach to rural research. Consultations also indicated that in some of the larger “international rankings” motivated universities, there was a poor connection between what research organisations want to provide, and what industry requires.

5.5.3 Research commercialisation

Income from commercialisation is an important metric of research effectiveness. That is, income from commercialisation, identified as a License, Option or Assignment of IP (LOA) is a tangible recognition of the usefulness of research outputs to a business in the production of goods and services. Rarely, however, is there a linear trajectory from a LOA to a product or service. Other IP may be present (or required) and numerous investments in prototyping, scale up, marketing, and distribution are required.

The medical sciences are virtually unique in being able to point to the discovery of a protein, molecule, or vaccine, and chart a trajectory to adoption, application and use in a medical or clinical context. Discovery of genes in an agricultural context comes close – but there are many hurdles to cross before newly identified genes can enter general use. Australia has an excellent capability in animal and plant genetics, but the commercial licensing is only a first part of a path, involving many collaborators, competitors, and investors, to achieving economic and environmental impact.

Many research organisations were criticised during consultations for overtly transactional approaches to commercialisation of Intellectual Property, and difficulties in negotiating licensing agreements.

Approaches built around trust and partnership and the longer-term engagement do better in terms of business and commercial outcomes.

The formation of start-ups is also often seen as an indicator of research effectiveness. Politicians have had a habit of 'counting start-ups' as an indicator of research effectiveness.

There are several successful start-ups that have built a business around the commercialisation of university research. They include:

- CropLogic, based on IP from the NZ Institute for Plant and Food Research, and listed on the ASX in 2017
- Nexgen Plants, from IP at University of Queensland.

Universities and research organisations are taking an interest in commercialisation through support for early-stage investments, incubators and accelerators and the provision of coworking spaces. There is a great deal of interest in university centred innovation precincts. This is addressed in further detail in Report B and is the subject of an imminent report and possible budget initiative from the Department of Industry, Innovation and Science in the 2018-19 budget.

A survey of methods for translation of research for economic and social benefit was undertaken for the Australian Council of Learned Academies (ACOLOA) in 2015 (Howard, 2015).

5.5.4 Transfer and translation through extension and intermediaries

During Consultations many people observed the decline in Agricultural Extension by State Government Primary Industries Departments. Although arguments could be made for its reinstatement, it is important to look at other frameworks for communication and engagement involving both public and private sector initiatives.

Our understanding of the innovation system, and the science and research system, acknowledges the important role of *innovation intermediaries* who build and sustain connections and relationships between 'actors'. They can facilitate the formation of networks, development of technology markets (connecting buyers and sellers), and design organisations that bring capabilities together.

Intermediaries provide advisory, mentoring, brokage, and support roles and are a key element in innovation system performance. The scope, extent and contribution of intermediary activity can be underestimated. Improvements and adjustments in this area offer substantial potential for improving system performance. During consultation, people pointed to the historically important role of stock and station agents as intermediaries.

In a context of systemic and more complex change, due to climate change, digital technologies and changing market requirements, access to high quality information, advice and support is increasingly important for effective decision making at the producer level. Following the reduction in the provision of extension services by State governments these services are now provided by a diverse range of organisations, including some RDCs, State governments, universities, input and equipment suppliers, rural service organisations and fee-for-service advisors and consultants.

Building efficient way of linking research with practice is an important issue to address for the future of rural innovation. However, with closer collaboration between research organisations and business in some sectors, the requirement may be becoming redundant.

And so, you look at my fish farming industry, which salmon started in 1986. We knew. They never delivered the equivalent of extensions or anything. We've created completely new models which are much more modern. We are connected with Norway; we're connected with the Faroe Islands. We're connected ... It's a completely different environment and it's all about self-empowerment, not waiting on someone else to help you.

At Huon Aquaculture at the moment, they have 21 of their staff members who have done PhDs. They have more academic power than the University of Tasmania in salmon farming. So why would they go to an extension officer?

The evidence suggests that those producers who are more strongly oriented to growth and improvement are also more active in seeking and acquiring new knowledge from a wide range of sources, including specialised in-line information sources and blogs. With the greater access to and use of technology, intermediary services are under challenge. A recent article in the MIT Sloan Management Review identified several challenges for intermediary organisations.

Don't Get Caught in the Middle
Paul Michelman
 MIT Sloan Management Review: Winter 2018 Issue, November 03, 2017
 Editor's Note: This article is an expanded version of the article that appears in the Winter 2018 print edition.

Digital platforms are convening direct connections between traditionally intermediated sides of markets [value chains] by the thousands — in retailing, dating, personal transportation, entertainment, product development, and so on.

New industrial technologies like additive manufacturing will eliminate links throughout legacy supply chains. For example, a company that can make a needed replacement part through 3-D printing doesn't need to purchase that part from a distributor.

We are only now just scratching the surface of the internet of things (IoT). IoT promises to deepen connections between manufacturers and end users of their products — and that threatens many traditional intermediaries.

And if I were in a field such as financial services, I would already be looking at blockchain with a great deal of trepidation. Who needs the "trusted intermediary" when trust has already been confirmed through blockchain technology?

For most of the industrial age, we took the value of intermediaries as a given. Organizational models were built on the assumption of their value. But the more we encounter example after example of their redundancy, the more we will see middlemen as usurpers of value rather than creators.

Most intermediaries will not disappear overnight. For instance, there are few organizational models that can withstand the wholesale removal of entire management layers in one fell swoop. But over the long term, genus *go-between us* may well find itself on the endangered list.

The intermediaries that persevere will be those that adapt. They will produce unique value, adding something to a transaction or relationship that is — at least for a time — irreplaceable. They will provide a bridge or translation between two parties who would otherwise be unable to fully appreciate each other. Intermediaries will increasingly become specialists offering customized services that are too expensive or rare for the parties they serve to justify building on their own.

<https://sloanreview.mit.edu/issue/2018-winter/>

5.5.5 Concluding comment

Australia is leading the world in the fields of genetics and plant biology. This reflects a very long-term commitment to research, both in terms of investment and the organisational capabilities, personnel, facilities, and equipment. As discussed in the Strategic Perspectives Report (Document A) this can only be maintained by ongoing investments.

These areas have also demonstrated success in commercialisation, nationally and globally.

5.6 Research, Development, and Innovation Impact

Key points

- Approaches to assessing research impact are not well developed.
- There is a concern with using “big numbers” to demonstrate impact; assumptions, data sources, and methodologies must be transparent
- There is limited information on commercialisation impacts, in terms of jobs created, new sales, new investments called forward, and exports.
- Case study approaches are important, and there is an argument for adopting consistent approaches across all components of the rural innovation system.
- There are very few “stories” that provide in depth insights into how innovation has happened.

Assessment of performance impact involves addressing the question “what has changed because of the investment? Has the investment made a difference? What has changed and is the change for the better)?

Change is reflected in -

- Benefits to industry and the economy – contribution to GDP, industry GVA, increased business income (sales), additional jobs, additional investment, and additional exports
- Environmental benefits – preservation/repair/restoration of natural capital, reduction of waste, recycling, reduced carbon emissions

- Social benefits – improved quality of life, security and safety, new opportunities.
- Evidence of change (for the better) in rural communities

There is a demand by policy advisers, advocates, commentators, etc, for single “big numbers” that indicate (“prove”) impact. The reality is far more nuanced (and policy makers more sophisticated), and “big numbers” on their own can be misleading.

Approaches that have been used to assess impact cover one or more of -

- Economic modelling (general equilibrium modelling, impact multipliers, statistical analysis)
- Economic estimation
- Commercialisation studies
- Case studies
- Historical tracing and ‘storytelling’
- Expert judgement/peer review
- Principles and criteria-based approaches

Each has specific methodologies, assumptions, strengths, weaknesses, and limitations. In the following pages assessments of each approach are outlined, drawing attention to where they have been used and the findings. Methodologies for many approaches are, however, still emergent.

5.6.1 Economic analysis and statistical analysis

A detailed discussion of economic modelling and impact for investment in rural research, development and innovation is set out in Appendix 3.

The search for a single metric of research and innovation performance and industry impact has proved to be illusive.

Sector based economic impact multipliers have been drawn upon in numerous consultants reports that endeavour to indicate impact. However, multiplier analysis is fraught with measurement and conceptual problems. They are often seen as interesting but are more reflective of public relations strategies around the appeal of “big numbers”¹⁶.

When dissected, big numbers can be very sensitive to the compound interest rates implied. For example, \$1 invested today in R&D could increase economic output to a value of \$10.83 over 25 years at a compound interest rate of 10 per cent. This would be impressive, if all the underlying assumptions of the modelling held true. If, however, the interest rate is closer to five per cent, the economic impact would be \$3.39.

There is some evidence of the R&D contribution to growth, *over the longer term*, as discussed in Appendix 3. But it requires a continuous and sustained commitment. One-off injections may be dissipated very quickly and lost in the economic system.

5.6.2 Economic estimation

Estimation of the benefits of rural research, development and innovation investments are reflected in submissions to reviews and inquiries, including, for example, the Productivity Commission. They are also used in publicity and promotional material by RDCs and research organisations.

¹⁶ The ABS has drawn attention to the shortcomings and limitations of input-output multipliers in a number of areas: Lack of supply-side constraints; Fixed prices; Fixed ratios for intermediate inputs and production; No allowance for purchasers' marginal responses to change; Absence of budget constraints; Not applicable for small regions. See <http://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/5209.0.55.001Main%20Features42014-15?opendocument&tabname=Summary&prodno=5209.0.55.001&issue=2014-15&num=&view=>

There are concerns about methodology including assumptions, time frames, and the capacities of supporting institutions to deliver the projected results.

If these approaches are to be at all useful, the sector should impose quality standards on organisations undertaking this work.

5.6.3 Commercialisation

The Department of Industry Innovation and Science supports regular surveys of research commercialisation, but they do not identify agriculture, forestry, fishing separately.

The nature of the survey is such that collection of industry related data might be difficult. It is possible, however, to identify start-ups from the collections and supporting case studies.

5.6.4 Case studies

One of the few realistic ways to assess impact is through case study methodologies. The fundamental question to be addressed in this sort of approach is “what has changed as the result of the implementation of an idea?”.

The UK has adopted an approach to documenting case studies in the Research Excellence Framework (REF) initiative (successor to the Research Assessment Exercise, RAE). The ARC is also currently going through a process to develop a case study methodology.

FIAL has produced case study reports over the last two years. Case studies of varying length and depth have been produced by CRCs, the CSIRO and RDCs. It is important that case studies provide insights on *how* an innovation came into being (especially as regards decision-making and judgment under uncertainty and in the face of risks), as well as what occurred. Case studies come undone when they are put out mainly as ‘publicity’.

A standardised case study format could be developed, and performance ratings identified for several categories of impact. These could be the well-accepted evaluation metrics such as financial revenue (sales), new jobs created, new investment stimulated, exports. Experience has demonstrated that these metrics must be independently validated. Other, more qualitative impact measures could also be defined.

Validation would occur through a standardised “expert opinion survey” as developed for this Report.

Impact information should be followed through with a narrative that constitutes “a good story”.

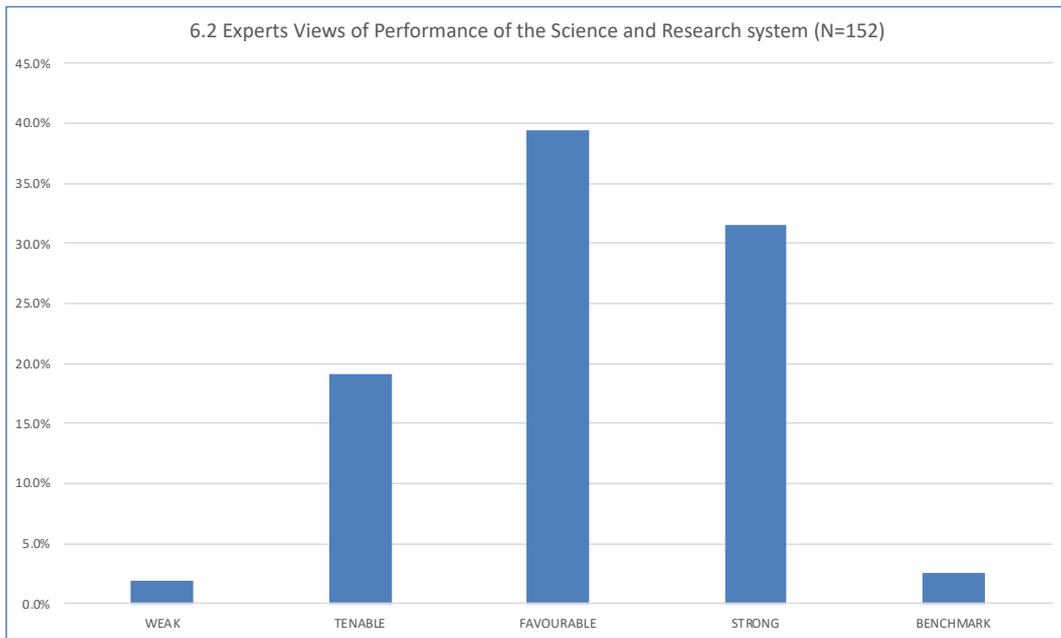
5.6.5 Historical tracing, story telling

Only a few good narratives about rural RD&I system from economic history and history of technology perspectives – for example Jan Todd *Colonial Technology* (Todd, 1995) , John Kerin’s *magnum opus* (Kerin, 2017)

5.6.6 Expert judgement, peer review

By way of example, the Expert Opinion Survey undertaken as part of the Review, asked people who identified as Rural Innovation experts to provide views on aspects of innovation system performance. A total of 188 respondents lodged the Survey Instrument. More detailed responses are attached.

Rural Innovation Experts considered the performance of the Science and Research System to be favourable to strong, as indicated in Figure 59. Consultations supported the perception of a strong performance, but with areas for improvement.

Figure 59: Experts Views on the Performance of the Science and Research System

Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 1918

5.6.7 Principles and criteria-based approaches

These approaches are aimed at assessing the extent to which a project achieved what it set out to do. Such approaches seek to identify whether impact went according to plan, or whether the results were serendipitous or occurred by chance – for example, because of unexpected changes in the operating environment.

The criteria for success, or how success will be known, can be written into projects at commencement and monitored progressively. They would be identified milestones and could be process as well as outcome oriented depending on the stage of the project.

5.7 Critical Interactions with other National Systems: An Assessment

Key points

- The rural science research and innovation system interacts with several other national systems. The performance of these systems can have a major impact on rural innovation performance.
- There is concern, reflected in the Expert Opinion Survey, that the Education and Training System has not kept pace with the evolution of the rural innovation system.
- There is a concern about declining university enrolments in agriculture, forestry, and related courses, although Review Consultations indicated that rural industries called on a broadening range of knowledge, skills, and capabilities – including management
- Innovation ecosystems, precincts, and clusters, and coworking spaces have become a major focus of policy attention and investment by State and Territory Governments, Universities, and lead businesses
- The regional development system could be better aligned with the rural innovation system. However, universities have a key role in supporting and enabling rural innovation
- The rural enterprise (entrepreneurial development) system is supporting the growth of a new entrepreneurial approach in rural businesses.
- Experts indicated that more could be done to strengthen the natural environment and biodiversity management system.
- Experts indicated that the performance of the Internal Trade and Foreign Investment System was generally favourable, as was the Financial System and the Regulation, Certification, and Inspection System.

- Experts indicated concern in relation to the infrastructure system, particularly in relation to energy – but were supportive of the potential for farm businesses to diversify into locally generated energy systems.
- Experts also had concerns about the performance of the agri-political/public policy system.

In earlier parts of the Report several national systems that complement, enable, and add value to the rural research and innovation system have been identified, covering Education, training and talent acquisition, Rural and regional economic development, Rural enterprise development. Ecosystems, Trade and foreign investment, Finance, Transport, storage and logistics, Regulation certification and inspection, Natural environment and biodiversity, Energy, and Agri-politics (public policy).

Not all activities and events in these systems involve innovation – but the ways they work and operate can be important as enablers of innovation – as well as barriers. The efficiency, quality, and effectiveness of interactions between and within systems is of vital importance to innovation system performance.

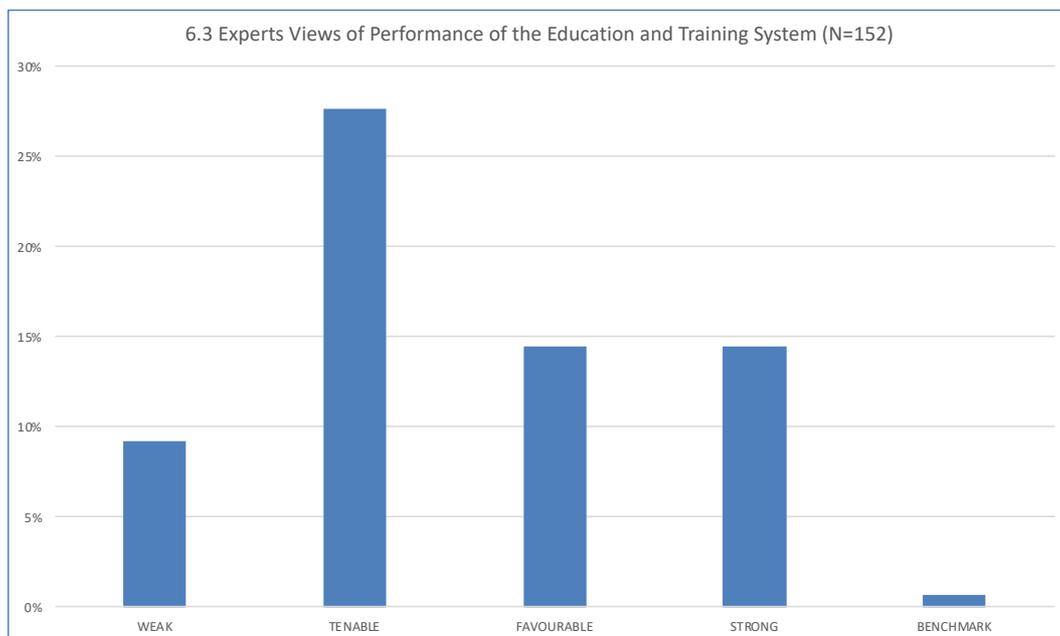
5.7.1 The Education, training, and talent acquisition system

Key points:

- There is concern that the education and training system has not kept pace with the evolution of the Rural Innovation System
- Education and training in agricultural sciences at universities and in VET has been falling behind, but there is a resurgence.
- A change in emphasis towards a rural value chain approach to rural innovation will require a very broad range of skills, knowledge, and capabilities
- There is a “mainstreaming’ of skills and qualifications, particularly around technology.
- There is a strong demand/requirement for business management skills

Experts’ views of the performance of the education system were generally favourable or tenable, suggesting that there is significant scope for performance improvement, as indicated in Figure 60.

Figure 60 Experts Views of the Performance of the Education and Training System



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

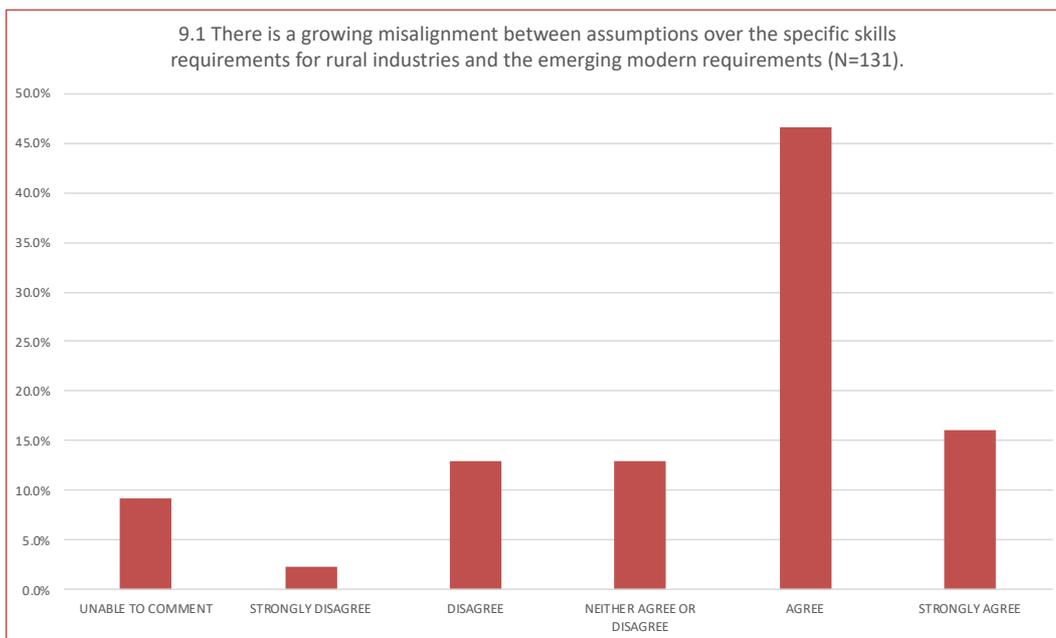
▪ **Contribution of the education and training system to rural innovation**

Consultations indicated concern about contribution of the education and training system to rural innovation performance. This is reflected in the Expert Opinion Survey in response to the proposition:

There is a growing misalignment between assumptions over the specific skills requirements for rural industries and the emerging modern requirements.

Figure 61 indicates a high level of support for the proposition.

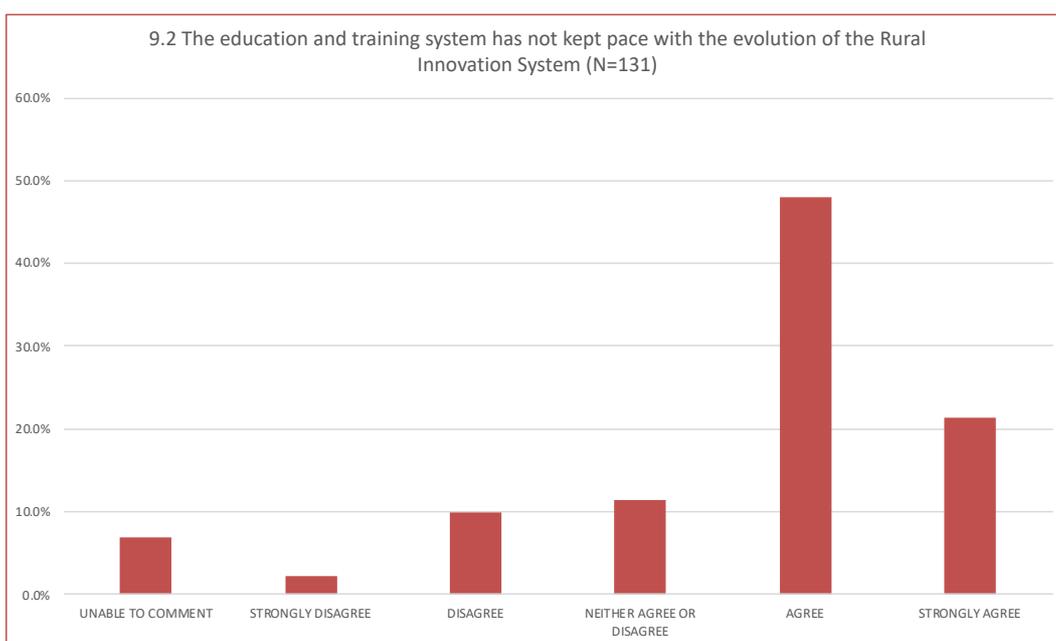
Figure 61: Expert Opinion Survey – Alignment in skill requirements



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

In response to the specific proposition that “The education and training system has not kept pace with the evolution of the Rural Innovation System”, the response was equivocal, as indicated in Figure 62.

Figure 62: Expert Opinion Survey – Conformance between the education and training system and the Rural Innovation System



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

Aspects of these concerns are addressed in the remainder of this Section.

- **Skills shortages**

Evidence from government organisations, industry groups, academics and almost anyone who has ever tried to find highly skilled candidates for agriculture job vacancies, is that the Australian agriculture sector faces a near critical skills shortage¹⁷.

Agriculture is the biggest employer in rural and regional Australia, employing around 300,000 people directly and more than 1.6 million people across the supply chain. However, skills capacity looms as the sector's most significant issue. With increasing industry and technical complexity, the composition of jobs and available career paths has changed considerably over the last 10 years.

There have consistently been many more jobs available in agriculture than there are qualified candidates. University graduates finishing agriculture-related degrees can expect to have full-time employment secured before they've completed their degree. Indeed, according to the latest research from Charles Sturt University's Professor Jim Pratley there are upwards of five jobs for each graduate in the current market.

It needs to be said that most of these graduates (and indeed many of the people employed in the agriculture sector) are not farmers. The CEO of Agrifutures has commented:

We must bust the myth that agriculture equals farming. You don't have to be a farmer to work in agriculture, you don't have to have an agricultural background or qualification to work in agriculture, and you don't necessarily have to live in a rural area to be part of the sector.

Really, it's any job that is involved in the production of food, feed, and fibre or that supports that production and helps get those products to market. It's everything from a graphic designer working on packaging concepts for supermarket rice cakes to engineers building robots to monitor fruit trees to the train driver delivering wheat to port and much more.

The future of the rural sector depends on more farmers with business skills *and* on people who work or set up businesses in the "off-farm" segments of the value chain.

Talent is also sourced through international personnel movements. Rural industries are global in their orientation and there is a continual flow of people to and from Australia to work in all aspects of the value chain. Unskilled seasonal international workers are also important as a boost to the Tourism industry.

Automation will have significantly regional impacts of workers replaced with automated processes. But progression is inevitable, particularly in horticulture.

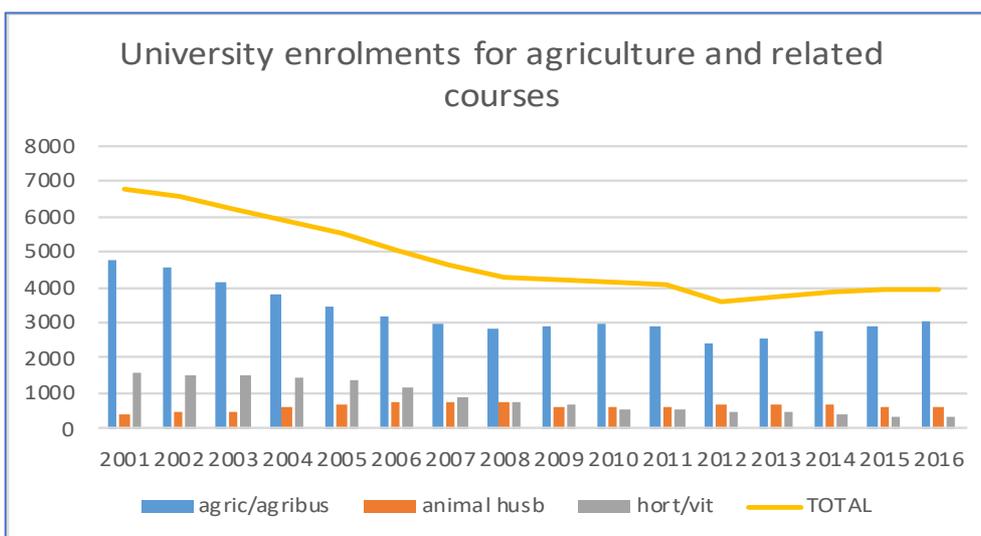
It used to be thought that to secure agriculture's future young people had to be kept on the land and working on farms. Now we know we must not only develop and retain young farmers we must also attract people with skills, knowledge and experience drawn from many other professions and vocations.

- **Trends in university enrolments in agriculture and related courses**

Information on enrolments and completions in agriculture and related courses is reproduced in Figure 63 below.

¹⁷ John Harvey, Agrifutures, <http://www.agrifutures.com.au/news/overcoming-the-agriculture-sector-skills-shortage/>

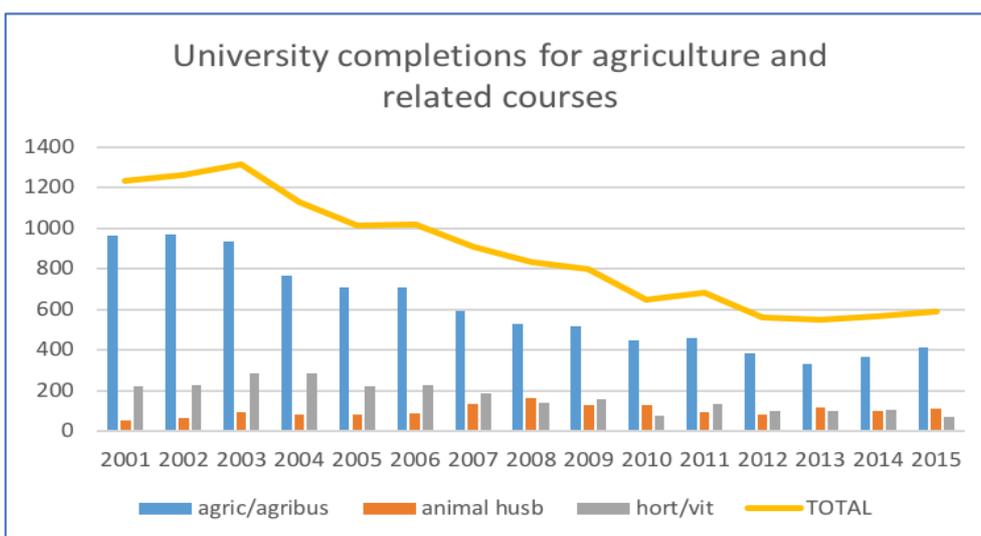
Figure 63: University Enrolments for Agriculture and Related Courses



Source: Professor Jim Pratley, Council of the Deans of Agriculture

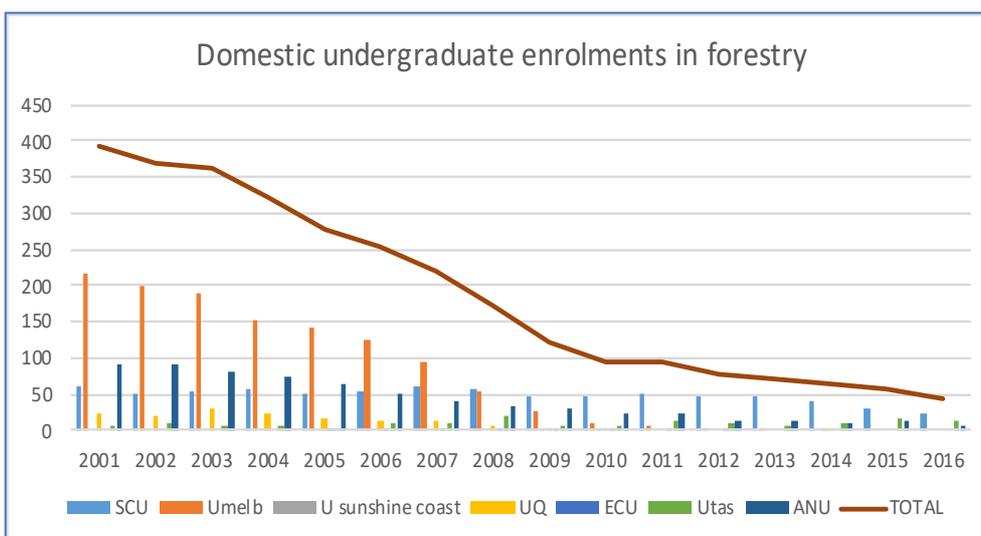
Figure 63 indicates that there has been an increase in enrolments starting in 2012. Enrolment data from university agriculture courses shows women have outnumbered men (albeit marginally) since 2003. Charts below show further information on enrolments and completions.

Figure 64: University Completions for Agriculture and Related Courses



Source: Professor Jim Pratley, Council of the Deans of Agriculture

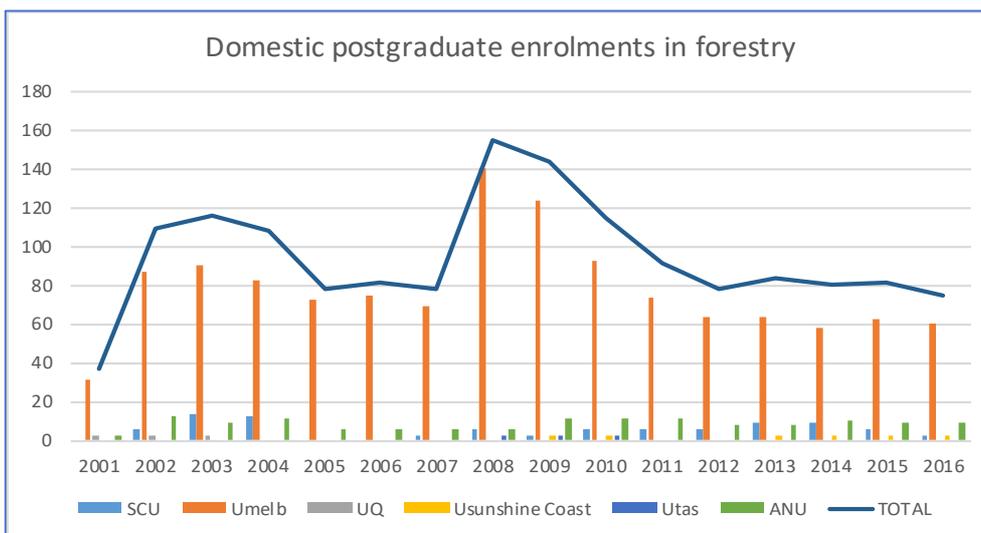
Figure 65: University Domestic Undergraduate Enrolments in Forestry



Source: Professor Jim Pratley, Council of the Deans of Agriculture

The data on domestic enrolments indicates a continuing decline in undergraduate interest in Forestry. Post graduate interest has been steady from 2012, as indicated in Figure 66.

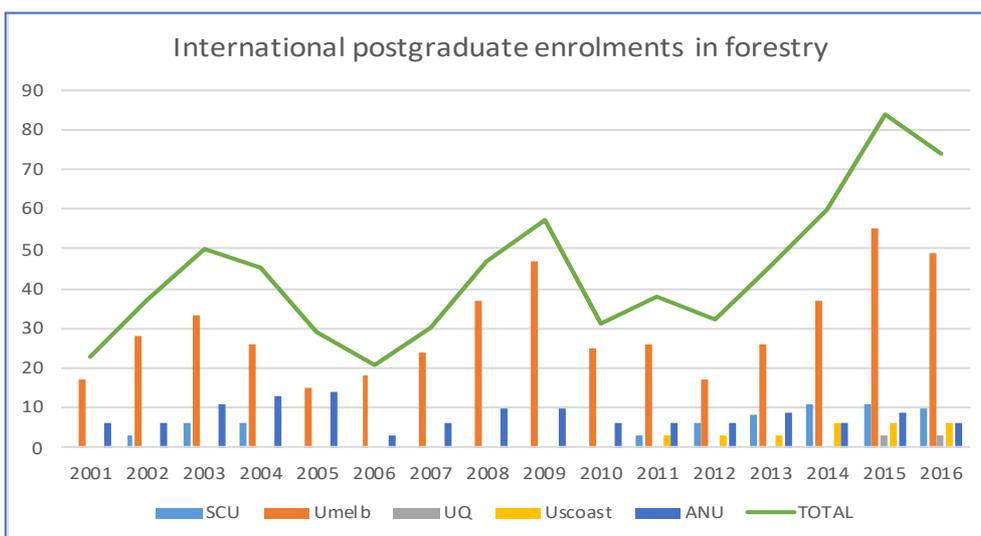
Figure 66: University Domestic Post Graduate Enrolments in Forestry



Source: Professor Jim Pratley, Council of the Deans of Agriculture

There has, however, been a very strong international interest in Forestry, particularly at the University of Melbourne.

Figure 67: University International Postgraduate Enrolments in Forestry



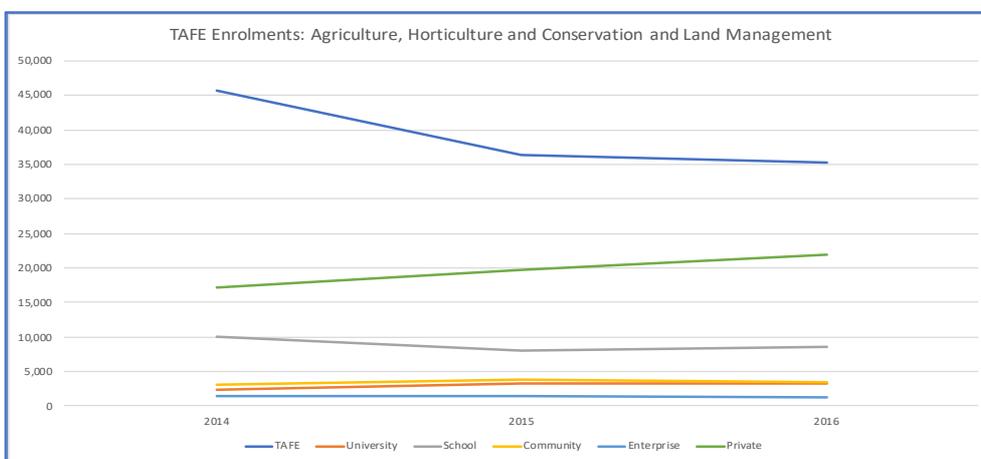
Source: Professor Jim Pratley, Council of the Deans of Agriculture

This interest is linked to the emergence of forestry industries in our neighbouring countries.

▪ **Trends in vocational education and training**

Information on vocational education and training has been drawn from published NVCA data sources. It shows a generally declining demand for courses in areas associated with rural production.

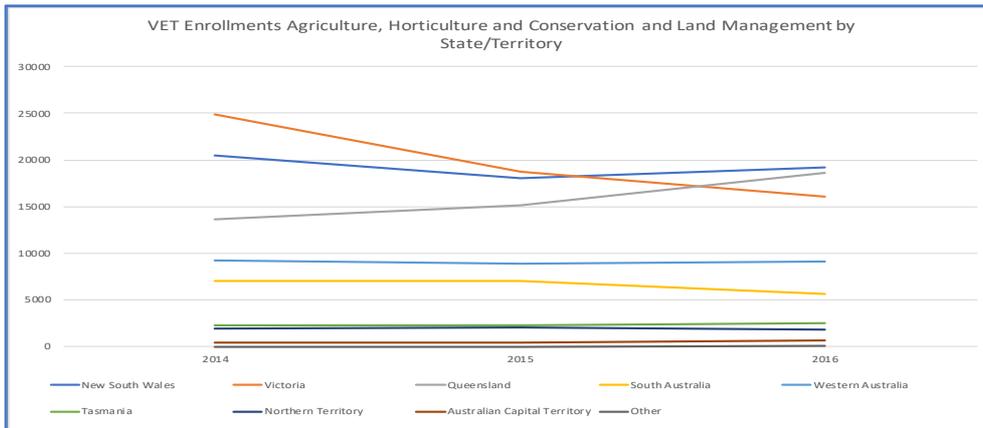
Figure 68: VET Enrolments in Agriculture, Horticulture, Conservation and Land Management



Source: NVCA, Data Slicer: Total VET Students and Courses, 2016

The trend decline is most pronounced in Victoria, but there have been increases in the year-on-year figures from 2015.

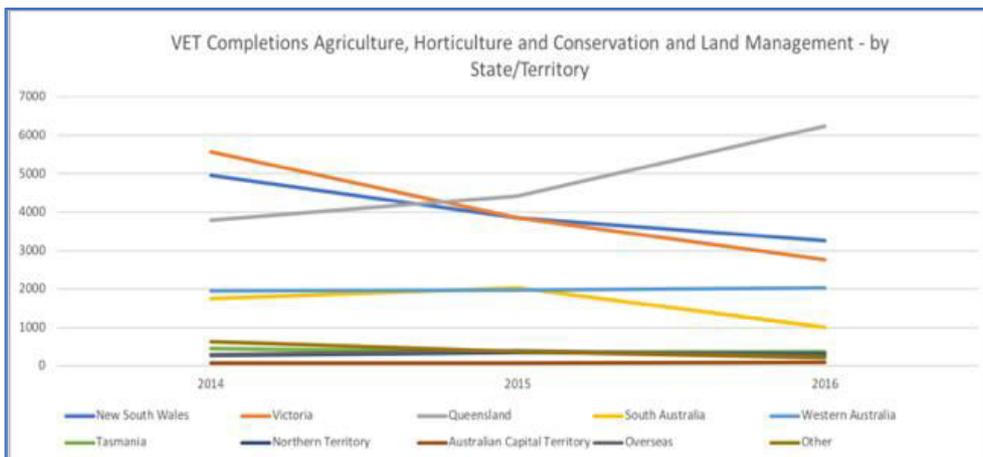
Figure 69: VET Enrolments in Agriculture, Horticulture, Conservation and Land Management by State /Territory



Source: NCVER, Data Slicer: Total VET Students and Courses, 2016

In terms of completions, there has been a strong increase in Queensland.

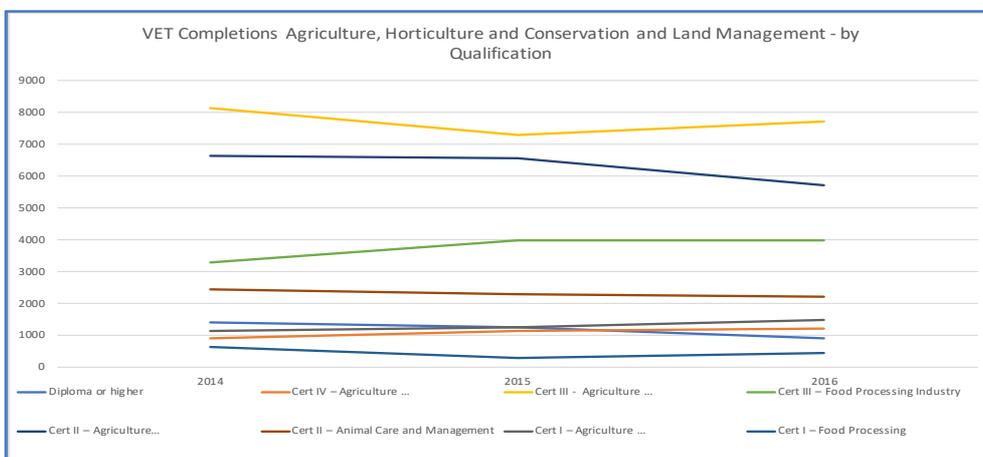
Figure 70: VET Completions in Agriculture, Horticulture, Conservation and Land Management by State /Territory



Source: NCVER, Data Slicer: Total VET Students and Courses, 2016

Completions are strongest at the Certificate III level in Agriculture.

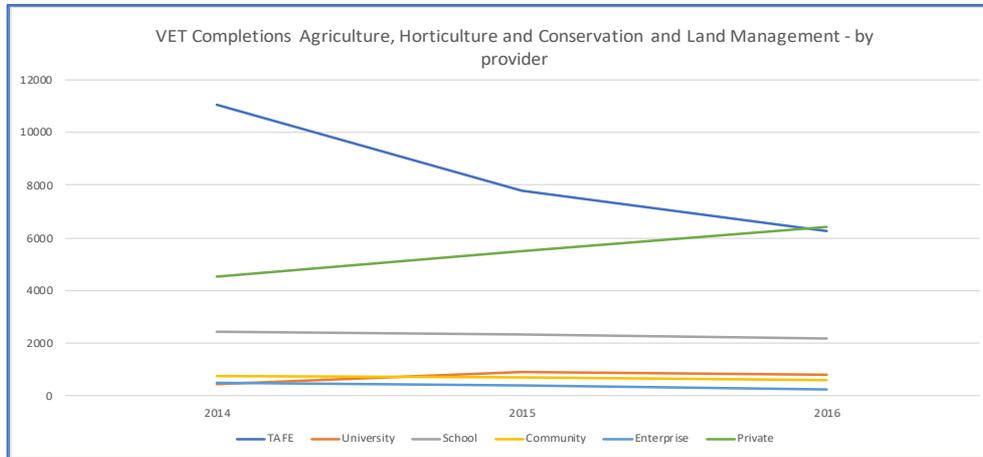
Figure 71: VET Completions in Agriculture, Horticulture, Conservation and Land Management



Source: NCVET, Data Slicer: Total VET Students and Courses, 2016

Completions in the TAFE sector have declined, whilst increasing in the private component. This is indicated in Figure 72 below.

Figure 72: VET Completions in Agriculture, Horticulture, Conservation and Land Management by Provider Category



Source: NCVET, Data Slicer: Total VET Students and Courses, 2016

▪ **Schools involvement in agricultural curriculum**

Consultations during the Review indicated a renewed importance of agricultural high schools and courses in agriculture, particularly in NSW, where agriculture is part of the school curriculum.

NSW is seen to be “reinventing” Ag High Schools; Hurlstone Ag High is now integrated with Western Sydney University. There are four Ag High schools and seven “lighthouse” schools. Tumut High School is seen to be a leader.

Tumut High School Close ties with the community

For the last 20 years, Tumut High School has been forging connections with rural cattle producers, local businesses, show societies and other schools as part of its Rural Youth Cattle Enrichment (RYCE) program.

“The program teaches students about caring for cattle as well as preparing cattle for shows and the market,” says Tony Butler, who was named Tumut’s 2015 Citizen of the Year for his work as Senior Teacher, Agriculture and Primary Industries at the school. “Our aim is to encourage an interest in agriculture and help our students gain knowledge, skills and, where appropriate, a career pathway. The program also helps students to develop personal qualities such as confidence, self-esteem, and leadership skills.”

<https://business.nab.com.au/art-and-science-bring-young-people-and-farmers-together-13047/>

In terms of VET in Schools, enrolments of students in agriculture and related courses have been falling, as indicated in Table 13.

Table 13: Students enrolled in VET in Schools Agriculture, Horticulture and Conservation and Land Management - by State/Territory and place of course delivery

	2014	2015	2016	2016	2015-16
	No.	No.	No.	% All students	% Change
New South Wales	5460	6015	5280	5.4	-12.2
Victoria	1840	400	250	1.2	-37.5
Queensland	2115	1885	1810	2.1	-4.0
South Australia	0	0	0		
Western Australia	895	925	975	19.1	5.4
Tasmania	100	90	95	3.5	5.6
Northern Territory	35	40	55	4.6	37.5
Australian Capital Territory	0	0	15	0.3	-
Total	10445	9355	8480		

Source: NCVET, Data Slicer: Total VET Students and Courses, 2016

Discussions indicated a need to link agriculture with science, technology, engineering, and mathematics (STEM) as well as the creative disciplines associated with the humanities, arts, and social sciences (HASS), and to get curriculum materials into SCOPUS (Elsevier's widely used abstract and citation database).

Interviewees saw an important role for Royal Agricultural Societies and Show Societies in building interest in farming, as well as film and television documentaries about rural lifestyles and entrepreneurship.

▪ **Rural RDCs**

Cotton Australia has accessed funds from government and others to deliver program for young people in a school environment.

We find the culture is very positive to skill development, education. Again, there's new skills that we need, that, data analysis... and working with augmented reality and things that, that we're not even really contemplating yet, but we're going to need those skills. We invested in scholarships for people to go the Silicon Valley. So, they can come back with those sorts of skills that aren't part of our industry now. Go and get inspired, come back, and have a leadership influence in our industry. Not in our research community as much as our industry.

▪ **Community and service organisations**

In rural communities, service organisations play a leading role in supporting young people to participate in tertiary education and extend the education experience through international exchanges. They are also strong supporters of the Country Education Foundation (CEF) which fosters the further education and training, career, and personal development opportunities of rural youth.

The Country Education Foundation
<p>CEF is a national not-for-profit organisation that awards small financial grants and community support to regional and remote students to help them transition from high school into higher education, training, or employment.</p> <p>Young Australians in rural and remote areas are as bright and ambitious as those living in metropolitan centres. But when it comes to higher education and jobs, thousands of them are missing out.</p> <p>For many, the financial, emotional, and social obstacles are just too great – and they are unable to relocate in order to take up further study or work.</p> <p>Through our network of 43 local foundations, communities support students with demonstrated financial need and realistic career and training goals. This financial support helps with the costs of textbooks, tools, accommodation, travel, and resources.</p> <p>Established in 1993 in Boorowa, NSW, the Country Education Foundation family has expanded into Queensland, South Australia, and the Northern Territory. Local foundations are volunteer-driven – teams of committed people representing a broad cross section of their communities across education, business, agriculture, community, and government. Each foundation raises the funds they award within their local area.</p> <p>The community-based model identifies students at risk of falling through the gaps, or students that warrant additional encouragement to flourish, and provides financial and community support to follow their desired career goals.</p> <p>CEF partners with more than 30 universities, as well as corporate and philanthropic organisations across the country to leverage and increase the support we provide.</p> <p>Approximately 90 per cent of grant recipients go on to complete the course or training for which they are funded. Independent research shows that for every dollar invested in our work a return of \$3.10 is created in social value – changing the lives of young Australians, their families, and their communities.</p> <p>https://cefcfdn.s3.amazonaws.com/wp-content/uploads/2017/11/27130012/Annual_Review_2016_17_Final_web.pdf</p>

The current CEF strategy includes the following actions:

- Support 1000 students nationally by 2022
- Develop a national mentor program
- Improve servicing of students and communities
- Focus on closing the education participation gap between country and city youth
- Advocate to achieve better outcomes for country youth and encourage equity
- Enhance the reputation of Country Education

▪ **Grower organisations**

Landcare and farmer groups have had a longstanding role in rural innovation, particularly from a natural resource management perspective.

Informal farmer groups have also had an important role and have been encouraged by facilitators and supported by the RDCs. A Queensland Growcom facilitator summarised his role in the following terms:

My role is Hort 360 innovation coach. Hort 360 is our best management practise system that we've developed. It is a new role. As I was wandering around, accessing grants to get practise change, to improve water quality for the great barrier reef, and reflecting on my experience in running a small business for 16 years, I realised no one's got a business plan.

Developing the business side of rural businesses is an important and ongoing aspect of rural innovation.

5.7.2 Innovation ecosystems: precincts, innovation districts, clusters, co-working spaces

Key points

- There is many initiatives supporting the formation of precincts, innovation districts, clusters, and co-working spaces – but size, scalability, and sustainability are issues
- There is a need to develop impact and outcome measures for these initiatives
- There are also issues concerned with long term commitment – many started with short term government grants, and their future will be contingent on ability to attract investments from other sources.

Innovation precincts, districts, clusters, co-working spaces are a major focus of policy attention and regional initiative internationally, and currently in Australia. The rationale for innovation clusters is captured below¹⁸:

Innovation clusters are a widely recognised concept used worldwide as an effective means to stimulate urban and regional economic growth. It is now widely accepted that the productivity and competitiveness of industries that participate in such an initiative improves significantly.

Cluster initiatives are usually projects organised as collaborations between a range of groups including private businesses, government agencies and academic institutions.

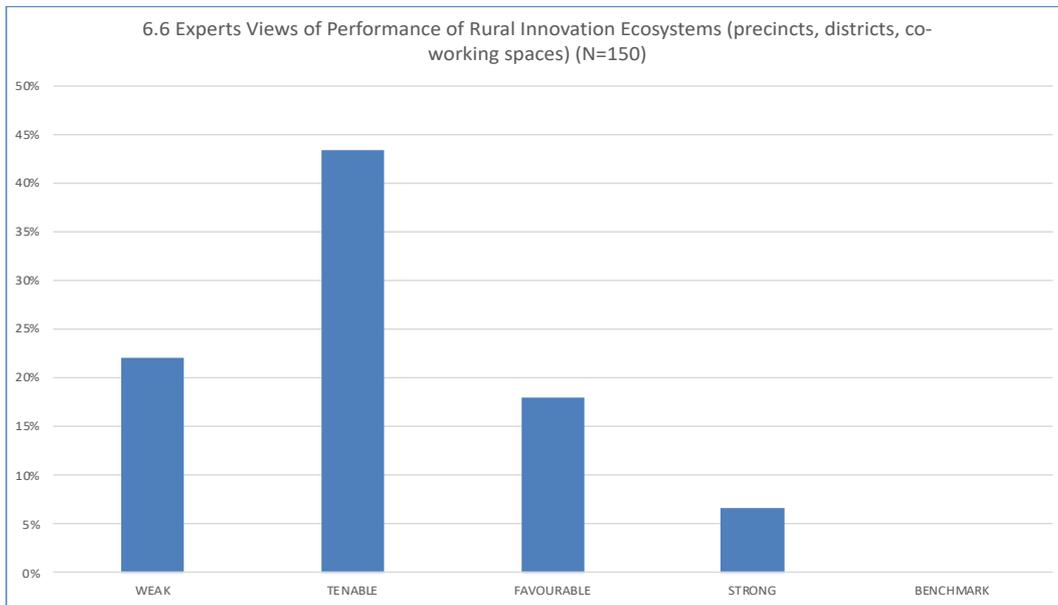
Clusters facilitate the building of partnerships to initially prioritise and then activate local economic development opportunities. Generally, businesses that are part of a cluster are more likely to collaborate and innovate than independent firms.

Clusters work by collaborating and sharing information for common goals, which leads to a greater return on investment for enterprises, regions, and the state.

Rural Innovation experts suggest that there is considerable scope for improvement in ecosystem performance, as indicated in Figure 73. Developments are at an early stage, with many initiatives in train.

¹⁸ http://www.pir.sa.gov.au/premium_food_and_wine/innovation_clusters

Figure 73: Expert Opinion Survey – Experts views on performance of the Rural Innovation Ecosystem



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

Reported below is a summary of Australian national and state-based initiatives.

▪ **National approaches**

FIAL is placing a major emphasis on the development of food innovation clusters. An overview is provided below.

FIAL Food Cluster Programme

Through matched funding, our Cluster Programme encourages businesses, public agencies, research, and educational institutions to align and work together, to build on their competitive advantage, and develop solutions to challenges and opportunities that they otherwise could not resolve on their own.

A cluster is a group of businesses, government agencies, research and associated organisations in a defined geographic area that are interconnected and share a common purpose or interest where each contribute to enhance the innovation, growth, and competitiveness of both the region and businesses.

There are many examples around the globe that show innovative clusters accelerate:

- New knowledge and capabilities.
- New product development.
- New business start-ups.
- Private & public investment.
- Productivity improvements.
- Increased competitiveness, and
- Export growth.

<https://fial.com.au/cluster-programme>
 Cluster funding guidelines at [https://fial.com.au/Folder?Action=View_percent20File&Folder_id=105&File=20171013%20Cluster%20Programme%20Guidelines%20\(FINAL\)\[2\].pdf](https://fial.com.au/Folder?Action=View_percent20File&Folder_id=105&File=20171013%20Cluster%20Programme%20Guidelines%20(FINAL)[2].pdf)

▪ **New South Wales**

NSW has a program to support regional innovation hubs. One of those is the New England food cluster.

State-wide pilot program champions AgTech in Armidale
30 June 2017

The New England region is set to become a hub for the growing ag-tech sector thanks to the NSW Government's AgTech Cluster initiative, launched by Member for Northern Tablelands Adam Marshall in Armidale today.

Mr Marshall said Armidale had built a reputation as a centre for high-quality research and development thanks to innovative local businesses and efforts from the University of New England, including the Smart Farm and Smart Region Incubator.

"Armidale's selection as one of three pilot clusters to be developed in NSW will help build a strong AgTech sector in our area, and in turn spur rural innovation and create jobs for the future," Mr Marshall said.

"When similarly, minded businesses work in proximity with one another – it's not only more efficient but leads to greater productivity and improved working life compared to entrepreneurs going it alone."

"Internationally, we see the growth of industrial centres like Silicon Valley or Hollywood – where resources and skills are shared to everyone's benefit. Armidale's industrial cluster will bring together the best and brightest AgTech pioneers, making our patch the centre of development for technology in agriculture.

"Our new 'Cluster Champion' Chris Celovic will work to bring small and medium sized businesses to the region, as well as forging links between global companies and entrepreneurs.

"The Cluster will work across research, ideas development, commercialisation, and education, helping to grow networks and idea sharing, investment and global relationships.

"This development will not only bring jobs, skills, and industry to Armidale – but help keep Australia on the forefront of innovative agricultural technology. *Our goal is to help create the next billion-dollar AgTech company in our backyard.*" [OMG!]

Minister for Regional NSW and Minister for Small Business John Barilaro said the Armidale AgTech Cluster would bring together businesses, industry, educational institutions, and government to boost business and grow jobs in the area.

"The Armidale cluster is an initiative of the NSW Government-backed Jobs for NSW and part of a broader pilot cluster program to create jobs, drive innovation and build a stronger entrepreneurial culture across NSW," Mr Barilaro said.

"The Jobs for the Future report, commissioned by Jobs for NSW, found geographic business clusters offer greater access to knowledge, infrastructure, investment, and talent with NSW clusters accounting for more than 26 per cent of recent jobs growth.

"High-performing clusters grow jobs at more than double the state average, create higher paying jobs, are twice as likely to export and generate more innovation, and have small businesses that are 21 per cent more likely to survive."

The cluster program will run from mid-2017 to mid-2019 when the NSW Government will review it in hopes of expansion of the program.

<https://www.industry.nsw.gov.au/business-and-industry-in-nsw/news/news/state-wide-pilot-program-champions-agtech-in-armidale>

University of Newcastle is involved with the Central Coast Food Innovation Cluster, described below.

About the cluster

The Joint UON and Central Coast Food Innovation Cluster brings together researchers from across multiple disciplines within the University of Newcastle as well as experts from within the Central Coast food and beverage industry and government members.

Cluster Aims

The cluster aims to use the diverse skills, backgrounds, and expertise of its participants to ensure an innovative approach to solving issues relevant to the food and beverage industry.

The cluster will also generate new ideas and create new opportunities for research breakthroughs which translate into practice.

<https://www.newcastle.edu.au/research-and-innovation/innovation/clusters/food/people>

▪ **Other States and Territories**

The South Australian Premium Food and Wine Co-Innovation Cluster Program is an initiative to support local regional agriculture, food, and wine businesses to become more collaborative, productive, and globally competitive.

Tasmania is working on cluster through the TIA.

The Australian Capital Territory is considering the development of an agribusiness cluster project.

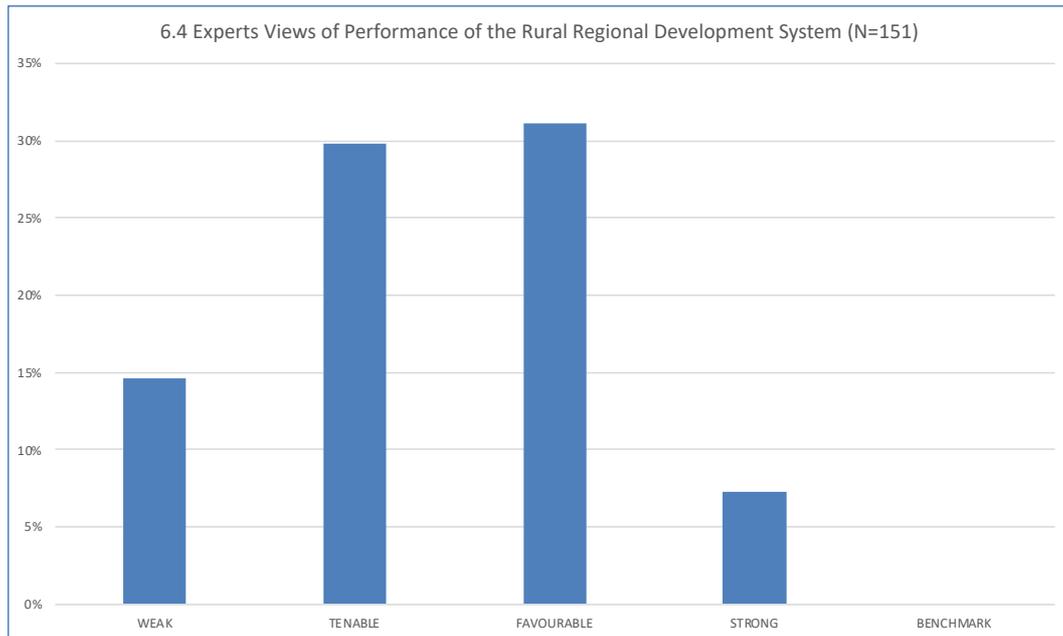
5.7.3 The rural and regional development system

Key points

- There is strong potential for a stronger rural and regional development focus as a key component of the rural innovation system.
- There is a challenge of achieving consistency and coherence across Commonwealth-State Territory approaches and the multiple interests and agencies involved.
- Regional universities play a very important role in the design and implementation of regional development strategies.

The rural and regional development system concerns strategies, actions, and initiatives to promote and sustain rural and regional economic development. Social and environmental strategies are also an important component of rural and regional development. Rural innovation experts' views on performance, which are tenable to favourable, are indicated in Figure 74 below.

Figure 74: Expert Opinion Survey – Experts views on performance of the Rural Regional Development System



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

The performance of the rural and regional development system provides an important foundation for rural innovation performance. It provides supporting organisations, institutions, and development strategies, as well as supporting cultures and attitudes towards innovation.

▪ ***Links between innovation policy and regional policy***

Australia, reflecting its “loosely federal” ethos, does not have a system of closely coupled regional governance. Responsibility for regional policy is principally a matter for State/Territory Governments, whilst the Commonwealth Government has a major role in science, technology, and innovation (STI) policy. The Commonwealth has struggled with regional economic development policy with emphasis waxing and waning depending on whether it is a Labor or Conservative Government in office.

Many Commonwealth and State Government agencies have regional organisation structures, with regional managers located in cities and towns that are considered to provide a regional administrative and service base. Regional coverage may be defined by an LGA, or postcode. These organisations employ local staff and develop plans and budgets in areas such as community services, school education, primary industries, police and emergency services, administration of justice, transport, planning, postal services, maritime services, fisheries, industry and economic development, and enterprise development services.

Many of these government organisations have been pulling back on their regional commitment, with significant impacts on rural and regional economies. The complexity of public administration at a rural and regional level creates a major challenge for consistent and coherent policy and strategy relating to regional and rural innovation.

Regional policy has not, until recently, has a strong link to innovation. Policy has had a strong focus on infrastructure, initially around road building and more recently about support for major development projects and job creation. Statutory rural and regional planning has tended to focus on land use and ignore, or by-pass, commitment to innovation. Increasingly, however, LGAs are making a connection between their statutory powers and support for innovation and technology precincts. In several States Governments are providing assistance and support for innovation precincts and clusters.

▪ ***Regional universities as engines of growth***

There is a view, reflected in consultations that regional and rural focussed universities can be 'engines' regional development and take a lead role in the development of rural innovation systems.

The Regional Universities Network of Universities (RUN) have a view, borne out by research, that regional universities make a major contribution to their regions through:

- being major employers across a wide range of occupations, purchasers of local goods and services, and contributors to cultural life and the built environment of towns and cities. Investment in regional university campus infrastructure to support the core business of teaching and research directly helps regions. Higher education is a major "value add" industry in regional Australia.
- developing human capital and skills through their graduates and attracting talented employees to regions. About three-quarters of those graduates who study in the regions stay in the regions to work, boosting regional economies.
- contributing to research and innovation.
- their missions to 'give back' to the communities in which they operate, including facilitating the social, cultural and community development of the regions through widening participation, including of Aboriginal and Torres Strait Islander people,
- contributing to health, arts, culture, and sport, and through international links, including via staff and students; and
- engagement of staff and students in local and civil society, and by contributing to regional governance and planning.

This view was conveyed strongly during consultations with the CEO of the Regional Universities Network, and senior staff at Charles Sturt University, University of New England, Southern Cross University, the University of Tasmania, and with officers and leaders at Regional Development Australia Committees.

▪ ***Regional Development Australia (RDA) committees***

Consultations indicated that Regional Development Australia (RDA) has a potentially important role to play on rural innovation.

RDA is a national network of Committees made up of local leaders who work with all levels of government, business, and community groups to support the economic development of their regions. RDA Committees have an active and facilitative role in their communities and a mandate to develop regional economies and "harness their competitive advantages, seize on economic opportunity and attract investment".

Although there is wide variability in focus and capability across the 55 RDA Committees, there is a potentially strong role. A new charter announced in August 2017.

STRONG, CONFIDENT AND VIBRANT REGIONS

A NEW CHARTER FOR REGIONAL DEVELOPMENT AUSTRALIA

Working in close partnership with fellow RDA Committees, all levels of government, and the private sector, RDA Committees will:

1. Collaborate with relevant stakeholders to identify economic opportunities and leverage private and public sector investment to the regions.
2. Connect regional businesses, councils and industry sectors with international trade partners, financial markets, and potential investors.
3. Promote and disseminate information on Australian Government policies and grant programs to state and local governments and industry, business, and community sectors.
4. Support community stakeholders to develop project proposals to access funding.
5. Develop and maintain positive working relationships with the local government bodies in their regions.
6. Facilitate public and private sector decentralisation.
7. Assist in the delivery of Australian Government programs, where relevant and when requested by the Minister.
8. Engage with regional entrepreneurs and emerging business leaders to explore new opportunities to grow local jobs in their regions.
9. Provide information on their region's activities and competitive advantages to all levels of government, industry, business, and community sectors.
10. Provide evidence-based advice to the Australian Government on critical regional development issues positively and negatively affecting their regions.

Senator the Hon Fiona Nash, Minister for Regional Development, August 2017

▪ **Regional Innovation Smart Specialisation Strategies**

The European Union (EU) has adopted smart specialisation as an approach to regional innovation within the context of the overall Cohesion Plan. A regional *Research and Innovation Smart Specialisation Strategy* (RIS3) is an approach to economic development that involves “the development of science, technology, and innovation initiatives for economic development, growth and jobs”.

RIS3 aims to provide an integrated, place based, and transformation policy framework that:

- Concentrates public resources on innovation and development priorities, challenges and needs
- Establishes measures to stimulate private investment in research, technology, and innovation investment
- Builds on regional capabilities, competencies, comparative advantages, and potential for excellence in a global perspective
- Fosters stakeholder engagement and encourages governance innovation and experimentation
- Is evidence-based and includes sound monitoring and evaluation systems.

The RIS3 approach embraces a method of *entrepreneurial discovery* - an interactive process in which market forces and the private sector discover and produce information about new activities, and public organisations [governments, research, and teaching organisations] are empowering those actors most capable of realising the potential’.

RIS3 represents a significant departure from traditional approaches to regional economic development planning. It offers a strategic approach to *regional innovation system* planning, and in doing so, it has the additional advantage of taking a *place-based* approach to innovation.

Several regions have embraced Smart Specialisation in Australia and there are strong connections between the EU, Regional Development Australia, and universities is furthering the approach (UTS, UniSA in particular)

5.7.4 The rural enterprise (entrepreneurial) development system

Key points:

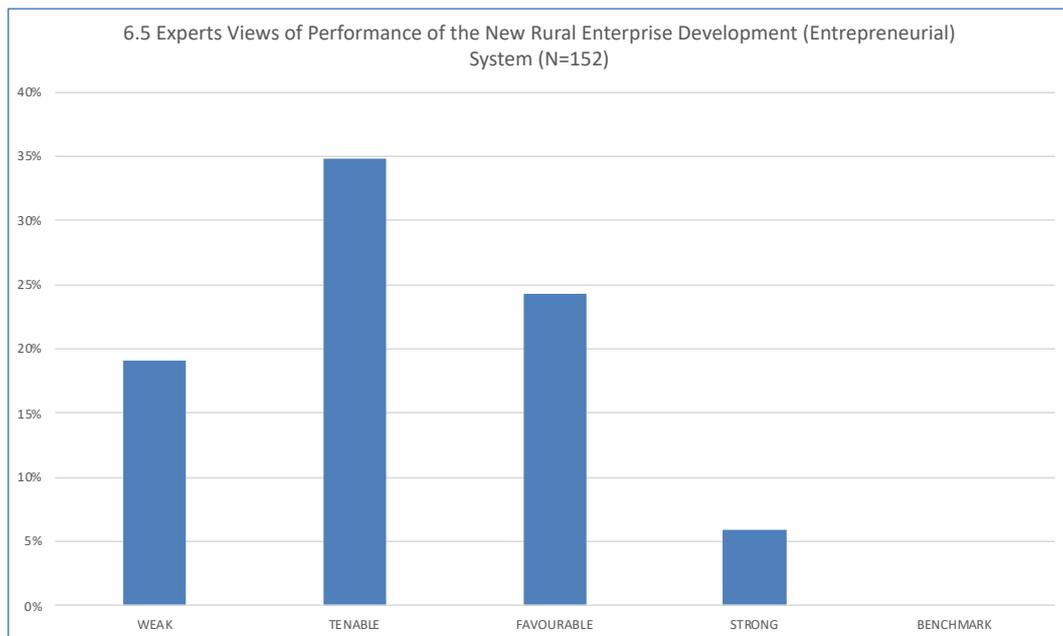
- Public programs are being instituted to support the development and growth of rural enterprises
- There is many assistance measures are available to assist farm businesses to manage and recover from drought
- Rural businesses can access many government enterprise development programs.

The scope of the rural enterprise (entrepreneurial) development system covers all businesses across the rural value chain. It has a close connection with the Rural and Regional Development System.

Businesses sustain the rural economic system by making the investment decisions that increase and sustain sales and create jobs. As in other parts of the economy, Government does not see it is its role to prop up ailing and inefficient businesses, or to underwrite the operations of lifestyle businesses.

Rural Innovation Experts' views are reflected in Figure 75 below. Their opinions centre on a "tenable" assessment, suggesting (based on Consultations) that while there has been progress in recent years, there is much scope for performance improvement.

Figure 75: Expert Opinion Survey – Experts views on performance of the Rural Enterprise Development System



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

Specific aspects of system performance are covered below.

▪ ***Emergence of a new “entrepreneurial approach” in rural businesses***

Consultations indicated that there is a new “entrepreneurial” approach emerging in farming and farming related agribusiness enterprises. Observations included

- New agribusiness opportunities being captured by new and emerging businesses and high growth firms.
- Family farms becoming corporatised and run more as businesses.
- A different type of farm manager is emerging – educated/trained, skilled in business, keen to learn.
- RDCs have been active in supporting these trends
- Small businesses can develop niches and be profitable. Small to medium enterprises can now be in a game that only the larger corporations could do in the past. Education, training, and informal networking can encourage this process.

Aquaculture has demonstrated strong growth and future potential, particularly through innovation in value chains:

It used to be the case in the Southeast Trawl, which is one of our biggest volumetric fisheries, there were seven transactions from when a fisher caught and sold the catch through to consumption. *It was bought and sold seven times.* Everyone a clip.

Now these days supply chains are getting down to three clips, sometimes two, sometimes one - directly from boat to the chef. The innovation in that has been really, important. And the key is connecting a fisher out on a boat and a chef trying to plan that night's dinner – and how can the chef have the information to plan the menu in the knowledge of what's going to arrive.

Consultations suggested that farmers and fishers have become much more attuned to market conditions, and it is likely that will continue to grow in capacity. This is seen as an innovation, not necessarily in classic research and development, but in DE&M (Development and Marketing) and more generally in the business models of these adaptive businesses.

▪ ***Specific assistance and subsidy arrangements***

The Australian Government continues to provide several assistance measures to support farm families, farm businesses and rural communities “to prepare for, manage through and recover from drought and other hardship”. These include a range of additional measures announced in the [Agricultural Competitiveness White Paper](#).

The following measures are aimed at “helping to build a strong and resilient agriculture sector”¹⁹.

- Dairy Support Package
- Farm Household Allowance
- Farm Management Deposits (FMD)
- Taxation measures
- Rural Financial Counselling Service (RFCS)
- Farm Business Concessional Loans Scheme
- Drought Assistance Concessional Loans
- Drought Communities Programme
- Managing Farm Risk Programme
- Enhanced social support
- Pest and weed management
- Farm Cooperatives and Collaboration Pilot Program
- Leadership in Agricultural Industries Fund

There are also a range of support measures provided by State and Territory Governments.

The extent to which these programs are monitored and evaluated - in terms of value created for the economy, the rural industries, producers, and the community in terms of efficiency, effectiveness, and appropriateness - is by no means clear.

Two decades ago the Department of Agriculture had been taking a stronger interest food processing through programs such as the National Food Industry Strategy and the [New Industries Development Program](#), which focussed specifically on agribusiness ventures. Many of these initiatives have been “mainstreamed” into general government business development programs or are being taken up by the Food and Agribusiness Industry Growth Centre (FIAL) or the RDCs.

▪ ***Access to enterprise development programs***

The Commonwealth, State and Territory Governments make available assistance and support for sustaining and supporting new and potentially high growth businesses through a wide variety of programs and interventions. Some are specific to the sector, but others are more generally available.

Grant programs available to farm and agribusiness from Commonwealth and State/Territory sources listed on the website [Bullet Point](#) during February - March 2018 included the following:

- Accelerating Commercialisation: to assist in the commercialisation and business building process.
- Global Connections Fund Bridging Grants (GCF BG): Up to \$50,000 is available to support researcher-SME partnerships globally with the range of early research translation or commercialisation activities.
- Managing Fruit Fly Regional Grants Program: Up to \$800,000 is available to support projects that will reduce the impacts of fruit fly in Victoria.
- Innovation Connections: funding to support collaboration between businesses and research sector and develop new ideas with commercial potential.

¹⁹ A summary of these assistance measures is available in the [Supporting farmers and rural communities factsheet](#).

- AgriGrowth Loan Scheme: Funding to help farms and agri-businesses with low interest loans to develop the agricultural sector.
- Supply Chain Facilitation: A program to assist businesses interact with new or existing markets and improve their supply chain performance.
- Entrepreneurs Programme: Grants to grow a business.
- Agriculture Infrastructure and Jobs Fund (AIJF): to support projects in building better roads and bridges that will reduce costs and improve access for dairy farmers.
- Young Farmers Scholarship Program: for farmers to develop their skills and be equipped to face challenges and opportunities.
- Food Source Victoria: Up to \$20M is available to support activities that add value to agricultural produce sourced from regional Victoria. Applications close 30 June 2019.
- Australia China Agricultural Cooperation Agreement (ACACA): Up to \$55,000 is available to support projects or trade missions which promote cooperative agricultural relationships with China.
- Small Business Development Fund: Up to \$100,000 is available to help small business grow and create jobs in the north. Applications for both Business Expansion Grant and Start Up Business Grant close 30 June 2019.
- Landing Pads: A program designed to give market-ready start-ups the opportunity to access innovation hubs around the world. Applications close 21 May 2018.
- [Dairy Recovery Concessional Loans](#): Up to \$1M is available to help farm businesses affected by the 2016 reductions in farm gate milk prices. Applications close 30 June 2018. Concessional loans for farm business improvement and drought assistance are also available from the Department of Agriculture and Water Resources.
- The [Farm Innovation Fund](#), a NSW Government package to assist primary producers identify and address risks to their farming enterprise, improve permanent farm infrastructure and ensure long-term productivity and sustainable land use, and aiding in meeting changes to seasonal conditions.

▪ ***The role of RDCs***

During the Consultations for the Review there was often a discussion about the role of the RDCs in supporting specific farm and broader agribusiness interventions.

There was a particular interest among RDCs in business capacity building, collaborations for improved practices and take-up of knowledge, including adoption of best practice. One RDC CEO commented that their role is in innovation – not in business continuity, and it is important not to confuse the two approaches.

The importance of RDC management, leadership, and networking initiatives came out strongly in Consultations.

▪ ***The future of “lifestyle farming”***

For many rural businesses there is an important lifestyle dimension, rather than driving productivity improvement. Their main driver is to have enough of a return for a comfortable life. For these businesses value creation isn't necessary more income, providing there is enough to get by.

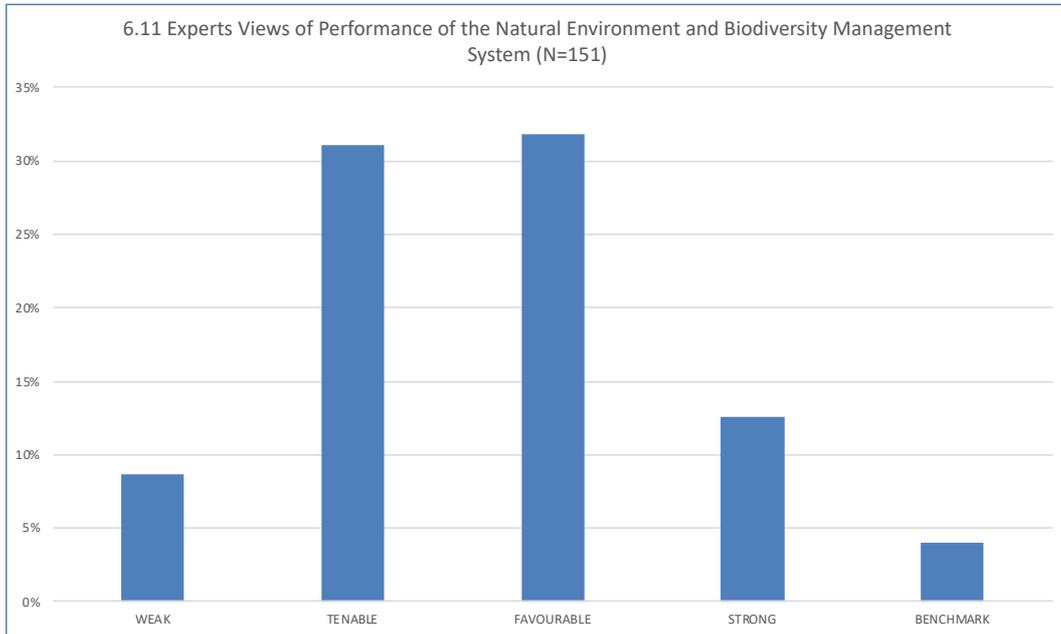
▪ ***Summary observations on performance of the of the rural enterprise development system in supporting innovation***

A great deal of assistance is available to build rural entrepreneurial capability, but it does not appear to be well targeted at the specific requirements of rural enterprises. A more detailed evaluation of these programs might identify potential for improvement.

5.7.5 The natural environment and biodiversity management system

Rural Innovation Experts' views on the performance of the environment and biodiversity management system are provided in Figure 76. Most views fall between tenable and favourable.

Figure 76: Expert Opinion Survey – Experts Views on Performance of the Environment and Biodiversity Management System



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

Comments on aspects of performance are provided below.

▪ **Key natural resource endowments**

Rural production places a significant claim on Australia's natural resources – land, water, forests, soils, oceans. Utilisation of those resources is not generally counted as an economic transaction and therefore tends not to be measured in production input costs.

Among OECD countries, Australia has the *third largest area of agricultural land* (after China and the US), and the *highest arable area per capita* (followed by Canada and the US). This is reflected in Table 14: Global Rural Resource endowments

Table 14: Global Rural Resource endowments

	GDP	GDP per capita	Population	Total land area	Agricultural land	Arable land per capita	Freshwater resources	Freshwater resources per capita
	Billion USD (2012)	PPP USD (2012)	Million (2012)	'000 km ² (2012)	'000 Km ² (2011)	Hectares (2011)	Billion m ³ (2011)	m ³ (2011)
Australia	1 632	44 407	23	7 882	4 087	2.14	482	22 088
Brazil	2 253	11 716	197	8 459	2 750	0.37	5 418	27 512
Canada	1 821	41 150	35	9 094	626	1.25	2 850	82 647
China	8 227	9 059	1 377	9 327	5 191	0.08	2 813	2 093
European Union	16 687	34 064	504	4 238	1 879	0.21	1 505	2 963
India	1 842	3 813	1 237	2 973	1 798	0.13	1 446	1 184
Indonesia	878	4 876	247	1 812	545	0.10	2 019	8 281
Russia	2 015	23 501	143	16 377	2 153	0.85	4 313	30 169
South Africa	384	11 255	52	1 213	964	0.24	45	886
United States	16 245	57 869	314	9 147	4 113	0.51	2 818	9 044

Source: OECD stat; WDI (2013), World Development Indicators Database. World Bank, <https://data.worldbank.org/indicators?locations=AU>

However, Australia has the *second lowest endowment of freshwater resources* (after South Africa), and a *lower level of freshwater resources per capita* than Canada, Brazil, Russia, but much higher than the USA, China, EU, India, Indonesia, and South Africa.

The diversion of water from environmental use to agricultural use is currently an issue. Australia needs innovative approaches to assess the economic costs of natural capital degradation and to focus attention on its conservation, preservation, restoration, and repair. Technology is currently, and will in the future, be important in this area.

▪ **Experts views on biosecurity performance**

The contribution of RDCs to biosecurity has stepped up following abolition of LWA. Fisheries CEO commented –

When you look at this performance system and you ask what you're trying to do and where we're trying. One is being responsive to anticipate. If you do responsive, biosecurity's killing me now. I spend my whole time responding to government stuff ups. Literally. So, I've now concluded the government biosecurity system has failed. And it will continue to fail, so now what I've got to do is just agree that it'll fail, so what do I need to do now? I need to anticipate failure but put in better places so I'm bio securer.

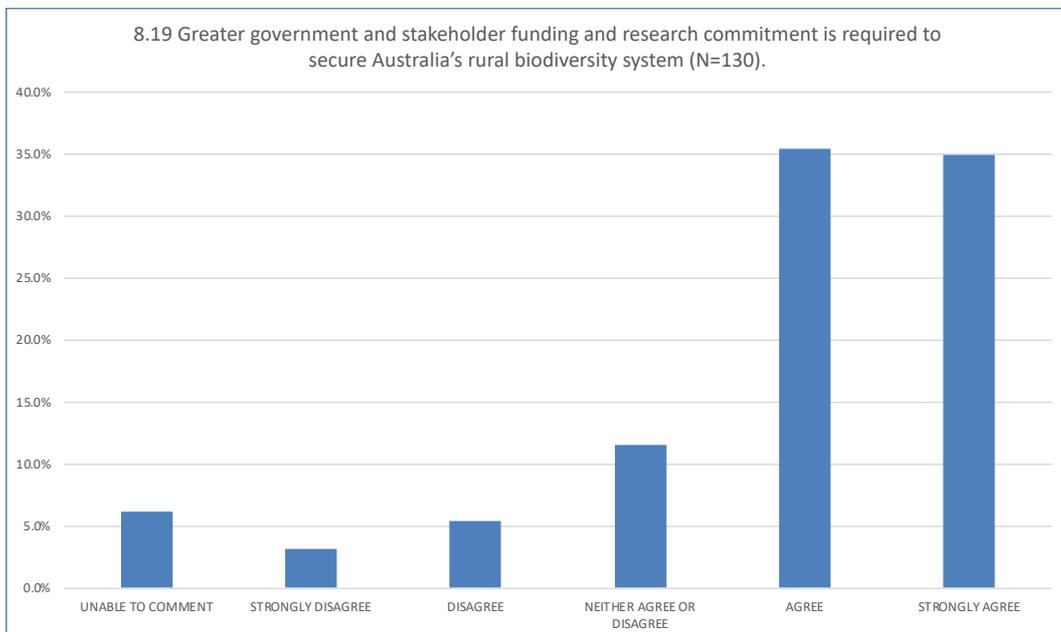
Because it will continue. I only have to look at the fact that they've just reallocated all this green prawn to come back into the country. And already people are working around it. I don't know if you've seen all the shipment coming in from Brunei now.

Now, my Moreton Bay fishers who fish for prawns, cannot sell product to Sydney because of Whitespot. But a Vietnamese farm can sell to Sydney.

Several RDCs have taken a role in weeds and soils.

Experts indicated that there was a need for a greater funding and other resource commitment to secure Australia's biodiversity management system.

Figure 77: Expert Opinion Survey – Funding and commitment to secure Australia's rural biodiversity future

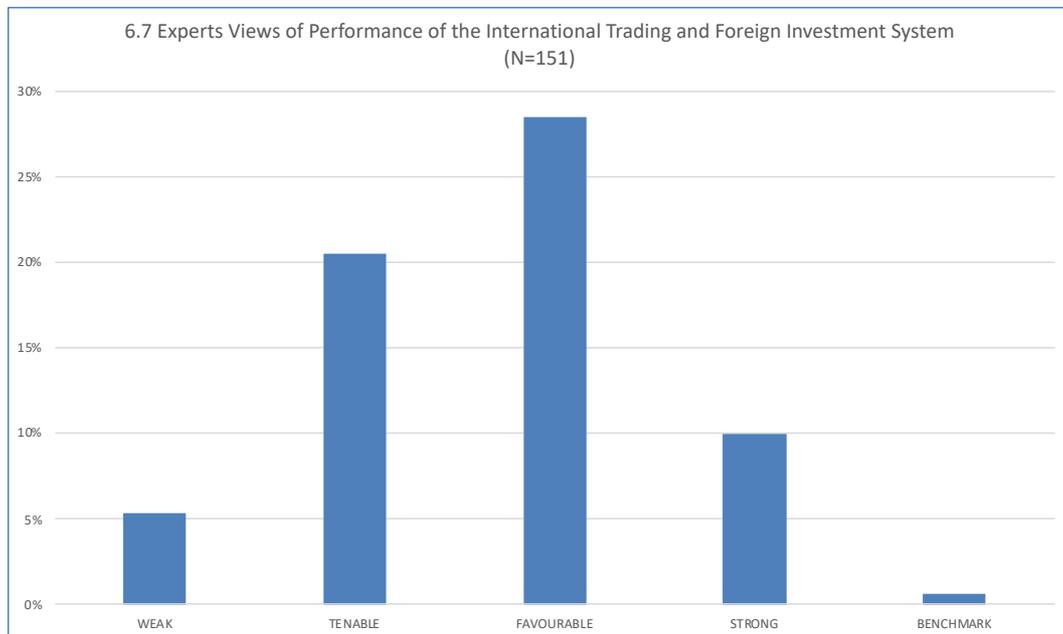


Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

5.7.6 The international trading and foreign investment (commercial) system

The system covers international trade and commerce, and its efficient and effective performance vital for production and innovation performance. Rural Innovation Experts on the performance of the environment and biodiversity management system are provided in Figure 78 below.

Figure 78: Expert Opinion Survey – Experts Views on Performance of the International Trading and Foreign investment (Commercial) System



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

Specific comments on performance are provided below.

- **Trade agreements and market access**

The Australia 2030 Innovation Plan suggests (page 47) that the Australian Government can also ensure Australian companies are not disadvantaged in the regulatory requirements for exporting. World Bank analysis shows that Australian documentary compliance obligations are heavy, relative to peers, rating Australia 32nd of OECD countries for the efficiency of its processes.

This means that Australian businesses face higher average time and costs for exporting and importing processes. The average time to complete border compliance for exports is 36 hours in Australia compared with less than 15 hours among other OECD countries

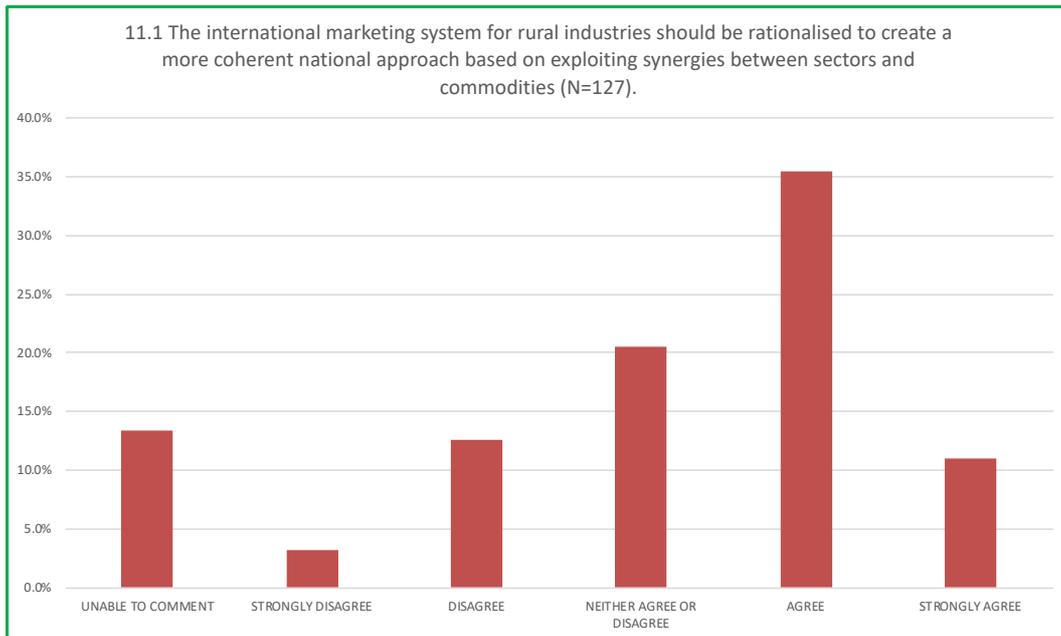
- **Multiple marketing and communications efforts**

Australia's federal system has encouraged State and Territory Governments to set up marketing entities that promote and profile state-based products. It is not clear whether a "NSW", "Victoria", "Queensland" brand is more valuable than "brand Australia". Some see this as a problem.

However, brands are the basis of competition, sending messages about the product, its reputation, authenticity, consistency, positioning, and so on. Many would argue that competition between States and Territories is healthy and likely to increase sales – which is the result of a national focus on competition.

Responses to the proposition "The international marketing system for rural industries should be rationalised to create a more coherent national approach based on exploiting synergies between sectors and commodities" are provided in Figure 79.

Figure 79: Rationalisation of marketing strategies to create a more coherent national approach based on exploiting synergies between sectors and commodities



There is a concern, expressed in Consultation interviews, however, when RDCs are marketing to their internal stakeholders, to build support for a Board, rather than focus on selling products and services to a customer.

- ***Foreign direct investment***

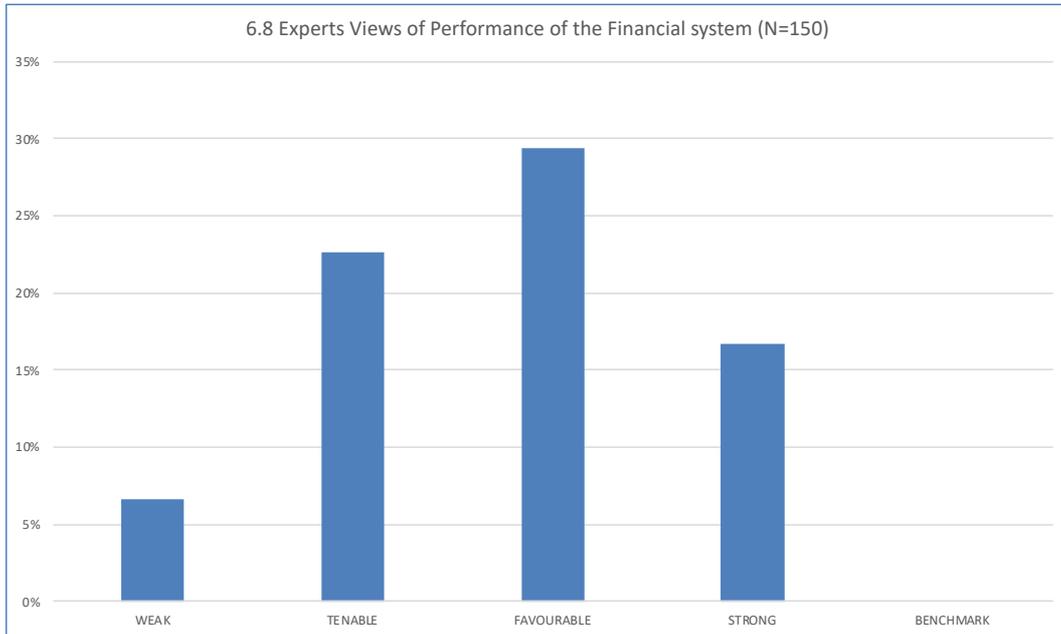
Although the level of foreign direct investment in food and agriculture is of popular concern, it was not raised often in Consultations. One of the underlying issues is the need to build scale across the pastoral sector – larger farms and larger paddocks - and in the food processing sector.

5.7.7 The Financial System

Throughout history financial innovations have played an important part in innovation. Efficient and effective performance of the financial system is vital for rural innovation and sustaining rural production, particularly underpinning opportunities for growth and development in agribusiness across the value chain.

Rural Innovation Experts rate performance as generally favourable, with some regarding it as strong, and others tenable and weak. This is indicated in Figure 80.

Figure 80: Expert Opinion Survey – Experts Views on Performance of the Financial System



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

Aspects of performance are addressed below.

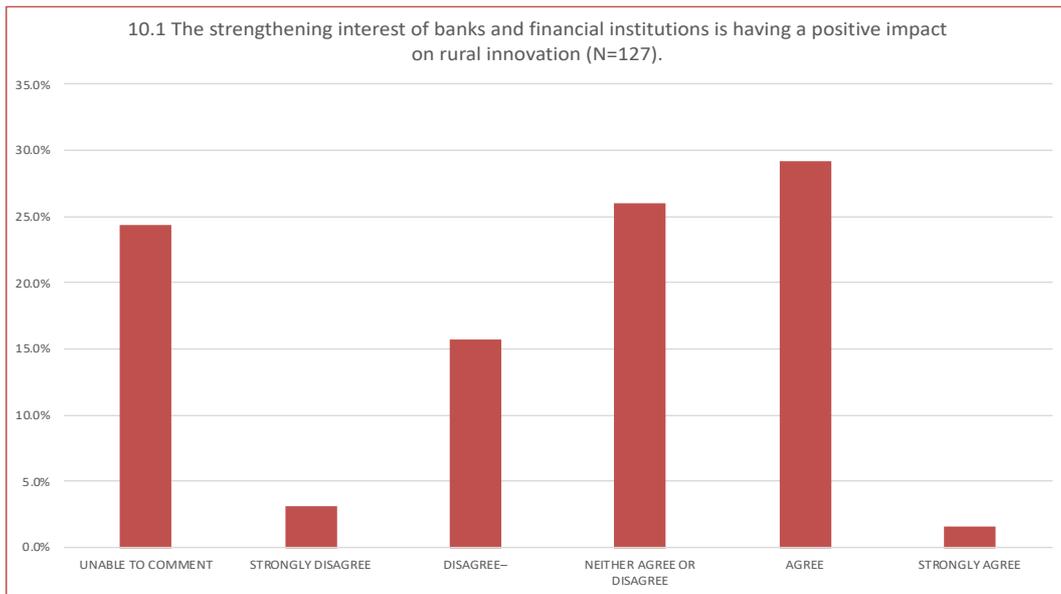
- ***Australian and global banks***

Australian banks currently hold \$65 billion in farm debt. A new style of agribusiness banking is committed to ensuring that agribusiness succeeds. Banks tend to invest in established businesses with potential growth.

The Big Four trading banks all have agribusiness divisions and many regional banks have been set up with an agribusiness focus. Rabobank has a long-established interest through its takeover of the Primary Industries Bank.

Rural Innovation Experts have a favourable view of the performance of banks and financial institutions.

Figure 81: Expert Opinion Survey – Impact of banks and financial institutions



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

▪ **Agribusiness schemes**

Agribusiness managed investment scheme have emerged to invest in livestock, farming, horticultural or forestry projects. There can be tax benefits to these types of investments. These investments are generally long-term with no early exit opportunities. In recent years, agribusiness schemes have received bad press due to several high-profile failures.

How agribusiness schemes work

An agribusiness scheme is set up to run an agriculture-related business on your behalf. You rely on the manager's efforts for any profit.

In livestock schemes, you may buy one or more animals and pay regular fees to a manager to look after the animals and sell them.

In horticultural and forestry schemes, you usually lease some land that is used to grow trees or plants. The promoter or manager is responsible for planting, maintaining, harvesting, and selling the crop. You may pay all your money upfront or there may also be regular fees.

For schemes with an Australian Taxation Office (ATO) product ruling, you can claim a tax deduction for the money you invest.

In all agribusiness schemes, you are investing money now in the hope of getting a financial return many years in the future.

<https://www.moneysmart.gov.au/investing/complex-investments/agribusiness-schemes>

▪ **Private equity and venture capital**

Private equity funds have become very active in recent years in the agribusiness sector. Five to 10 years ago, private equity was not going into agriculture opportunities because of the risk of primary production, but the sector is becoming very attractive because of the strong growth opportunities in Asia.

Private equity targets Aus food producers
Jared Lunch, *Farm Weekly*, 18 June 2014

From January 2011 to March 2014 private equity buyers comprised 14 per cent of mergers and acquisitions. While that was a "relatively small" proportion, private equity firms were "much more prevalent" in larger deals. Private equity investors were involved in two of Australia's 10 biggest deals in the past three years.

TPG Capital bought Ingham Enterprises, one of Australia's biggest poultry producers, for about \$880 million in June last year. Two months earlier, Catalyst Investment Managers reduced its 49 per cent stake in vegetable wholesaler Moraitis Group to 15 per cent after Hong Kong-listed Chevalier International Holdings secured control of the company for \$212 million.

There have been several large successful PE exits both within Australia and overseas, demonstrating that this is an attractive sector for PE. Private equity investors were particularly interested in packaged foods and meats, which accounted for 77 per cent of PE global deals. Buyers were looking for companies that had strong brands that they could use to improve their own portfolios and sell into Asia.

The trade agreements that the Abbott government has recently struck with Japan and Korea would enhance those opportunities, Mr Bacon said, particularly for cheese, beef, horticulture, and wine exports. These agreements should also make Australian companies more attractive to foreign investors. It means companies need to be prepared to sell if they get an approach from out of the blue and respond quickly.

There was also interest from private equity firms in food distribution businesses. One of the biggest deals in that sector was Bright Foods Group acquiring 75 per cent of Food Holdings from CHAMP Private Equity for about \$516 million

<http://www.farmweekly.com.au/news/agriculture/agribusiness/general-news/private-equity-targets-aus-food-producers/2702346.aspx?storypage=0>

There are number of new private equity players in Australia. They are listed in Table 15 below.

Table 15: Major private equity funds in agribusiness

Fund	Website
Australian Agricultural Investment Fund:	https://www.aarif.biz/
QIC	
FarmInvest:	http://farminvestaustralia.com.au/about-farminvest/
ROC Partners	
Catalyst Partners	
Aux Ventures:	http://www.auxventure.com.au/investment.aspx
Hamersley Agriculture	http://www.hamersleyagriculture.com.au/view/about-us

▪ **Hedging and derivatives**

Hedging, derivatives, and financial innovations are becoming important and significant in the rural sector, and particularly for crops. Pastoral companies have been learning how to use these innovations:

McDonalds would say, "The biggest problem we've got with our franchise is the variability of the price of meat. Because we make our menus out 12 months in advance and we don't know what we're paying for our meat." And when it turns up, they can get a shock about the price of those burgers. Doesn't happen in chicken, doesn't happen in pork.

So how do you solve that?

Pastoral companies know roughly what their percentage of manufacturing beef's going to be. They know that they're going to have ... this guy's going to pay in US dollars and be influenced by US dollars and this guy's going to be producing in Aussie dollars. It's pretty basic stuff. What about a currency hedge? Or a currency risk programme? What about some form of meat hedge?

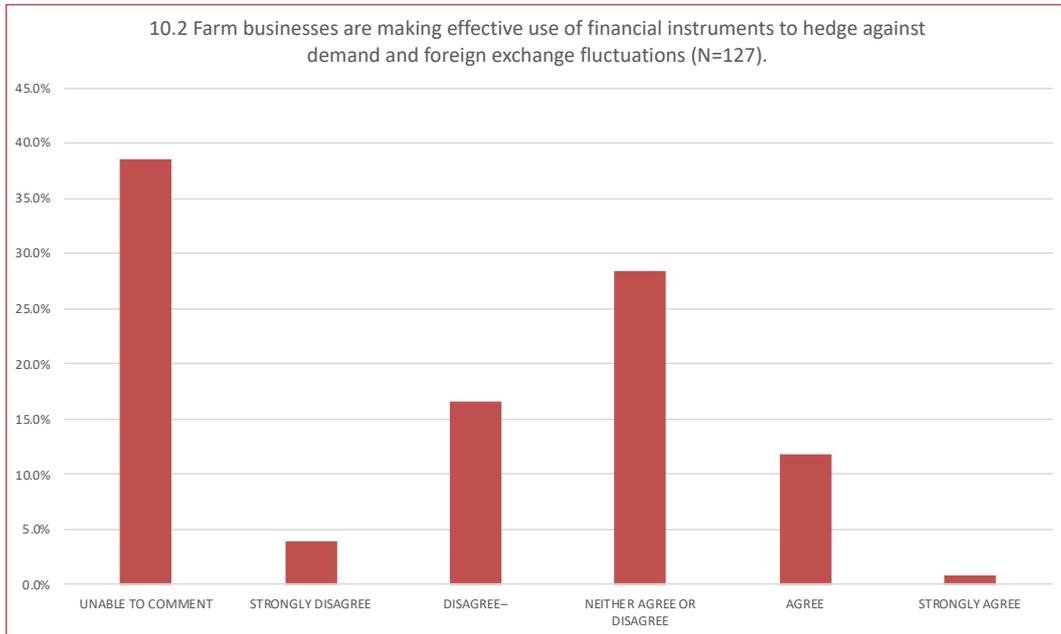
Now, in the US they weren't happy with that because you can trade live cattle feed and cattle, and obviously corn is the input. So, there's a crush margin or spread that comes with it that says, what's the price of the animal? How much corn you going to feed it to get to its finished weight to achieve its yield that you want when you're going to cut its head off? So, what does that equal? So, if the price of that animal doesn't pay for the corn you're going to feed it, why do it? And it's just simple maths,

So, to be able to use options in a producer viewpoint or swaps, even better, just to make yourself neutral as these two guys are priced, would be a desired state. So, convert the fact that you've got a contract, if you're buying at market price because you have to, you've got a contract at which the processor sits in the middle. Then either he can be dealing at both ends or somehow you can deal in the international markets, and you might end up not knowing that you're going to have these two hedges in the market. Speculators, so the guys that come in and create liquidity, they're traders.

We don't have that in Australia. They'd much rather complain about the rain and no rain or no water.

There was a concern in Consultations that rural businesses, farms, and others, are not making effective use of financial instruments to hedge risks. Rural Innovation Experts seemed to be unfamiliar with this issue, as indicated in Figure 82

Figure 82: Expert Opinion Survey – Effective use of Financial Instruments to hedge demand and foreign exchange fluctuations



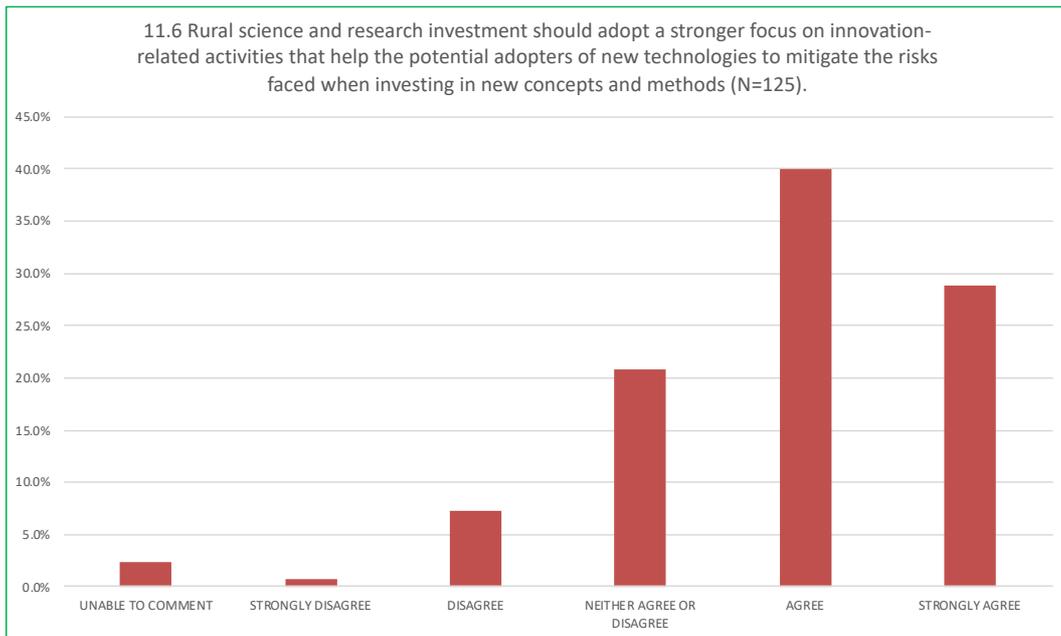
Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

- ***Seed and start-up funding***

There is quite a lot of money around for the early-stage investing. Funding is more constrained for expansion capital. As mentioned elsewhere, tends to push growing companies towards listing. Global seed and start-up funds are very active and investing in incubators and accelerators.

- ***Risk mitigation***

During Consultations there was a view that rural science and research investment could adopt a stronger focus on innovation-related activities that help the potential adopters of new technologies to mitigate the risks faced when investing in new concepts and methods. This was tested in the Expert Opinion Survey, with the results indicated in Figure 83 below.

Figure 83: Expert Opinion Survey – Investment focus on adoption and risk mitigation

Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

▪ **Summary observations**

The financial system has played a major enabling role in supporting rural innovation. As the system becomes more sophisticated and develops a focus on new AgTech and GeneTech businesses the potential for value creation across the rural value chain will be extended. There are now several websites and blogs that report on start-ups, funding, and technology investment opportunities.

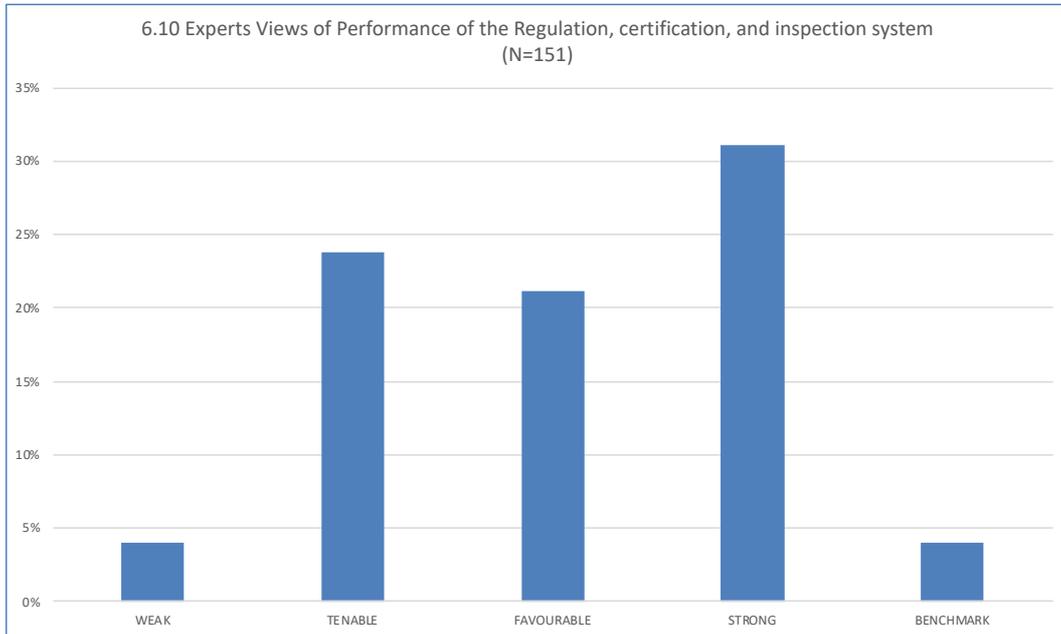
With the gradual removal of protective practices for rural industries these opportunities will no doubt continue to evolve. Some see this as a “mainstreaming” of rural innovation into the broader innovation system.

5.7.8 Regulation, certification, and inspection system

The efficiency and effectiveness, covering credibility and integrity, and performance of Australia’s regulation, certification and inspection system is vital for the future of rural production and for providing opportunities for capturing innovation returns. Australia’s national systems are highly regarded, as are State based systems and many private certification and quality accreditation systems.

Most Innovation Experts (32 per cent) regard the system as strong, and four percent see it as benchmark. This is indicated in Figure 84 below.

Figure 84: Expert Opinion Survey – Experts Views on Performance of the Regulation, Certification, and Inspection System



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

There were some issues raised in Consultations.

▪ **Concerns with overregulation**

There was a concern in Consultations about over-regulation, and the potential to stifle innovation:

Aquaculture could feed the world if we get it right. And without question, there have got to be constraints and rules and regulations, and we're probably the most regulated in the world. I can't think of many, many places that would be more regulated. And you sit there, and you go, at what point do you say, enough? And this is where this whole stuff comes back to you could have the most innovative, clever, cutting-edge technology. If the world doesn't like it, then it isn't going to get up.

▪ **Underwriting food and fibre quality, provenance, and security systems**

Quality assurance and certification is in rural industries, as in most other industries, is now a mandatory requirement to operate, and a "condition of entry" into global value chains. Quality is not, of itself, a source of competitive advantage.

Nonetheless, Australia has highly regarded systems in relation to:

- Quarantine and inspection services
- Ag and vet chemicals regulation
- Commercial food standards and accreditation schemes
- Local Food Inspection

It is important to ensure that these systems facilitate innovation and are innovative in their own domains.

▪ **Better Management Practices**

Consultations indicated that farm management practices have come a long way over the last generation. The current Chair of Cotton CRC, commented -

I was the first farm in the world to be ISO 14001, which is the environmental system and OZCOT being the corporate farm had a systemized approach to their environment management. So, then

Alan Williams wrote the manual with funding from Cotton Research and Development Corporation and the Murray Darling Basin commission in those days under Don Blackmore and so they were the two funding, oh and LWA, Land and Water Association, which became Land and Water Australia, which is probably going back subsequently during that period.

So, when we went to the EPA, I went to the EPA and said how do I store chemical on my farm? They said we can't tell you that, you do it and we will come and inspect it and tell you what is wrong with it

I identified five environmental risks and one of them was people. So, then I started to get into OH&S, and it was a blank space in the mid 90s, it had nothing. The department of Labour and Industry couldn't tell you anything it was, they didn't have anything on farms, there was nothing designed. So that's what the BMP did, was write a whole OH and S module, one of the four modules was OH and S.

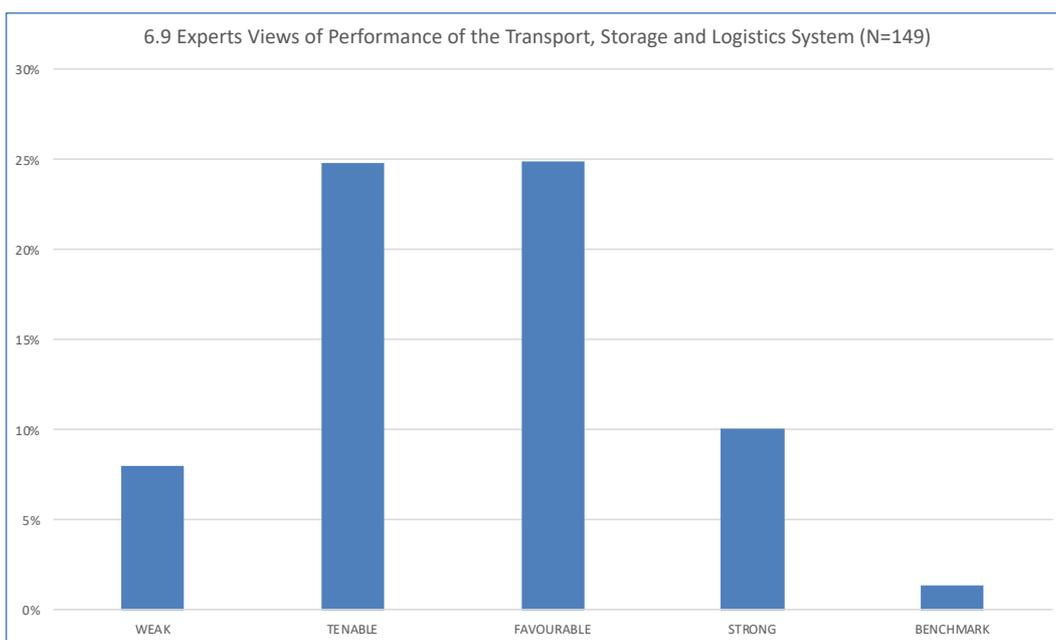
Best management practise but it was environmental best management practise. Which then broadened into a whole sort of industry, farming system best management practise. It included farm design and layout, included chemical storage and handling, it included pesticide application.

These innovations in farm management practice are becoming, more widely adopted, and having an impact on the scope and environment for innovation.

5.7.9 Infrastructure systems

During Consultations for the Review concern was expressed about the performance of aspects of the *transport, storage, and logistics system*. Experts' views are captured in Figure 85.

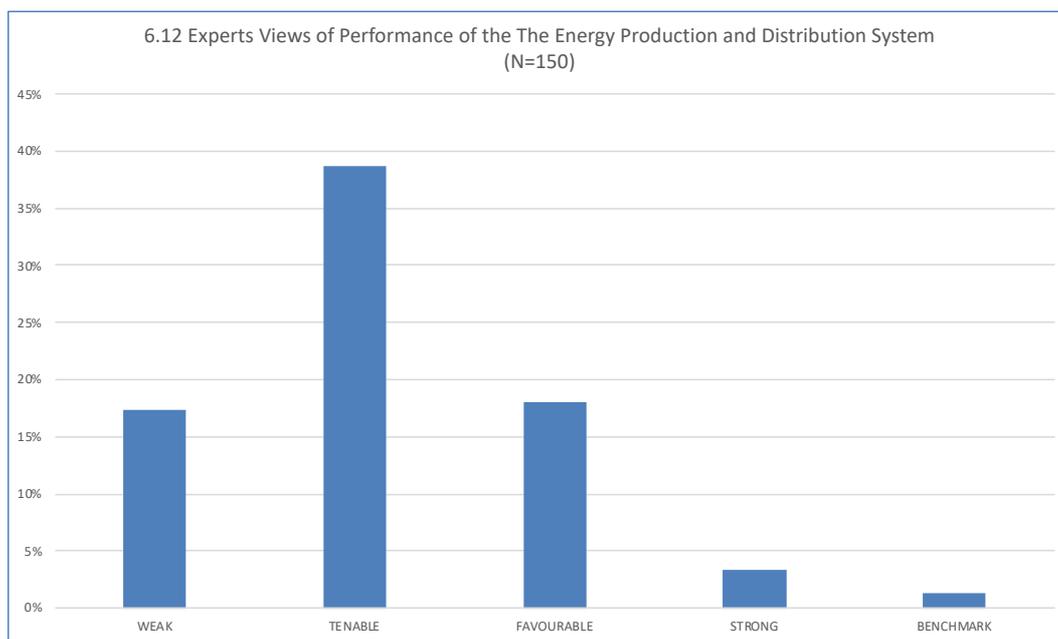
Figure 85: Expert Opinion Survey – Experts Views on Transport, Storage and Logistics System



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

There was deeper concern with the performance of the energy production and distribution system, as indicated in Figure 86.

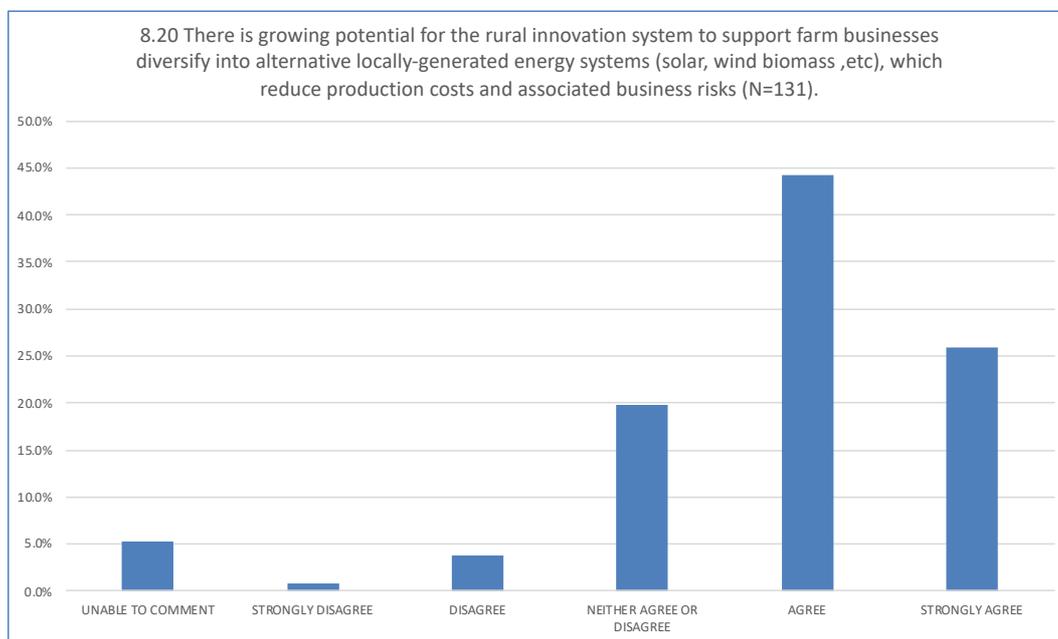
Figure 86: Expert Opinion Survey – Experts Views on Performance of the Energy Production and Distribution System



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

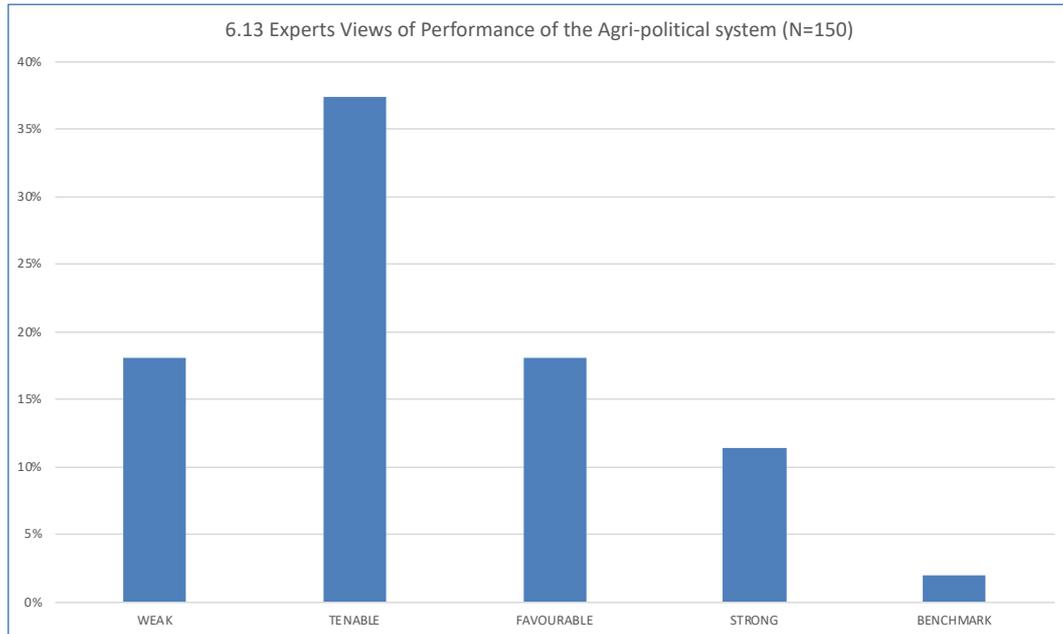
Experts were generally supportive of initiatives to support rural businesses diversify into alternative locally generated energy systems, as indicated in Figure 87.

Figure 87: Farm business involvement and diversification into alternative energy systems



5.7.10 The public policy system

Experts were asked for their views on the performance of the agri-political/public policy system. Views are indicated in Figure 88.

Figure 88: Expert Opinion Survey – Experts Views on Performance of the Public Policy System

Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

Comments made during Consultations include the following:

- The system has multiple organisations and voices, competing for attention, and often with inconsistent messages
- RDCs aren't allowed to advocate using government funds– but creates a challenge when they have critically important data to share
- The policy related issues for many aspects of the rural value chain aren't inside the Agriculture Department. They're in trade, industry, and energy more so than they're in the department side. Structurally, that creates a challenge.
- Policy development is seen to have defaulted to the RDCs and the large national organisations. RDCs are charged with producing the empirical and policy argument to support what they want for the commodity sectors they represent.
- The Department tends to be reactive rather than active in the policy decision making process. However, the Department has major roles in the bio-science arena.

5.8 Appraisal of Institutions and Organisations in the Rural Innovation System

Key points

- The efficiency and effectiveness of institutions and organisations is vital for effective innovation system performance
- The comments made in this Section about organisational performance are preliminary: a detailed assessment would require performance reviews of the more significant organisations in a broad Review context.
- Collaborative organisations, including CRCs, perform a vital role in innovation system performance.
- New collaborative partnership models are emerging
- There is little support for further integration of State agricultural research institutes with universities

Science and research is delivered by Commonwealth agencies, predominantly the CSIRO, State Government Research agencies, universities, and private enterprise. As argued throughout this Report, institutional and organisations are important.

Organisations have responsibility for funding research investment, undertaking research (research performers), and assessing quality and impact. Some organisations undertake two or more of these activities. Organisations also have diverse characteristics, missions, and cultures, which may not always be in alignment

5.8.1 Funding/research investment organisations

Organisations in funding investment in rural research and development can be grouped as follows:

- Government – Commonwealth and States/Territory Departments and agencies; research councils, including the Rural Research and Development Corporations (RDCs), the Australian Research Council (ARC) and the National Health and Medical Research Council (NHMRC)
- Universities – which fund research from internal sources. Approximately 50 per cent of university research is funded from internal university sources, including the notional 40 per cent of academic staff time
- International – numerous organisations that include NIH, WHO, UNESCO, etc
- Companies – through commissioned research and consultancy arrangements
- Banks, private equity – as part of an overall investment strategy
- Philanthropy – strong in medical research, that may spill over into agricultural research.

While there is good information about the investment patterns of Australian organisations, there is little information about investment from overseas organisations – public or private.

5.8.2 Australian Government Research Organisations

Organisations in this category include:

- CSIRO
- Institute of Marine Science
- The Bureau of Meteorology.

These organisations are consistently under budgetary and financial pressure due to fiscal austerity considerations. However, their comparative stability has served the rural sector well over many years.

5.8.3 State Government Research Organisations

Research institutes are major research providers in the rural innovation system. A list of State government research institutes is at Appendix 2 and separately in the *Research Report No 3*.

There is a very strong level of capability, particularly in NSW, Queensland, and Victoria, which operate at over 50 research, development, and innovation facilities.

5.8.4 Universities

Research Report No 3 identifies over 30 research centres and Institutes at Australian universities. Many have international profiles and are party to global collaborations.

5.8.5 Global agribusiness companies

Global agribusiness companies are active in Australia, and some collaborate with RDCs, research organisations, and universities. These are identified in Appendix 4.

5.8.6 Specialised and emerging agribusiness organisations

In recent years there has been growth in specialised Australian agri-businesses companies, many created around the opportunities to exploit and market technology. These are also identified in Appendix 4.

Research consultation businesses are also increasing prominence, especially around digital.

As the innovation ways shift towards digital and data, together with the growing commitment to consumer driven innovation, research is tending to move to the more commercially oriented consulting businesses.

5.8.7 Collaboration organisations

- **CRCs**

Over the period from 1991 to 2016 a total of 211 successful CRC applications have been awarded, with a total Commonwealth investment of \$3.972 billion. Successful CRCs have been heavily concentrated in the agriculture fisheries and forestry, environment, and health medical and biotech sectors.

Fifty of the successful CRCs have been in Agriculture, fisheries, and forestry, with a total value of applications of \$943.1m, amounting to 23.7 percent of the total Commonwealth investment value. Further detail on rural oriented CRCs provided in Research Report 3, which also includes information on currently operating CRCs. A listing of all past rural oriented CRCs is also included.

The Review Team sought access to evaluations of the funded CRCs, in terms of what had been achieved and impact, but they were not readily available. Such evaluations, in many cases years after their closure would be useful for informing policy and strategies about future collaboration arrangements.

The Review consultations indicated that the CRC program has been a major source of R&D investment for the rural industries sector. Whilst there have been many assessments of the economic impact of CRCs prior to, during, and after their operation, using various economic modelling techniques (Allen Consulting Group, 2012), there is little “on the ground” evidence of *sustained impact over time* in terms of value created for the sector, for farmers, for communities, or the economy. Anecdotally, we have been informed that this has been good.

Information on currently operating CRCs is provided in Table 16 below.

Table 16: Currently operating CRCs with a Rural Innovation connection

CRC	Period	C/W Funds	Purpose	Previous iterations
176 - Poultry CRC	2010-2017	27.0	To conduct research and drive education and training to help Australia's poultry industry achieve sustainable, ethical poultry production in the face of population growth and climate change.	No. 140 - CRC for the Australian Poultry Industries - 2003-2010
187 - CRC for High Integrity Australian Pork	2011-2019	19.9	To address the major challenge the Australian pork industry's faces in maintaining local production of high-quality food for a reasonable price without negatively impacting pig welfare, the environment, or the health of the consumer.	No. 152 - CRC for an Internationally Competitive Pork Industry - 2005-2011
192 - Invasive Animals CRC	2012-2017	19.7	To counteract the environmental, social, and economic impacts of invasive animals through the development and application of new technologies and by integration of strategic pest management approaches across agencies and jurisdictions.	No. 156 - Invasive Animals CRC - 2005-2012
191 Biosecurity CRC	2012-2018	29.7	To develop and deploy knowledge and tools to provide the scientific support essential for safeguarding Australia from the economic, environmental, and social consequences of damaging pest incursions.	No. 149 - CRC for National Plant Biosecurity - 2005-2012
206 - CRC for Sheep Industry Innovation	2014-2019	15.5	To enhance sheep wellbeing and productivity, value-based trading of sheep meat and deliver affordable technologies to transform the Australian sheep industry.	No. 163 - CRC for Sheep Industry Innovation - 2007-2014

Source: Department of Industry, Innovation and Science

Food Agility CRC, the High-Performance Soils CRC and the CRC for Honeybee Products were established in the most recent CRC round. The CRC for Northern Australia was established in the context of the Northern Australia White Paper.

Consultations indicated that CRCs have played an important role in rural innovation. But some of the earlier CRCs may have substituted for State funding, which did not recover when CRC finished. CRCs have been very important for regional universities.

▪ **RDC Partnerships, alliances, and joint ventures**

There is an emerging research partnership paradigm between RDCs, universities and business. It is particularly strong with MLA Donor Company (MDC), GRDC, CSIRO, Horticulture and Fisheries. For example -

Livestock Productivity Partnership to be expanded
15 November 2017
A major collaborative research partnership aimed at lifting the productivity of Australia's livestock industry has been expanded – with the potential for up to \$50 million worth of projects over the next five years.
The Livestock Productivity Partnership (LPP) was initially announced in February between MLA Donor Company (MDC) and NSW Department of Primary Industries (NSW DPI) and featured a \$17.5 million commitment from NSW DPI over five years, to be matched through MDC, for research projects that address key red meat and livestock priorities.
The LPP has now been expanded with the addition of research partners the University of New England (UNE) and CSIRO, with the potential for more partners to join.
The MDC Board recently approved the LPP Strategic Plan as well as co-investment for the partnership of up to \$50 million over five years, with 50 per cent of funds coming via MDC.
The LPP aims to develop and demonstrate, by 2022, region- and system-specific feedbase options, new animal phenotyping and farm management tools with quantified potential to reduce the cost of production (\$/kg liveweight) in commercial grazing enterprises in the improved pasture regions of NSW and southern/central Queensland by at least 5 per cent in real terms.
MDC CEO Dr Christine Pitt said \$6.5 million had been committed to commence the first set of LPP projects.
"The LPP will provide a vibrant, collaborative environment that will leverage the expertise, reach and depth of the partners to advance research to improve productivity for the red meat industry. It will also foster early career researchers and help build long-term capacity for the industry," Dr Pitt said.
"LPP will focus on research that addresses key industry challenges and the early development of viable commercialisation and adoption models.
"This collaborative model of engagement with universities, other research providers and state departments is a key focus for MDC, and we'd like to encourage more of these types of partnerships."

Dr Pitt said the LPP would complement and extend MLA industry-funded investments in livestock productivity RD&A, without duplicating the work being undertaken in those projects and is closely aligned to the Meat Industry Strategic Plan 2020 and R&D priorities identified by the Southern Australia Meat Research Council (SAMRC) and North Australia Beef Research Council (NABRC).

NSW DPI Director General Scott Hansen welcomed the additional partners to the LPP while reaffirming NSW DPI's commitment over five years.

"This is a pivotal investment that will boost the sheep and cattle industries, which have been key contributors to the record-breaking returns for the primary industry sector in 2016-17," Mr Hansen said.

"Sustaining these returns over a long period benefit not only producers, but people working throughout the processing chains and in local regional communities."

The LPP Management Committee has now been formed to steer the partnership and an interim program leader, Dr Ian Johnson, appointed. A search has commenced for a full-time coordinator.

The committee said benefits will arise from the LPP through the sharing of skills, infrastructure, assets, and research data.

"The alignment of expertise, data and resources provides an ideal springboard for accelerated research, development and adoption, and has the potential to bring transformational change to the industry," the committee representatives said.

<https://www.mla.com.au/news-and-events/industry-news/livestock-productivity-partnership-to-be-expanded/>

▪ **University-Government collaborations**

Collaborations between universities and State Agriculture Institutes are strong in NSW, Victoria, and Queensland, although there is concern about reductions in State Government commitment, particularly in NSW.

The Tasmania Institute of Agriculture, which integrates State Government research with university research has been an important initiative, and seen as a model for regional universities in other jurisdictions

The Tasmanian Institute of Agriculture (TIA)

The Tasmanian Institute of Agriculture is a joint venture between the University of Tasmania and the Tasmanian Government.

This partnership has brought together the human and physical resources of the Tasmanian Government with the scientific research and teaching capacity of the University of Tasmania (UTAS) to create a centre of excellence in agricultural research, development, extension, education, and training. TIA's activities are funded by the Tasmanian Government, UTAS, agricultural research, development and extension organisations, resource management organisations, other granting bodies and industry.

TIA has a state, national and international mandate. At the state level, we work closely with our partners in government and industry to improve the performance of Tasmania's agricultural sector, across all industries and value chains. At a national level we show leadership in research excellence and partner strategically with many other organisations around Australia. Internationally we are rapidly increasing our research portfolio, influence, and student numbers.

As an organisation on the boundary between science and society, TIA is positioned to create a constructive science community dialogue which is increasingly sought in the current environment. We provide straight-forward, technical solutions but we also address the difficult issues, characterised by contested values and conflicting objectives. Through the practical knowledge of our staff, we support the development of robust, innovative agricultural policy that facilitates Tasmania's growth and that firmly establishes TIA as a world-class, science-based organisation.

<http://www.utas.edu.au/tia/about-us/about-tia2/about-tia>

A RDC interviewee commented that "universities are a bit like a body corporate. You're not actually dealing with the university; you're dealing with an individual researcher. So, you've got that personal connection but then you've got the organisational constraints of the university".

In discussion the RDC pointed to three examples that work well with state government and universities, where there's significant cash being brought to the table and significant focus on not only what farmers want, "which we provide", but also what's good for the regional economy. *The state government is saying "this is a jobs and growth strategy"*.

▪ **Autonomous University-Industry rural research institutes and centres**

During Consultations interviewees pointed to the German Fraunhofer type model of demand driven research-business collaboration as a possible model for Australia, particularly in terms of an opportunity to create an environment to undertake genuine interdisciplinary research.

Many people in Australia have visited Germany to see the Fraunhofer model firsthand, and it is possible to see some elements in practice in several university research centres across regional Australia.

▪ **Concluding comment**

In terms of institutional and organisational arrangements for rural research, development and innovation, Australia has a very traditional institutional and organisational structures, based around the ancient (British) model of the university and government owned research facilities that fall under the fiscal direction and personnel caps of Commonwealth and State treasuries. Their capacity to take long terms strategic positions, and allocate resources, accordingly, is constrained. Apart from universities and industry-owned research and development corporations, government organisations are restricted in their capacity to carry forward surpluses for future investment.

A commitment to innovation in rural research and development should be accompanied by innovation in the way the research enterprise is conducted.

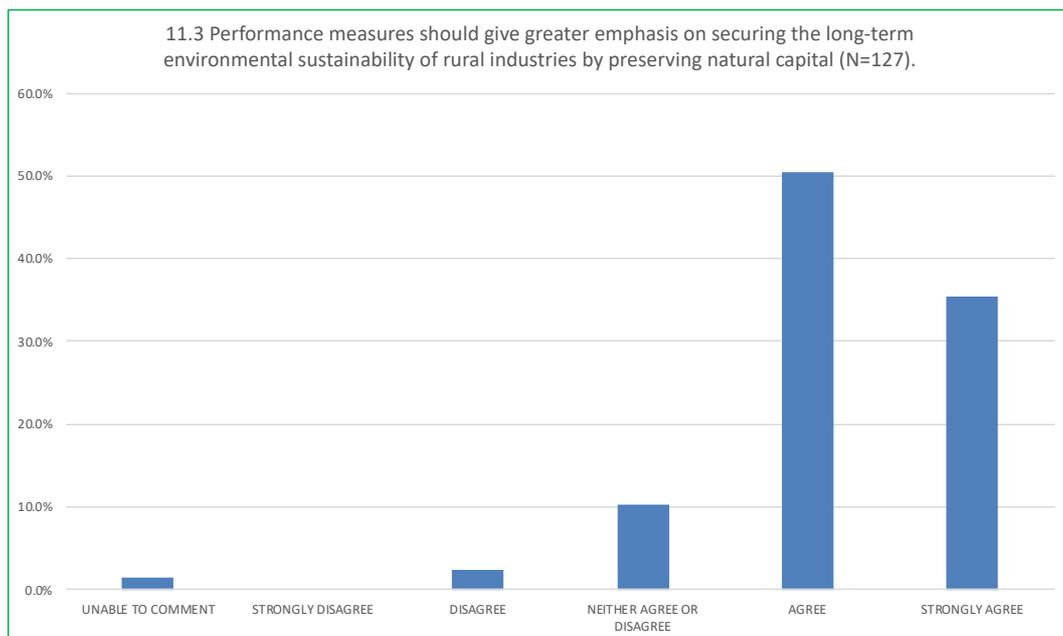
5.9 Monitoring and Evaluation

Key points

- Performance measures should give greater emphasis to securing long term environmental sustainability of rural industries by preserving natural capital
- The rural innovation system would be enhanced by placing a greater emphasis on general 'public benefit' data provision, relative to specific technology development projects
- better provision of general 'public good' data would be improved by allowing farmers and others to share data whilst protecting confidentiality

Consultations and the views of Experts indicated a concern with commitment to monitoring and evaluation. This applies not only to the performance of projects and programs but also to long term environmental sustainability, as indicated in Experts' responses in Figure 89

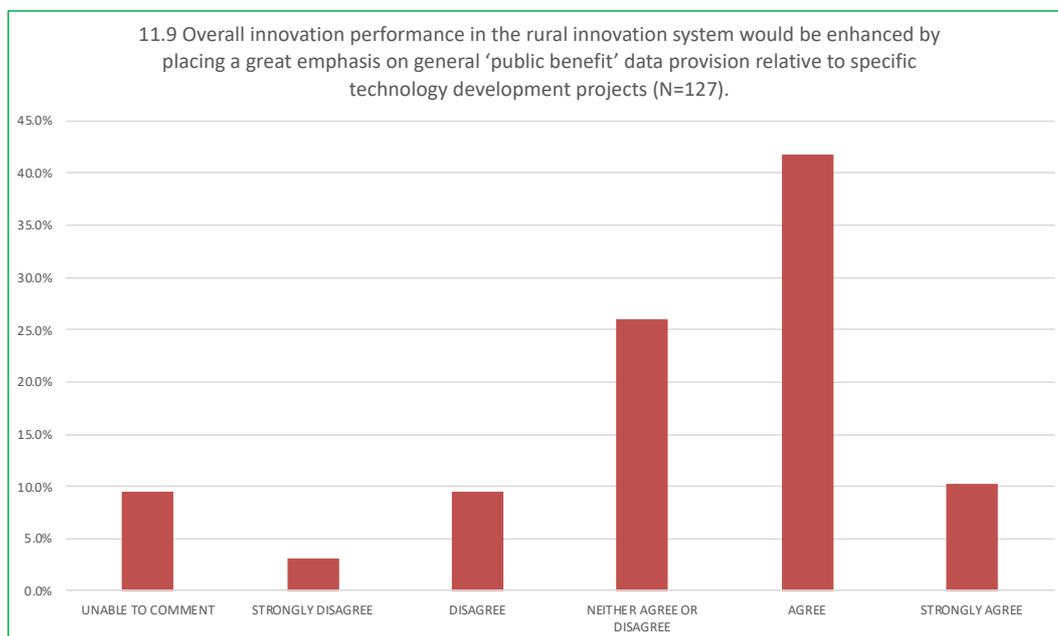
Figure 89: Performance Measures to secure long term environmental sustainability



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

Experts responded positively to the hypothesis that “the rural innovation system would be enhanced by placing a greater emphasis on general ‘public benefit’ data provision, relative to specific technology development projects”. This is indicated in Figure 90.

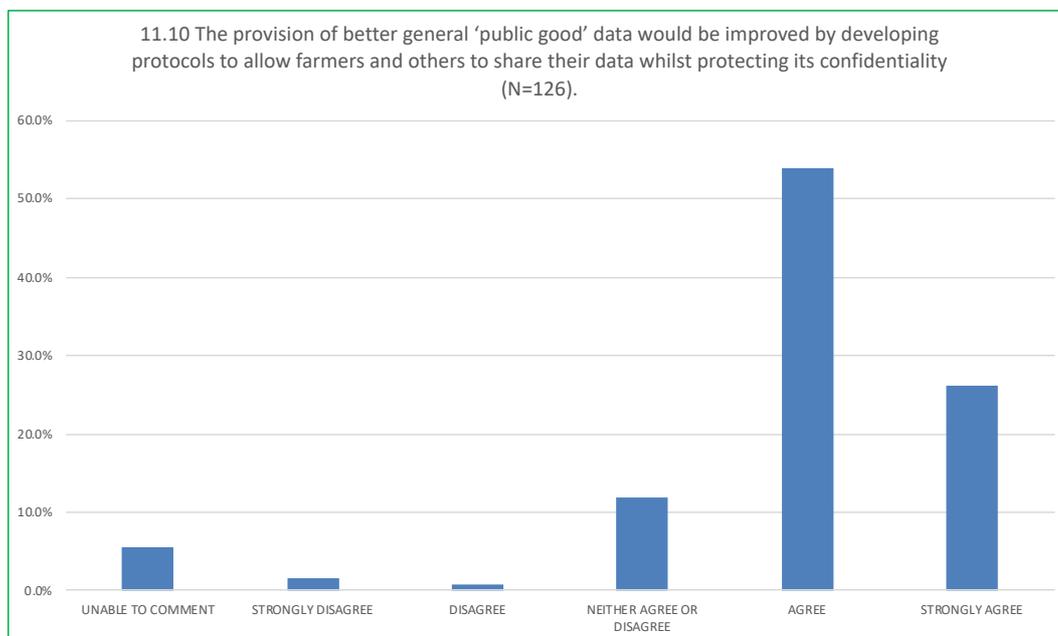
Figure 90: Performance Measures to secure national and industry benefit outcomes



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

Experts also strongly supported the hypotheses that better provision of general ‘public good’ data would be improved by allowing farmers and others to share data whilst protecting confidentiality. This is shown in Figure 91.

Figure 91: Protocols to share data



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

5.10 Experts' views on Overall Rural Innovation System Performance

Key points

- Experts indicated a high level of comfort with the performance of the rural production system – influenced by buoyant commodity trading conditions and farm incomes
- The science and research system is seen as a significant asset, but with scope for strengthening
- Policy attention is required to improve the performance of the education and training system
- The rural and regional development system is not regarded as performing strongly, and performance should be improved to support the rural innovation system
- Similarly, more attention is seen to be implied in relation to the rural enterprise development system, and the innovation ecosystems

To provide a more nuanced perspective on overall innovation system performance, the Review Team included in the *Expert Opinion Survey* an invitation for participants to rate performance of complementary systems on a scale of 0 to 5.

This approach amounts to a *peer reviewed* process, and parallels approaches used by some international ratings agencies to construct university rankings. The ratings could be further refined in subsequent iterations of a Performance Review of the Rural Innovation System.

Ratings have been defined on the following basis.

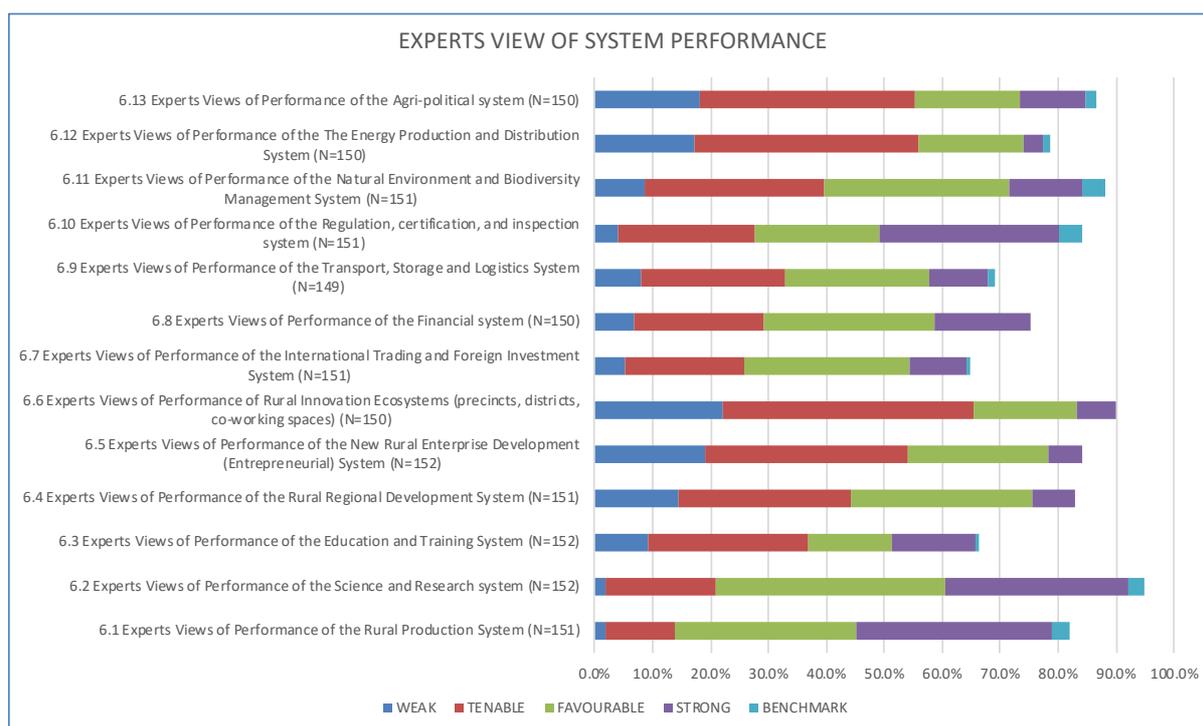
Table 17: Rating system for assessing innovation performance

Rating	Criterion	Interpretation
5	Benchmark	Defines the level of performance against which other rural innovation systems should be judged
4	Strong	Performs strongly but does not constitute the level of performance against which other rural innovation systems should be judged
3	Favourable	Performs reasonably well but with sufficient room for improvement to prevent in being classed as 'strong'
2	Tenable	Performs adequately but with considerable room for improvement
1	Weak	Does not perform adequately
0	Unable to comment	Not well enough informed to provide a view

As of 22 March 2018, a total of 180 responses had been received, representing a response rate of 30 per cent.

We are confident that this level of response, together with the outcome of our Consultations, provides a robust basis for making comments about rural innovation system performance.

The broad views from Experts about performance in the component systems on the above rating scale is represented in Figure 92.

Figure 92: Experts Views on Innovation System Performance – Major Components

Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

Experts considered that the Rural Production System, the Science and Research System, and the Regulation, Certification, and Inspection System, rated in performance predominantly between Favourable to Strong. Other systems rate predominantly between Tenable and Favourable.

None of the ratings reflected in Figure 92 are particularly outstanding, all pointing to areas where there is scope for significant improvement. However, the ratings broadly accord with the messages we had been receiving during Consultations and are reflected in the remainder of this Report where each system is reviewed in more detail. More specific measures and metrics relating to those systems are included in the relevant Sections, including bibliometric data relating to the Science and Research system.

Summary comments on the overall performance ratings are provided below:

- *The rural production system* – the highest rating (3.28 or an average 65 per cent rating), reflects the broad comfort with the system among interviewees about the robust commodity trading conditions and currently buoyant farm incomes. However, only about 40 per cent of those who provided a rating considered the system to be 'strong', while a similar proportion considered the system to be 'favourable'.
- *The science and research system* – this was the second most highly rated system (62.5 per cent average), although there was a wider range of views than for the rural production system. Clearly the majority of those surveyed see the science and research system as significant asset, but one with scope for strengthening.
- *The education and training system* – the experts' views on the skill development system were significantly less sanguine (53 per cent average) with the most frequent rating 'favourable' but almost 30 per cent of respondents rating the system as only 'tenable'. When we consider that skill and knowledge requirements are likely to increase sharply this is an assessment rating that signals a need for policy attention. It is vital that labour markets respond to changing requirements in rural industries, but also that careers are rewarding for those who invest in their skill development.
- *The rural and regional development system* – one of the five lowest ratings (average rating equivalent to 47 per cent) with a similar proportion of experts rating the system as 'favourable' and only 'tenable'.

- *New rural enterprise development (entrepreneurial) system* – closely related to the rural and regional development system, the entrepreneurial system is similarly rated (an average rating equivalent to 44 per cent) and over half of the experts surveyed considering that this system to be weak or only 'tenable'.
- *Innovation ecosystems (precincts, districts, co-working spaces)* – this was the lowest rated system with two thirds of the experts giving a rating of two out of five ('tenable') or lower ('weak'). The low ratings of these three complementary development systems indicates that the organisations and institutions that promote and support innovation at the local level are widely considered to be weak.
- *The international trading and foreign investment system* – over a third of the experts surveyed felt that they were unable to provide an informed assessment. Of those that did provide a rating the majority considered the system to be 'favourable' and the average rating was equivalent to 54 per cent. Clearly, most of the experts do not see this area as one that significantly impedes innovation in the rural sector.
- *The financial system* - while the average rating for the financial system was also equivalent to 54 per cent, the views of the experts were more diverse. As the performance of capital markets is particularly important for enabling investment in new enterprises and in new technologies the performance of these markets warrants further analysis in a rural innovation context.
- *The transport, storage, and logistics system* – the average rating for this system was similar to those for the financial and the trading systems, and like the ratings for those two systems, over a third of the experts rated the system as 'weak' or only 'tenable'.
- *The regulation, certification, and inspection system* – this system was rated relatively highly (an average equivalent to 62 per cent) and two out of five of the experts who provided a rating considered the system to be at least 'strong'. But views were mixed and almost a third rated the system as only 'tenable' or 'poor'.
- *The natural environment and biodiversity system* – the experts' assessments of this system were less diverse than for other systems – almost 70 per cent rated the system as 'tenable' or 'favourable'.
- *The energy production and distribution system* – not surprisingly the average rating for the energy system was one of the lowest and a half of the experts who provided an assessment rated the system as only 'tenable' (i.e., 2 out of 5) - almost a quarter considered the system to be 'poor'.
- *The agri-political system* – it was evident from our consultations that views on the agri-political system varied from sector to sector. This diversity is reflected in the wide dispersion of the ratings. The overall very low ratings for this system are evident in the finding that over 70 per cent of those providing an assessment considered the agri-political system as at best 'tenable'. This finding suggests that political dynamics in the rural areas are not currently aligned with a robust innovation system.

6. Areas for Potential Performance Improvement

Key points

- Respondents to the Expert Opinion Survey overwhelmingly indicated that Australia requires an overarching strategic vision for rural innovation based on market and technological change, biodiversity, and climate change and that this vision be used to coordinate state/territory level innovation support
- Experts were in overwhelming agreement that mind sets in the rural sector have not developed to reflect the realities of modern globally connected innovation, and the severity of long-term environmental challenges
- Experts were also overwhelmingly of the view that present government policy places too much emphasis on 'here and now' productivity and efficiency challenges and insufficient attention on new market and longer-term industry facing opportunities.
- Experts also saw major opportunities in developments in digital technologies as a basis for "creating a revolution in agricultural productivity and value chain development.
- Regional universities have a key role in enabling regional rural innovation, but there is a need for greater policy integration across Commonwealth and State/Territory agencies that have research, education and training and regional development within their remits.
- CRCs have been important for rural innovation. Commonwealth and State/Territory Governments might consider collaborating with RDCs and businesses to establish *CRC type* arrangements, following the model of the CRC for Northern Australia.
- Rural RDCs, as currently structured, are regarded by Experts as having been an enhancing factor in rural innovation. There was some support for the view that RDC roles should be made more contestable by private research providers. Experts generally did not agree that RDCs had displaced alternative user mechanisms for delivering research.
- The established Commonwealth-State/Territory collaboration infrastructure in primary industries provides a good starting point to think about developing a strategy covering all aspects of Australia's Rural Innovation System.

This Section reports on feedback from our research, Consultations, and the Expert Opinion Survey on areas for performance improvement. It reports on responses to several hypotheses include in the Survey Instrument. It provides input into the *Strategic Perspectives Report* (Document A)

6.1 National Rural Innovation System Strategy

Discussions and consultations pointed to the needs for a development strategy for the rural sector – that builds on innovation and other investments and covers the value chain, not just farming. Innovation should be part of the strategy, not the strategy itself.

The rural innovation system is considered by most people interviewed for this Report to be lacking in a strategy – what it is supposed to do and achieve, and how it will be done. This observation is made notwithstanding the multiplicity of policy statements, projections and wish lists that are summarised in Volume III of this Report.

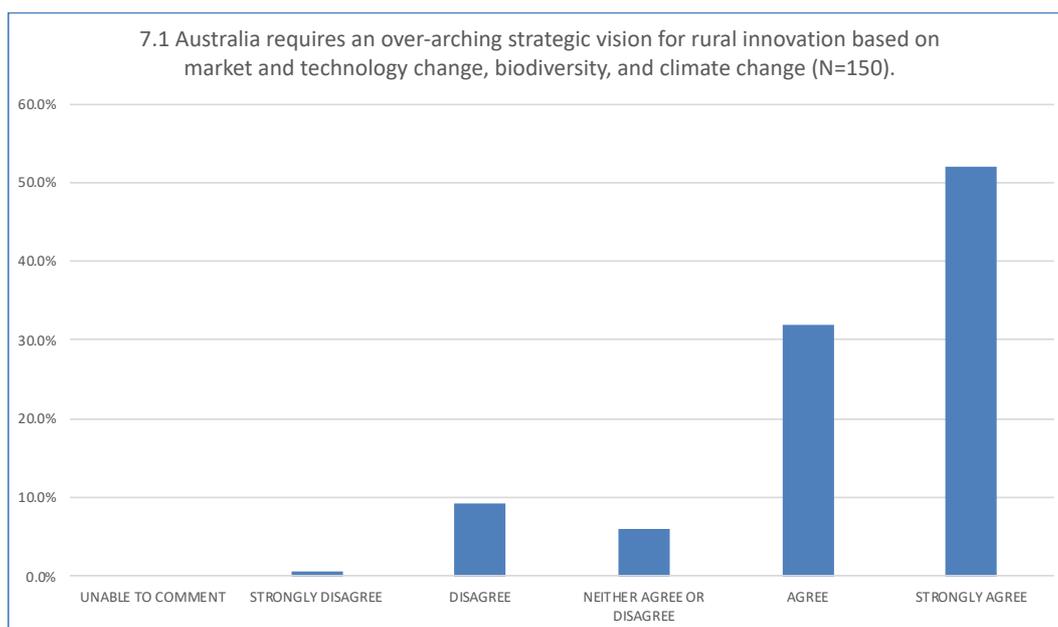
There is an absence of a narrative about the opportunities that the system can deliver – beyond a focus on the "noble farmer". The absence is exacerbated by the farmer being seen as the main client in the Rural Research and Development Corporation model – notwithstanding the substantial taxpayer contributions to rural research, development and innovation, and the broader involvement of businesses, universities and governments in its funding and delivery.

The point was made many times during the Review that the rural innovation system is much broader than the sectoral mandates of the Rural Research and Development Corporations.

Productivity and competitiveness is not a vision. It may be an economic imperative, but it is hard to drop down from an economic narrative to one that addresses the motivations and actions of national and international businesses, teaching and research organisations, and consumers.

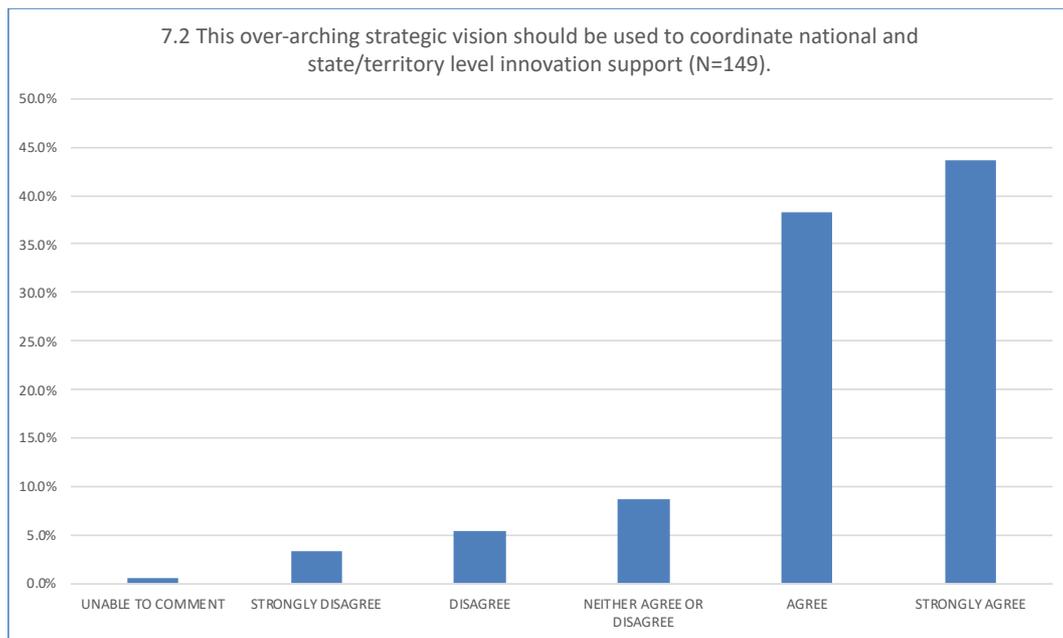
The Consultations for this Review provided very clear feedback about a strong desire for an overarching “rural innovation system strategy”. This is also reflected in the results of the *Expert Opinion Survey* for the Review and is indicated in Figure 93.

Figure 93: Expert Opinion Survey – Vision for Rural Innovation



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

Innovation Experts saw a strong role for a strategic vision for rural innovation to guide national and state territory innovation investments, as indicated in Figure 94 below.

Figure 94: Expert Opinion Survey – Role of The Strategic Vision

Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

Developing the vision and strategy would be a matter for a very senior leaders' group across government, the research sector, and the business community.

The Chair and the Board of Innovation and Science Australia recently led a strategic planning process culminating in the publication of *Australia 2030: Prosperity Through Innovation*. The Board continues to focus on building commitment and addressing implementation. It is an ongoing remit.

Whilst rural innovation could be 'mainstreamed' under the *Australia 2030* umbrella, agriculture, forestry, and fishing has a long history of Commonwealth-State/Territory collaboration in a very broad range of areas that impact on rural innovation. The Primary Industries Ministerial Council is a long-standing arrangement, first established in 1935. It is supported by the Primary Industries Standing Committee (PISC) and in turn the National RD&E (R&I) Committee.

The established Commonwealth-State/Territory collaboration infrastructure in primary industries provides a good starting point to think about developing a strategy covering all aspects of Australia's Rural Innovation System. This option should be explored before looking at other, new, structural options.

6.2 Policy and innovation leadership

Consultations with business, research organisations and in regions, indicated that the rural innovation system needed national leadership. Leadership does not, and cannot, mean control over all the strategic and resource allocation decisions made by the multiple organisations that constitute the system. As outlined above, it may mean however, setting a compelling vision and setting in place strategies and incentives that guide actions and behaviours towards achieving it.

This Review has revealed there is no shortage of plans. There are in fact numerous plans that cover most elements and aspects of the rural innovation. These are documented in Research Report 2. Some

focus on farming, others on food and agriculture, science and research, education, and training, and most recently AgTech.

There are few plans that focus on the whole Value Chain or innovation in the supporting national systems such as transport, communication, regional development and the natural environment and biodiversity management system and the broader public policy system. Those that do make little or no connection with the rural (or even national) innovation system.

These plans and projections are complemented by State/Territory Government plans and projections and the sector plans prepared by RDCs under the National R&I Framework. Some take a broad view, whilst others have a specific focus on farming and agriculture, or food, or on matters such as investment in research and development. There is some focus on education, training, and talent acquisition²⁰. But, in an overall sense, there is often very little apparent connection in plans and strategies across the rural innovation system.

It is well appreciated in the corporate sector that identifying problems, opportunities, threats, and weaknesses (SWOT) and formulating strategy is relatively straightforward – the hard part is implementation and delivery, including governance, institutional alignment, organisation, resourcing, risk, acceptable ROI, and securing change in attitudes and behaviours that support implementation. Plans must not only be desirable, but implementation must also be feasible and practical (workable).

Quite often plans just 'fly and then land' in the public domain, with little indication of who should be responsible and accountable for delivery, and how implementation should occur. This is almost a cry for rural policy and innovation leadership.

It is possible to underestimate the amount of leadership that RDCs provide in the rural innovation system. A CEO commented that RDCs tend to be doing things in areas that they're not specifically mandated to do across the supply chain because they're the only independent party sitting around the table. "In a couple of these forums we're not actually a member in it, we're an observer, but we're running the show and we're driving it".

This comes down to a 'default position' in the absence of any other policy and strategic leadership. It also reflects an ability in the RDCs to be forward looking when not specifically working to satisfy levy payer demands for research that specifically benefits them. However, it may not be desirable for RDCs to be taking policy leadership positions in the absence of an overarching vision for the rural innovation system.

Within the agora of Ministers, government agencies, research funding organisations, universities and public research agencies, and business, established and new, there are very few voices that speak for the totality of rural innovation from the value chain perspective - a perspective that must be a high priority for Australia's rural future.

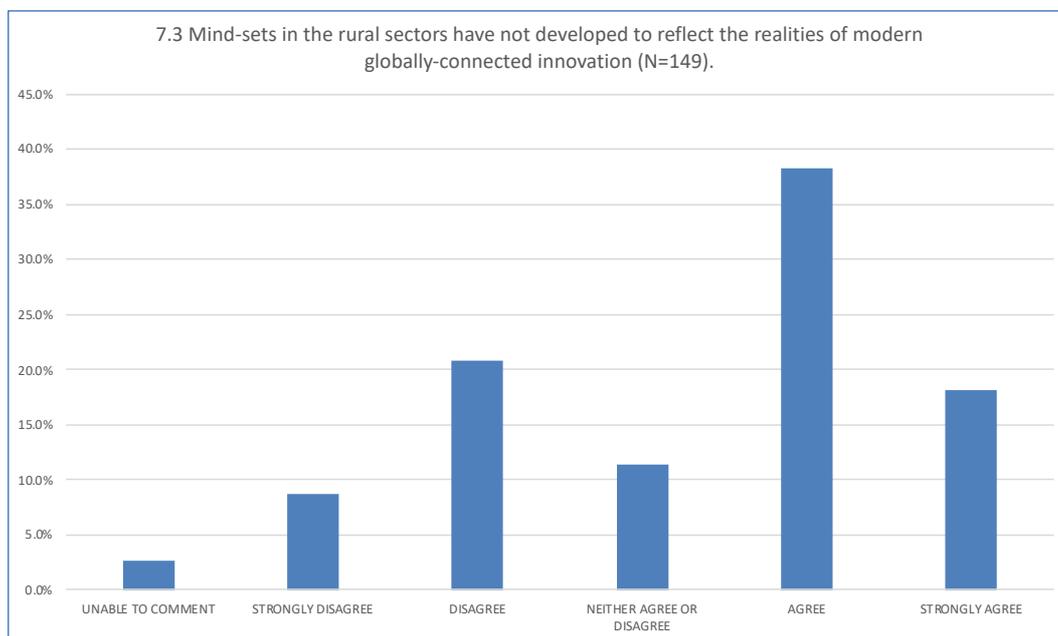
6.3 Innovation mindsets

Discussions during the Consultations for the Review often pointed to an absence of understanding of the "realities of modern globally connected innovation". Stereotypes abound of farmers disconnected from the realities of globally connected innovation and market imperatives. This is not generally correct, as Consultations indicated that there are many in the rural sector who fully appreciate this

²⁰ For example, Review into Agricultural Education and Training In New South Wales, <http://exar.nsw.gov.au/exar/wp-content/uploads/2015/12/Review-into-Agricultural-Education-and-Training-in-New-South-Wales.pdf>

innovation imperative. This view was tested in the Expert Opinion Survey with the result shown in Figure 95.

Figure 95: Expert Opinion Survey – Mindsets that reflect the realities of modern globally connected innovation

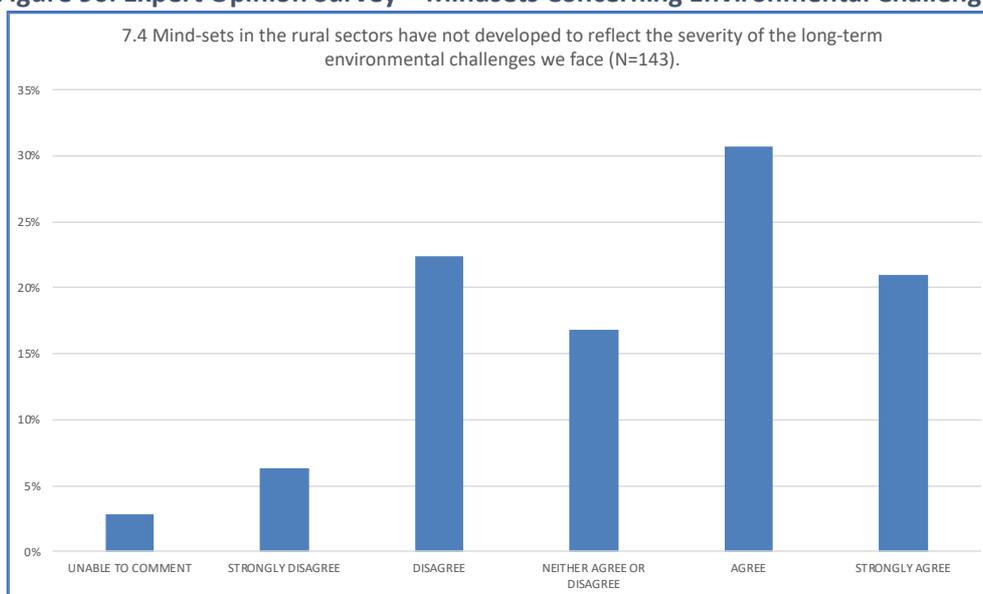


Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

The Experts' Opinions would seem to indicate that more needs to be done to communicate the realities of globally connected innovation in the rural sector.

The Expert Opinion Survey indicated that mindsets are a little more attuned to the severity of the long-term environmental challenges for the rural sector. This is reflected in reflected in Figure 96.

Figure 96: Expert Opinion Survey – Mindsets Concerning Environmental Challenges



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

Many see the RDCs having a continuing role is addressing environmental challenges. But as one interviewee commented -

And so, we've had to cobble together these very clunky, cumbersome things like the CCRSPI, the Climate Change Research Strategy for Primary Industries, where you go around and try and tax each R&D corp a little bit of money to put a collaborative program together. And you can't do anything on the sort of scale.

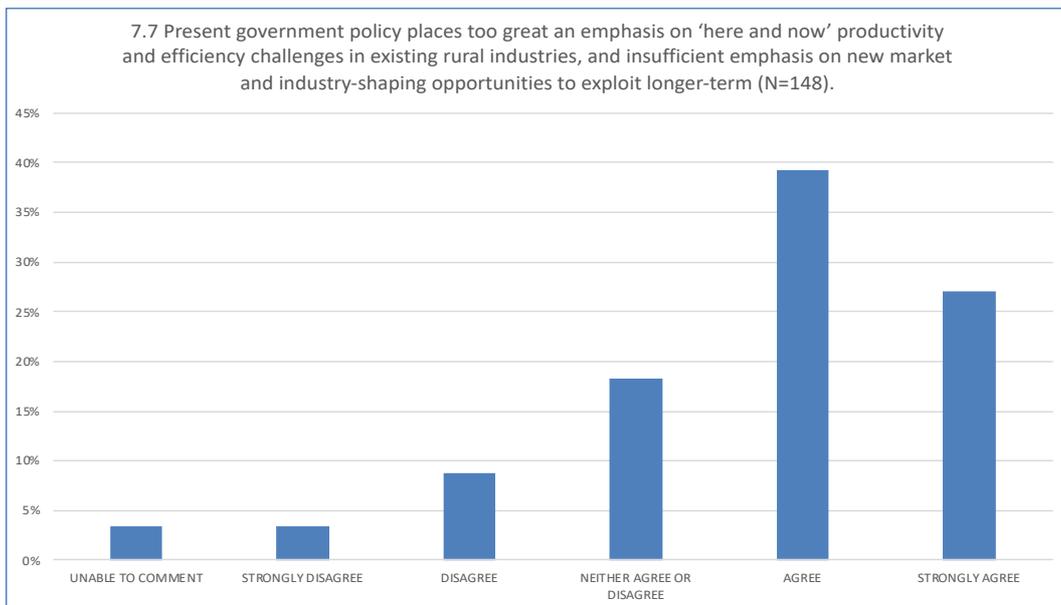
Several RDCs invest in cross sectoral issues such as soils, weeds, and pests. But the focus has been weakened with the abolition of Land and Water Australia. The CRCs have been and are active in these areas, with a soils CRC being formed.

But the environment is seen as an area that lacks a rural innovation system strategic perspective.

6.4 Strategic challenges and opportunities

A consistent theme in Consultations was a concern about relative policy emphasis on short term productivity and efficiency challenges in existing rural industries, a McKinsey *Horizon 1* perspective, rather than a longer-term commitment to new market and industry shaping opportunities (*Horizon 2*) and fundamental changes and disruptions arising from new science, consumption patterns, changing attitudes and behaviours towards food as a product, and regulations (*Horizon 3*). This concern is reflected in Figure 97.

Figure 97: Expert Opinion Survey – Productivity and Efficiency Challenges vs. Long term Industry and Market Opportunities

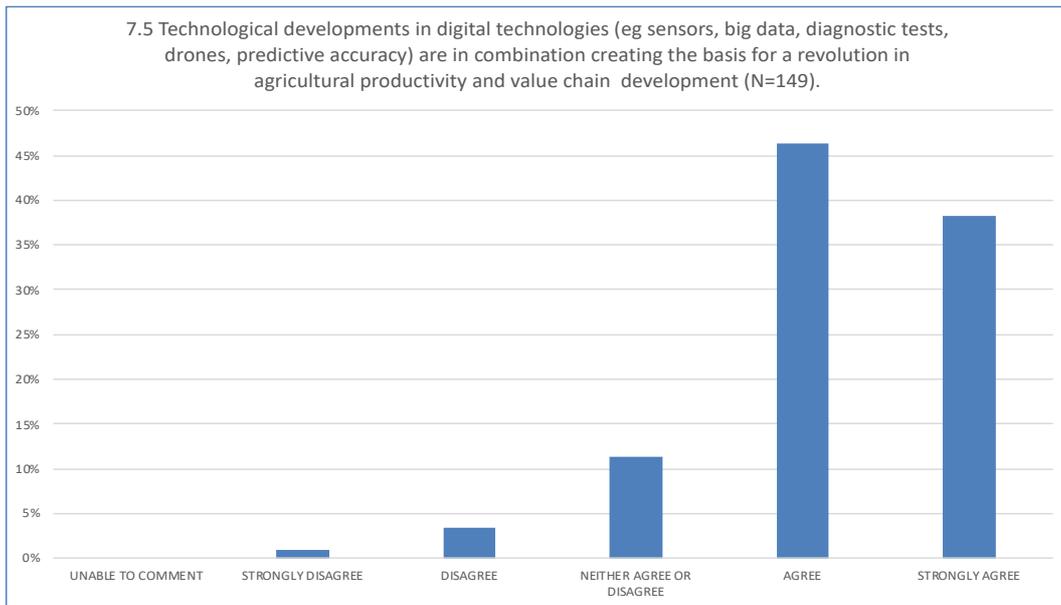


Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

Figure 97 suggests that almost 80 per cent of Experts agreed or strongly agreed about too much policy emphasis on “here and now” productivity and efficiency considerations rather than longer term marketing and industry challenges.

Consultations indicated strong understanding of opportunities in digital technologies and agreed that their application is creating the basis for a 'revolution' in agricultural productivity and value chain development.

Expert responses are captured in Figure 98.

Figure 98: Expert Opinion Survey – Opportunities in Digital Technologies

Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

The level of agreement is 84 per cent of respondents. This level of response would support the commitment and effort being made by the RDCs in the *Precision to Decision* project funded by the *R&D for Profit Program*. These emerging cross sectoral issues are around technology, digital, data, and analytics are an important focus for RDCs working collaboratively.

Some see it as a role for RDCs to further develop long-term market and industry strategies. But the RDCs have been focussed on agricultural commodities and farming, although in practice they are starting to move to a value chain perspective.

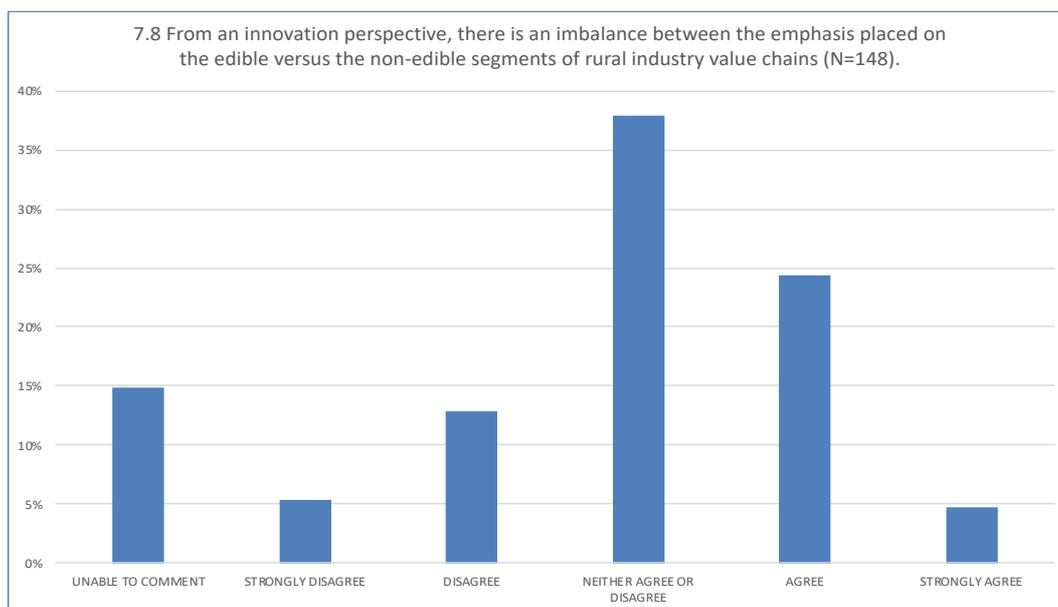
One of the biggest strategic issues to tackle is identified as climate. It has a high-risk multiplier as well as generating a big research agenda. Climate change and exacerbated climate variability has appeared in contexts where previously there wasn't any, or perturbed seasonality.

Moreover, in many countries a so-called triple burden has emerged: hunger and malnutrition; micronutrient deficiencies, which give rise to chronic issues like cognitive function and so on; and obesity with massive health cost implications. The connection between food, agriculture, environment, and health has been mentioned several times as a strategic issue in this Report.

Discussion and consultation indicated that there appeared to be a much stronger focus on the “edible” segments of the rural industries, and particularly food and fisheries. Non-edible components, relating particularly to fibres such as wool, cotton, and forest products receive less attention. Moreover, food crops may also have an important fibre component that can be profitable used for biomass and energy.

However, Experts gave an ambivalent response to the proposition that “From an innovation perspective, there is an imbalance between the emphasis placed on the edible versus the non-edible segments of rural industry value chains” as indicated in Figure 99.

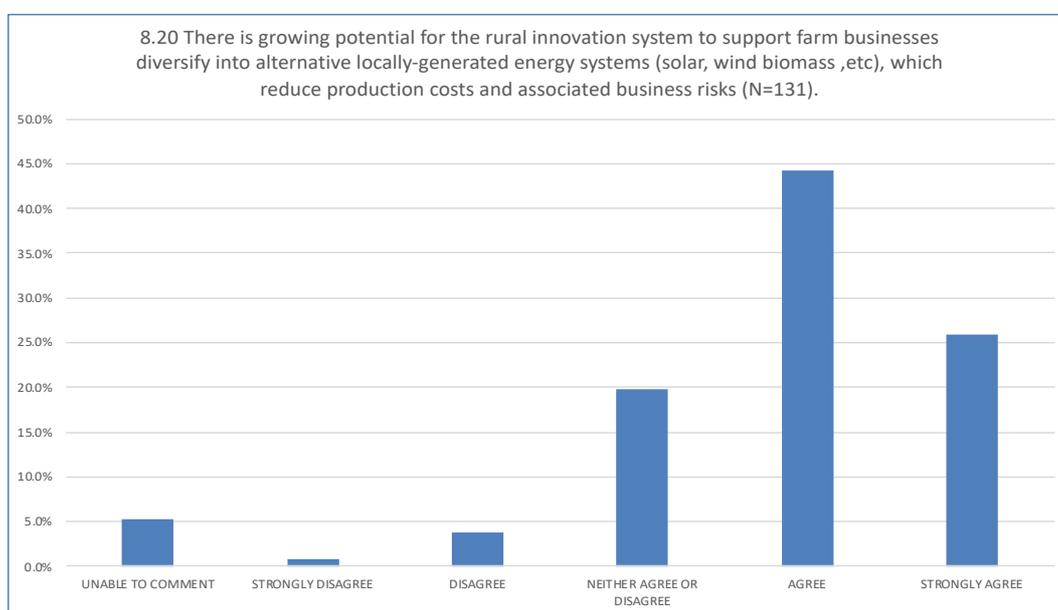
Figure 99: Expert Opinion Survey – Balance between emphasis on edible vs non-edible segments of rural industry value chains



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

Experts, however, indicated support for the proposition of greater “potential for the rural innovation system to support farm businesses diversify into alternative locally generated energy systems (solar, wind biomass and biofuels etc), which reduce production costs and associated business risks”. This is indicated in Figure 100 below.

Figure 100: Expert Opinion Survey - Potential for farm businesses to diversity into locally generated energy systems



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

Discussions with several RDCs indicated that several innovations in this area are underway.

6.5 The role of regional universities

During consultations mention as often made for ongoing commitment to regional universities research, teaching and innovation. The Vice Chancellor at UNE made a point that:

... if you're looking at technologies that can help in regional innovation, and you work in the middle of a big city, the understanding of the realities of living on the land and trying to produce improved productivity on the land, you're not really going to have it particularly well. Whereas here I was able to show some of our international colleagues two days ago, took them to the bottom of the garden of the vice chancellor's residence here, to the sheep paddocks that are part of our farm. Students don't have to go very far. The students are right in the middle of the area.

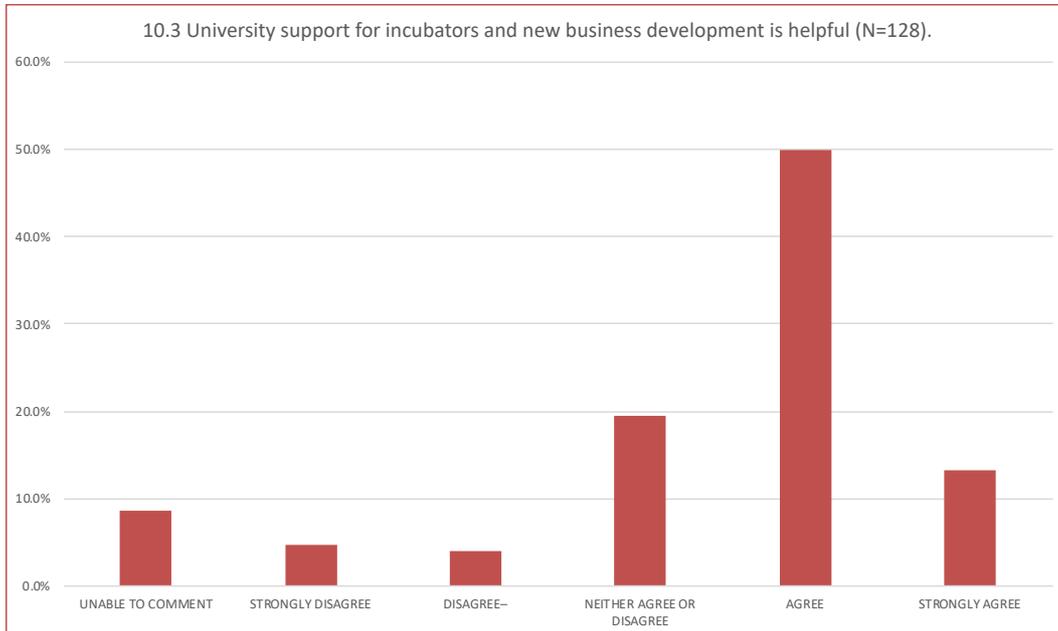
You must understand the drivers, you must be able to talk the language, you must be able to relate to people to get a true understanding of the real problems, but also to understand the real solutions to those problems. A solution that's developed in an area quite separately from the land for example isn't going to work. That's very much looking at it from a farming point of view, and we're much broader than that with innovation obviously. It is the true understanding of the problem that comes from being embedded in the community where the problems occur.

Australia needs a strong, geographically diverse, university and agriculture department system to provide R&D, education, and services to its rural and regional constituents. However, because of the sparse populations in such rural and remote regions, that system does not warrant independent regional development of critical mass by any one agency.

This calls for greater policy integration across Commonwealth and State/Territory agencies that have research, education and training and regional development within their remits.

Regional universities are also making important commitments to innovation and new business development through incubators and business development programs. Experts indicated a high level of support for these initiatives, as indicated in Figure 101.

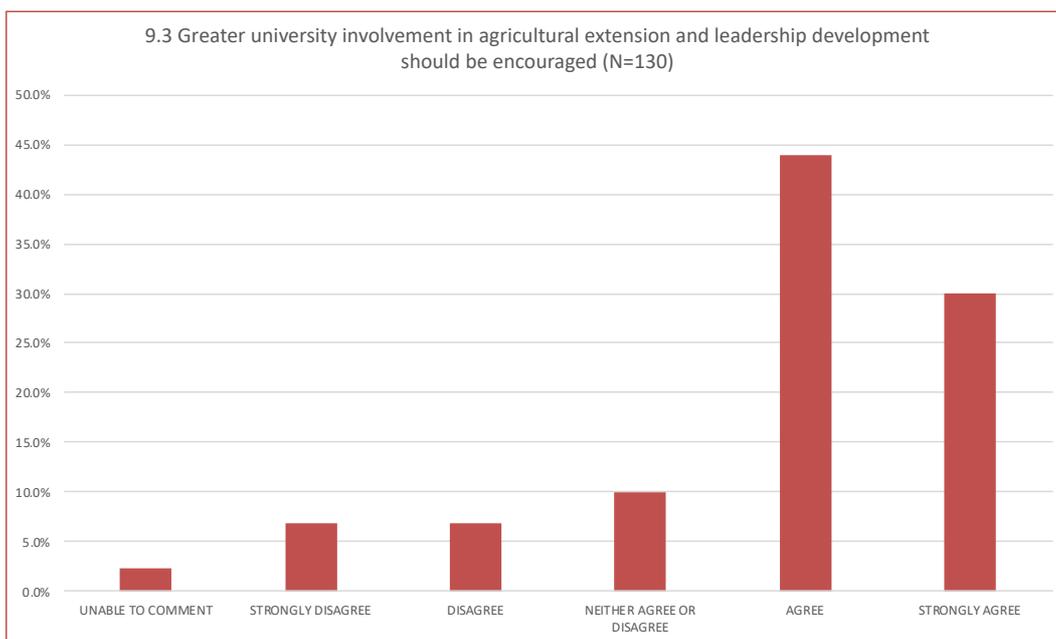
Figure 101: University support for incubators and new business development



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

Consultations indicated that regional universities have also developed an important profile on agricultural extension and leadership development. Experts were of a view that this role should be encouraged, as indicated in Figure 102.

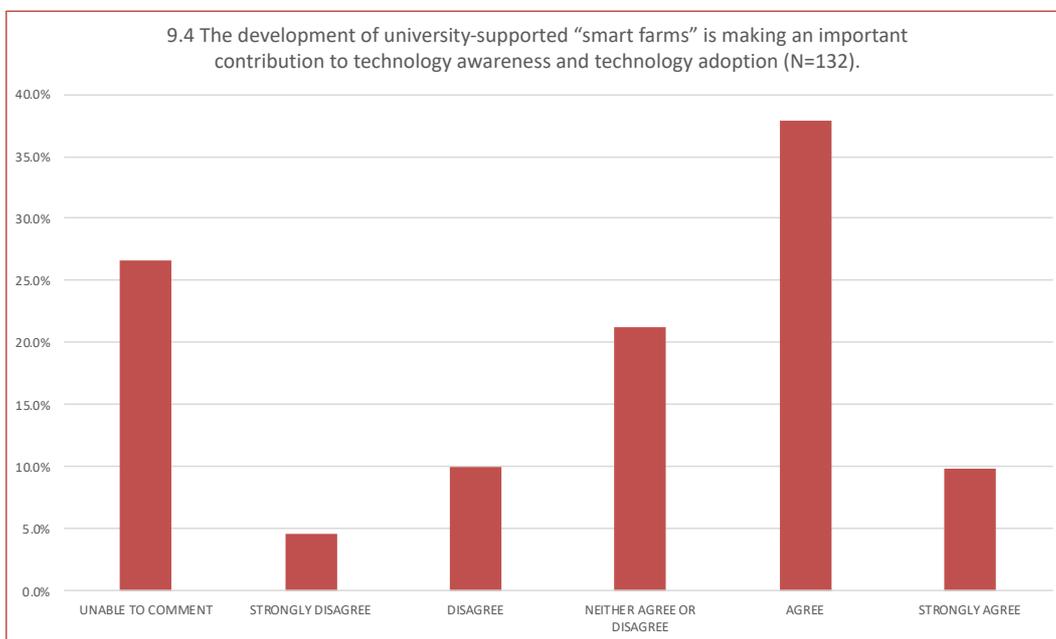
Figure 102: Expert Opinion Survey – Encouraging University roles in agricultural extension and leadership development



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

Consultations drew attention to the role of universities in developing ‘smart farms’ and their contribution to rural innovation. Experts were generally supportive of the initiatives, as indicated in Figure 103.

Figure 103: Expert Opinion Survey – University involvement in Smart Farms



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

6.6 Enhancing the role of CRCs in supporting rural research at regional universities.

CRCs have had an important role in rural innovation since the programme got underway in 1991. During Review Consultations there has been a reported concern, however, that States had been cost shifting their research investment effort from their own research programmes to the CRC programme.

UNE suggested in its submission to the CRC Programme Review in 2014 that the role of CRCs in research delivering benefits to rural and regional Australian productivity increases, across all sectors of rural Australia have declined over recent years, reflecting in part the decline in R&D capacity and reduced research investments over recent decades.

The reduced capacity and research investments are particularly evident in longer-term strategic research areas that in earlier decades (e.g., 1940s through the 1980s) yielded very significant R&D impacts for agriculture in Australia. Since the 1990s, CRCs have picked up some of those declining longer-term investments, but under current CRC guidelines, most existing agricultural CRCs will complete their terms within the next 1-4 years.

UNE argues that the winding down of CRCs is likely to impact very significantly on future research potential and industry collaboration across the rural and regional R&D landscape unless an alternative funding mechanism is identified and implemented as a matter of highest priority.

The successful application for a Soils CRC in the most recent CRC investment round is a positive development.

Commonwealth and State government agencies might consider collaborating to invest with research organisations and business in future *CRC type* arrangements – that is, longer term strategic collaborations with an outcome focus and with substantial investment funding made available. The Commonwealth has committed to a CRC type arrangement with the Northern Australia CRC.

6.7 Clarifying the roles of the Rural Research and Development Corporations

6.7.1 Background

There are currently 15 RDCs—five Commonwealth statutory bodies and 10 industry-owned companies (IOCs). All the RDCs manage R&D services, with most IOCs also providing other industry services, mainly marketing. Following legislative amendments in 2013, statutory RDCs are also able to undertake marketing activities at the request of industry, where supported by a statutory marketing levy.

The rationale for the RDC model was captured by Peter Core, in 2009 in a paper *A retrospective on Rural R&D in Australia*:

- the sector is characterised by many industries with many producers unable to capture sufficient benefits from R&D they would fund as individuals, which potentially leads to under investment.
- the collection of compulsory levies avoids free riding by some on R&D provided by others; and
- there are spillover benefits to the wider community that are not captured by the immediate industry.

The assumptions underlying this rationale are now being subjected to increasing challenge, particularly as sectors have evolved and matured, and a greater willingness of rural businesses to invest in innovation through other channels. Throughout the consultations for the Review suggestions were made that the model needs updating. The basis for these suggestions were varied, but included:

- Clarification of a difference between R&D an innovation and uneasiness about the “linear flow” argument for investment in research.
- A concern that RDC investments are being used for “business maintenance” for marginal businesses, rather than innovation²¹.

²¹ One RDC CEO was of the view that across the sectors only 50 per cent is spent on innovation.

- An emerging and important role for RDCs in facilitation of Innovation investment and a growing commitment to partnerships with R&D providers and industry
- The disruption in the sector with the emergence of AgTech and the emergence of new business models for innovation through start-up businesses and venture investment.
- Growing importance of investments that are not funded by levies and have a longer-term strategic focus.

In addition, the impact of the RDC “model” is uneven across sectors, with some RDCs having developed significant financial strength, with others operating at a relatively smaller scale. This is indicated in Table 18 which shows net asset positions of the RDCs.

Table 18: Rural RDCs, Net Asset Position, June 2017 (\$'000)

	Net Assets June 2017	
Agrifutures	22,120	3.3%
AMPC	39,263	5.8%
Australian Wool Innovations	106,382	15.8%
Cotton	37,535	5.6%
Dairy	40,335	6.0%
Eggs		0.0%
Fisheries	11,733	1.7%
Forests and Wood Products	4,850	0.7%
Grains	205,828	30.5%
Horticulture	64,221	9.5%
Live Corp	7,104	1.1%
Meat and Livestock Australia	116,843	17.3%
Pork	4,710	0.7%
Sugar	67	0.0%
Wine	13,119	1.9%
	674,110	100.0%

Source: RDC annual reports 2016-17

A significant proportion of net assets are reflected in an equity position in the form of accumulated statutory funds.

RDCs with strong balance sheets are, potentially, in a position to take longer term strategic investments for their industry and engage in “cross sectoral” initiatives. Consultations indicated that this was the case with Grains, Horticulture, and Meat and Livestock. Others considered that they had sufficient scale to “go it alone”, avoiding the transactions costs of collaborations. Some of the statutory RDCs are limited in their flexibility to undertake investments outside their “sectors”.

RDCS should be encouraged to commit to cross sectoral research, where there is a clear strategic benefit. Consultations with RDCs indicated that collaboration, for the sake of collaboration, and without clear strategic outcomes (including risk adjusted ROI) is not regarded as a sound business strategy.

6.7.2 RDC achievements

Beth Webster, a prominent Melbourne researcher, wrote in *The Conversation*, on 23 April 2014, that²²

There are now 15 organisations covering products from meat, eggs, wine, and sugar to forestry. Some of the most significant organisations include the Grains Research & Development Corporation and the Cotton Research & Development Corporation. Similar organisations also exist in mining and dairy manufacture.

The success of these organisations is well documented. The most recent evaluation, reviewed by Treasury and the Department of Finance, found for every \$1 invested, \$10.51 is gained over 25 years.

The economic benefits come largely from productivity gains, improved market outcomes and improved quality management.

An increase in value from \$1 to \$10.51 equates to a cumulative annual return on investment of six per cent over the 25-year period. There are many consultants’ reports, commissioned by RDCs that report

²² <https://theconversation.com/rural-australia-has-innovation-lessons-to-teach-us-all-24024>

similarly impressive multipliers. But success and achievement is more nuanced, and the environment is changing. Multipliers are too easily dismissed as diversions by policy advisers: demonstrated success lies in a strong narrative of achievement embraced by stakeholders.

And I come out of the commercial breeding sector, plant breeding sector, seed industry sector, and it has taken off. In the crops area Australia has succeeded where the rest of the world has failed. And that's because of a novel value capture system that was brought in and largely led by GRDC in the first place, and then restructure of the whole industry was led by GRDC the whole way and now that's the envy of the rest of the world.

As an example of how we've made radical, big picture changes to the way the whole industry works. And as a result, we've progressively pulled out of investing in the breeding of wheat, barley, canola, lupines, where we used to be the sole funder basically of it. And now it's market sustainable. And performing at a bar way ahead of where it was before.

That's an example of innovating performance, innovating success coming to a point, how do we quantify that? Do we need to? But we do need to talk about it.

One of the most important aspects of the *Australia 2030: Prosperity through Innovation* strategic plan is the narrative at the beginning of the document about the importance and contribution of innovation.

The Consultation Program also drew out some opposition and questioning of the RDC model. An interviewee with substantial RDC operational experience commented:

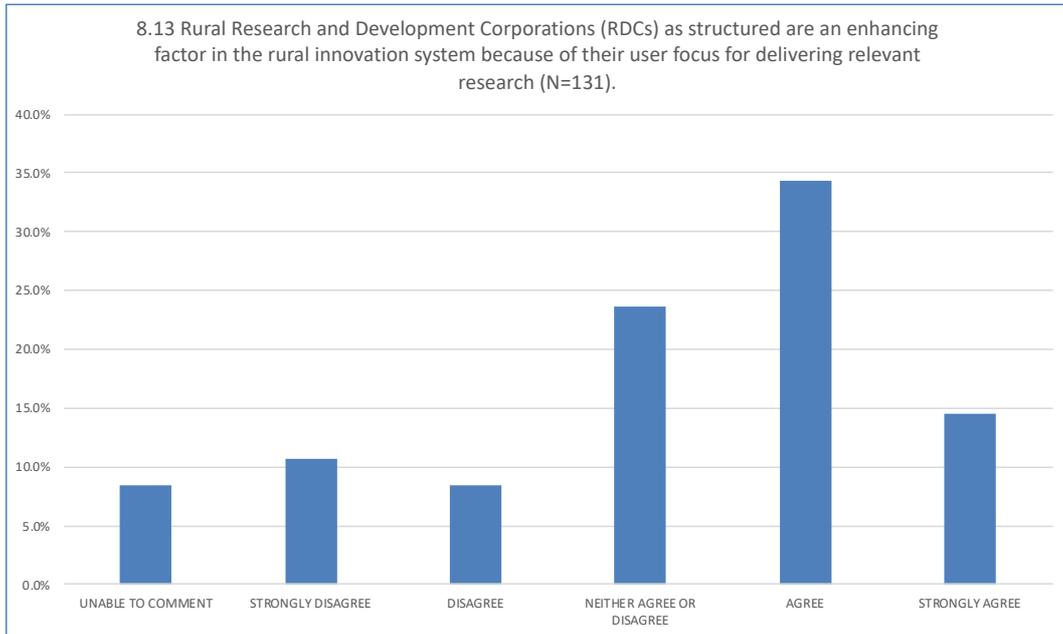
The RDC-based levy funded Rural R&D system is flawed. It was established to enable the collection of levies to mitigate "free rider" effects, but one of the unintended outcomes is a "silo-based" approach to agricultural research. These "commodity R&D-silos" have a single-commodity focused mission which is biased towards productivity gain at the expense of market diversity, biosecurity, and provenance as potential USPs for Australian farmers. This means that there is mismatch between the target outcomes for R&D and the needs of the multi-commodity-based levy-paying farming enterprises that they are intended to serve.

There was an ongoing concern in Consultations that RDCs were too focussed on meeting the short term demands of levy payers and overlooking the longer-term strategic requirements of the rural sector of the economy. Several RDCs have worked out ways to manage this, including the innovative approach of government funds and non-levy supported arrangements with industry partners, such as through the MLC Donor Company. This is addressed further below.

Nonetheless, across Consultations and from the Expert Opinion Survey there was a reasonably high level of support for RDC achievements. This is reflected in Figure 104 in response to the proposition that:

Rural Research and Development Corporations (RDCs) as structured are an enhancing factor in the rural innovation system because of their user focus for delivering relevant research.

Figure 104: Expert Opinion Survey – Extent to which RDCs are an enhancing factor in the rural innovation system



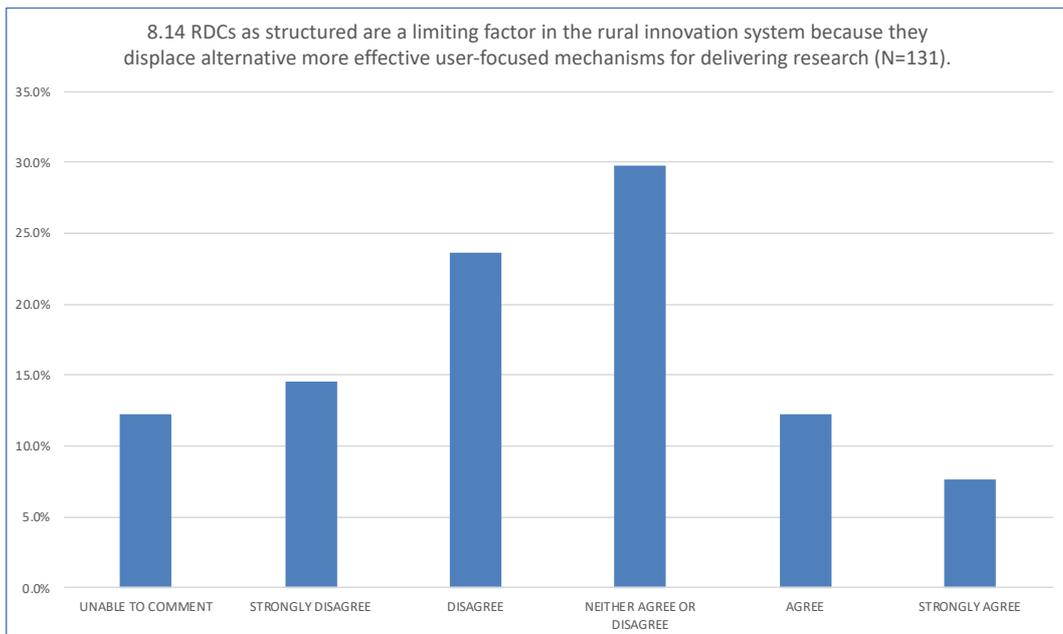
Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

A contra proposition was also included in the Expert Opinion Survey:

RDCs as structured are a limiting factor in the rural innovation system because they displace alternative more effective user-focused mechanisms for delivering research.

There was only limited support for this position, as shown in Figure 105, although there is a high level of ambivalence.

Figure 105: Expert Opinion Survey - Extent to which RDCs displace alternative user focused mechanisms for delivering research



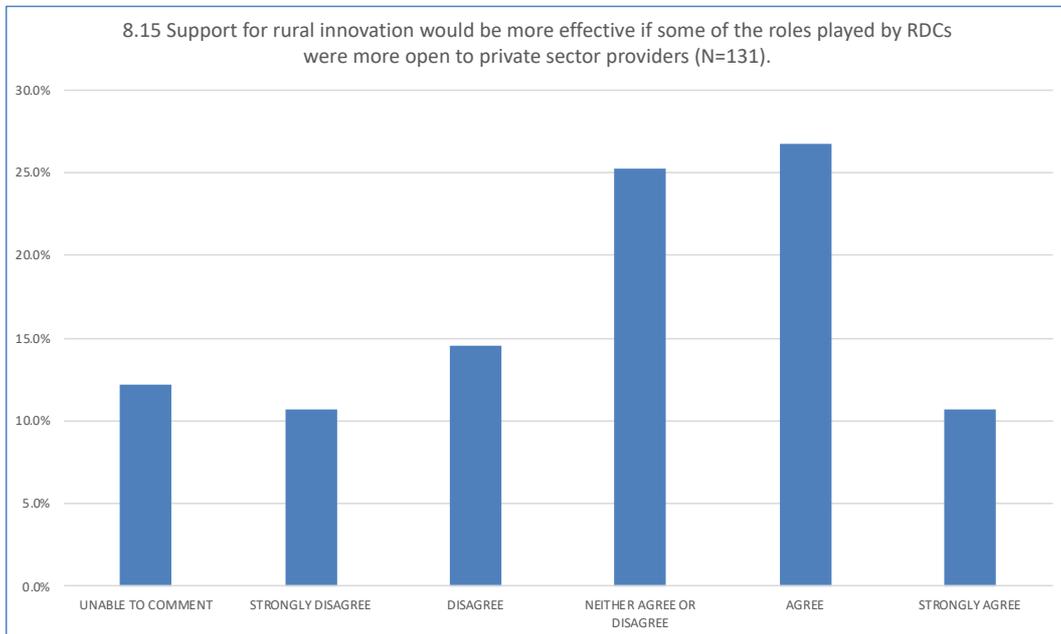
Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

In Consultations there was some suggestion that RDCs were “crowding out” private research providers. The Survey included a “contestability” the proposition to the effect that:

Support for rural innovation would be more effective if some of the roles played by RDCs were more open to private sector providers.

The responses, indicating modest agreement, are provided in Figure 106.

Figure 106: Expert Opinion Survey – RDC roles should be made more contestable by private providers



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

6.7.3 There is not one RDC “model”

The “ecosystem” of an R&D corporation is very dependent on the customer base it works in. Fisheries, for example, works in a marine and aquatic landscape. The environment fits with what it does.

The really nice thing about our legislation is that it is so flexible. And I think if there's one thing going forward, if you look at the benefit, we've just got to keep making it more flexible.

Some RDCs have a strong obligation around compliance – for example, wine, forests, horticulture. A third of the business of Wine Australia is regarded as compliance.

They manage “that thing called a bottle, product of Australia, 750 mls. All the provenance, residues, everything. They're a regulatory body. They're secondary a marketing body, and then lastly, they're an R&D body.

Horticulture does a lot of work in with chemicals, that many RDCs do not do.

Some RDCs have a greater commitment to marketing, although this does not qualify for government matching payments. The government wants to support R&D and is very clear about that. However, there is a great deal of *innovation* in marketing, market research, and consumer insight.

Australian Wool Innovation have been innovative at marketing and some RDCs CEOs suggested that they could learn a lot from what they're doing. Whilst some industry sectors do not have to work hard to create demand (like cotton which sells every bale) others must work hard in the market to create demand. With the intensity of global competition marketing becomes increasingly important, and strategic. One CEO commented:

I think one of the great things that the R&D corporations are doing now is they're blurring. It's no longer R&D and it's no longer RD&E. One of the biggest things we do is marketing. Market development, trade development - which is often nothing to do with RD&E.

There is a view that some RDCs have been “been asleep at the wheel” about their communication and messaging, and assessing the impact and value created through the marketing and promotion effort.

There was a view, however, that research and marketing are two different things, two different sets of skills and capabilities, but with the same board and organisation running both. This should not suggest a separation of function but a combination of people with deep research and commercial backgrounds working to achieve results and outcomes.

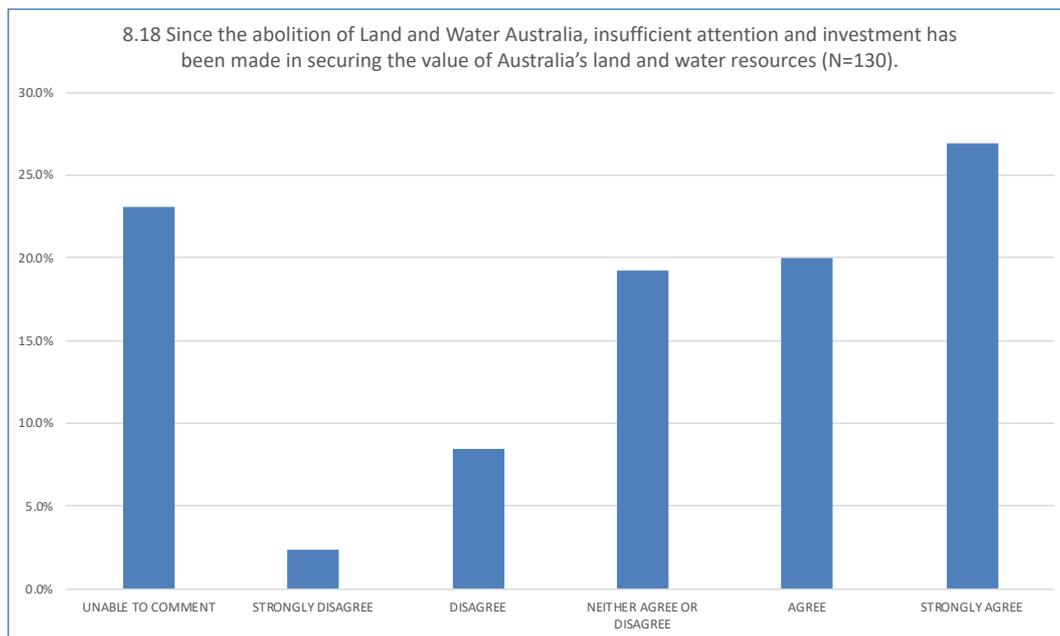
In a corporate and strategic sense, it is the task of boards and general management to integrate research, innovation, and marketing into a consistent and coherent strategy. As in the corporate world, there will always be tensions, but it is important that understanding of markets informs research, and marketing is informed of technical opportunities based on the latest discoveries and technologies. It is a creative, but productive, tension.

6.7.4 Land and water – a missing dimension

The former CEO of Land and Water Australia commented that “the whole architecture [of the RDC model] was just fatally wounded when they took Land and Water Australia out of the system”. The Minister at the time now acknowledges that the decision to abolish LWA was flawed. It took away the integrating dimension of the system.

There was a generally high level of agreement to the proposition that “Since the abolition of Land and Water Australia, insufficient attention and investment has been made in securing the value of Australia’s land and water resources”. This is indicated in Figure 107 below.

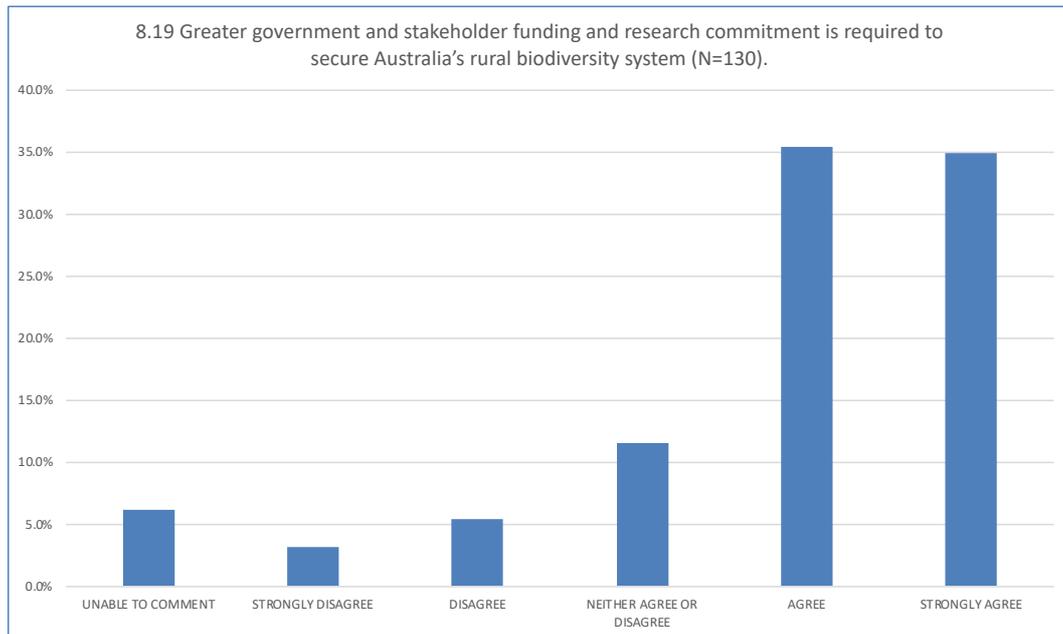
Figure 107: Expert Opinion Survey – Impact of the abolition of Land and Water Australia



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

With the abolition of LWA, many RDCs are taking initiatives in land and water areas, but in an overall sense, the environment and biodiversity management effort is seen to be underfunded. This concern is reflected in responses to the proposition that “Greater government and stakeholder funding and research commitment is required to secure Australia’s rural biodiversity system”, as set out in Figure 108.

Figure 108: Expert Opinion Survey – Concern over Government and Stakeholder commitment to securing Australia's biodiversity system



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

6.7.5 RDC investments in longer term projects

It was observed by several CEOs that most farmers believe that they pay a dollar in levy it will be matched by the federal government. It's not. There's no mechanism to do that.

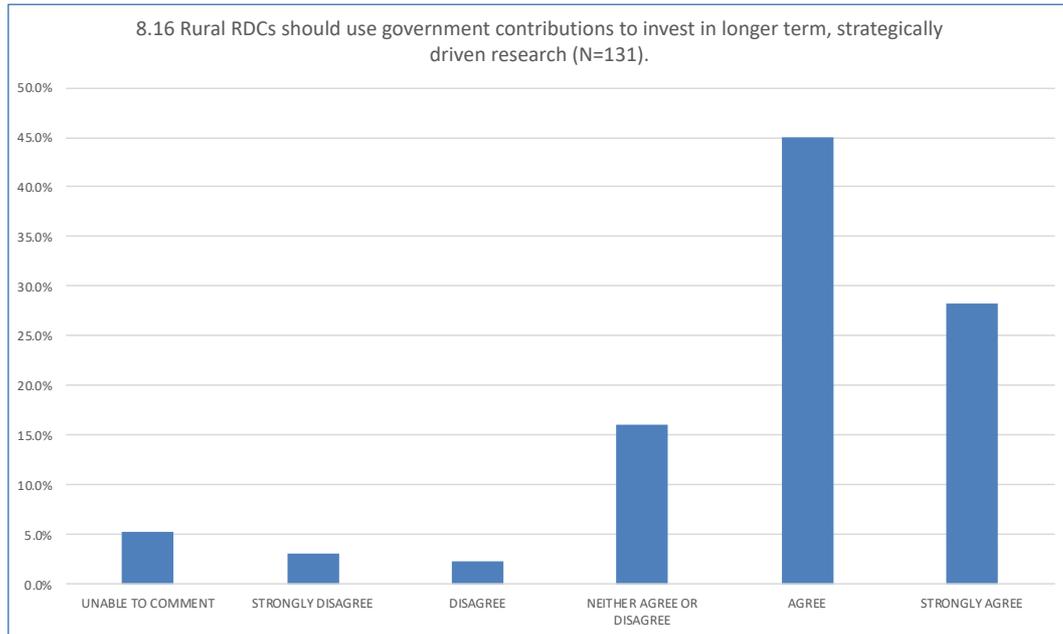
The government pays RDC 0.5 per cent of the gross value of production. And what triggers it is that we spend money out the door, it can be anyone's money, it can be levy money, it can be corporate money, private donor money and then we get co-investment against it from the Commonwealth. But there's this belief that they're entitled to a matching dollar.

But sometimes where your money comes and how money gets to you is a fundamental structural impediment to how you do things. I do think the RDC's going to have to look beyond this levy model. Because inherently it drives some disjointed behaviour where-

It was suggested that if there was movement away from producer-based levies being tied to producers it is possible to come up with a new model which is more flexible about how to use that matching dollar. There was an overwhelming view that the levy system and the nature of the matching contribution needs to be rethought from a strategic and practical perspective.

Consultations and the Expert Opinion Survey indicated that there was very strong support for RDCs to apply the government contribution to longer term strategically driven research. This is indicated in Figure 109.

Figure 109: Expert Opinion Survey – Application of Government Contributions to Invest in longer term, strategically driven research



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

The growing sophistication in some RDCs is seeing investment being approached on a funds management basis. They are identifying two broad fund categories:

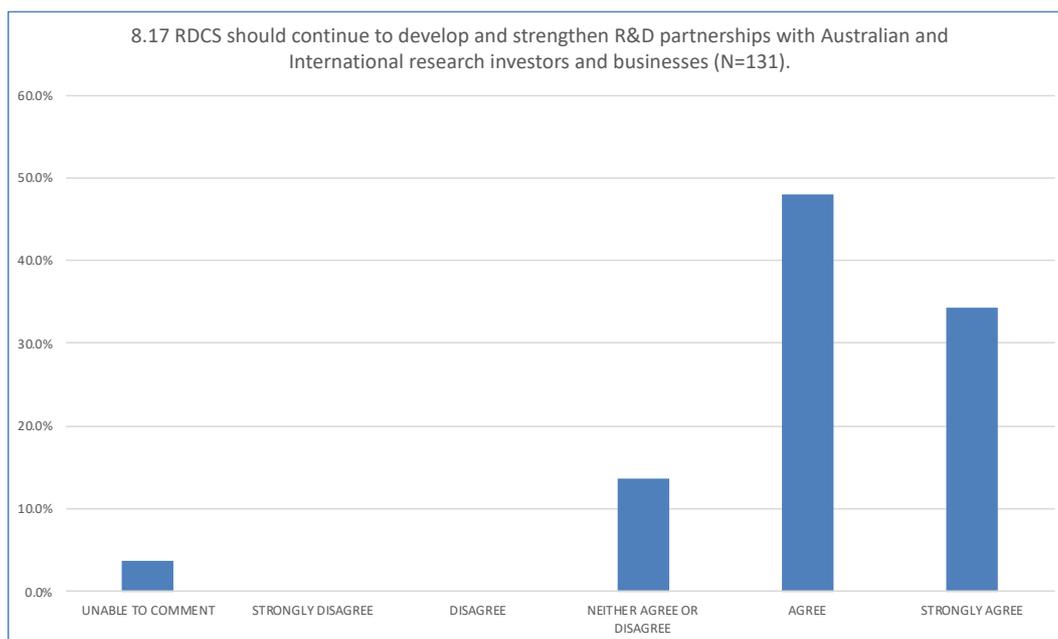
- an industry fund, sourced from levy payments, which is allocated specifically to projects and priorities determined by levy payers. These may be low risk and what were referred to as “farm maintenance” projects.
- a strategic fund, that allocates government contributions and other revenue sources to leverage investment from partners organisations to create longer term value and will have longer term impact.

When we are dealing with the government's money, we need to think longer term. We need to think about not what the growers want today, we need to be able to use government money to anticipate what they growers will want in five or 10 years and then go to the research community and say what do you think you can provide in five or 10 years? What will they need and where do they think the science is going to go? We wanted the government money to do, was to use the higher risk, more long-term, blue-sky type money.

Whereas the growers always wanted to solve last years' problem next year, it was a wet harvest, or it was a cold start, we need to get varieties that are better in cold temperatures in October. When you come to us with some ideas, we will see what we can do. Whereas with the government money, you can say, let's really go beyond that and let's be far more adventurous, riskier.

There was a high level of support for the proposition that RDCs “should continue to develop and strengthen R&D partnerships with Australian and International research investors and businesses”, as indicated in Figure 110.

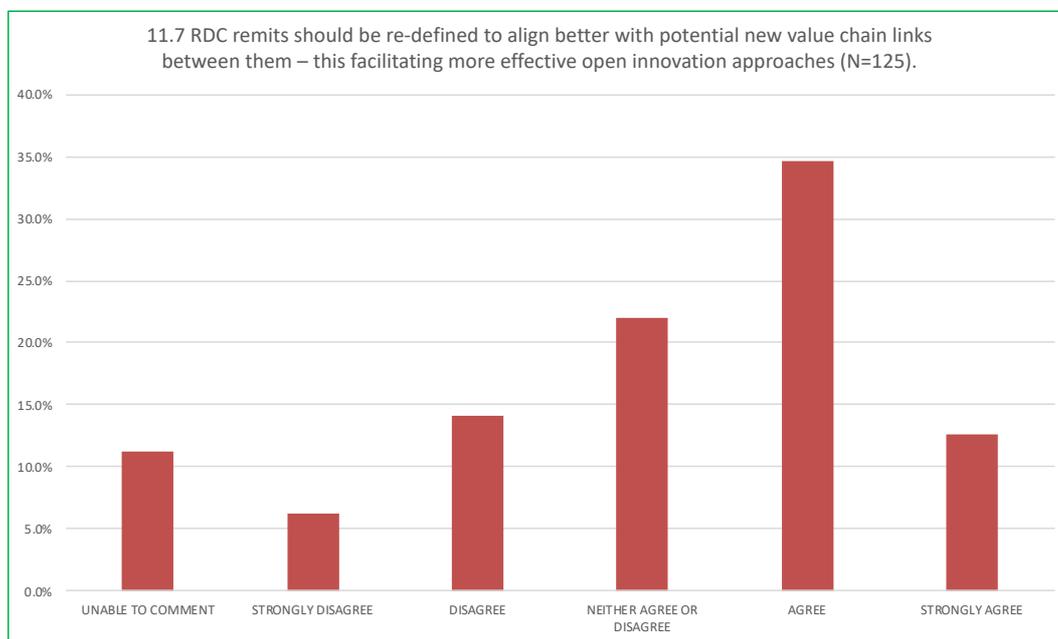
Figure 110: Expert Opinion Survey – International RDC engagement



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

There was also strong support for the proposition that “RDC remits should be re-defined to align better with potential new value chain links between them – this facilitating more effective open innovation approaches”. This is indicated in Figure 111.

Figure 111: Expert Opinion Survey – RDC alignment with potential new value chain linkages



Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey

6.7.6 Communication and networking

RDCs create opportunities for learning new processes from each other, and a lot of it is informal. Business managers, R&D managers, communication managers come together to create “communities

of interest” that involve exchanging knowledge and ideas all the time. This is seen as powerful but is not necessarily highly visible. But that is happening all the time.

Just like any network, it's the effort you put into it. The personal relationships. There are some things that are programmed, like through the Council's RDC's team, programmes regular meetings, periodic meetings of the various communities, but we are so often inspired by the next request from the government.

RDCs have collaborated on the R&D for profit grants program and a Best Management Practice Program, which includes work, health, and safety issues.

RDCs indicated that that they do not do enough seconding staff across each other. Bringing in that skill from horticulture, there's some fantastic people in the RDC. This is particularly important for the smaller RDCs.

6.7.7 Challenges and solutions

Many see that the RDC model needs structural change. Others see the model as having served the Australian rural sector well. But the context is changing as RD&E moves with the “waves of innovation” referred to earlier in the Report. A CEO of GRDC commented:

I think it's a good model. Could it be better? Of course, it could be better, I'm sure it could be. And it is the envy of the world and when you look at, I've done a lot of reviews of grains research models around the world and Australia is way, so far ahead because of the RDC system.

There was a widespread concern in the consultations that “we are just not thinking cross-sectorally”. A comment was made that -

... our whole funding architecture makes that worse, with the commodity based RDCs. That's where the most discretionary cash is in the system. It's the single biggest line in DAWR's budget. And so, we've had to cobble together these very clunky, cumbersome things like the CCRSPI, the Climate Change Research Strategy for Primary Industries, where you go around and try and tax each R&D corporation a little bit of money to put a collaborative program together. And you can't do anything on the sort of scale or projection. That should be a 20-year research program, with hundreds of millions of dollars.

There was a view that there might be too many RDCs. GRDC CEO commented -

Now you must ask questions however, why are there so many? In a livestock area, that's scary. And the grains area is aimed at the plant area, there's less of that, but there's still quite a bit. Every cotton grower's a grain grower. Last time I looked, rice was a grain as well. We could go on.

One of the big strengths of GRDC is the fact that we have 25 crops. And we don't have independent wheat growers saying, "I want my contribution back". So, wheat is subsidising other things because wheat's the big one. It is subsidising potential growth in our crops and work with the horticulture sector.

Technically RDCs are only allowed to work on their 'sector'. This is seen as by some as “bizarre and works against collaboration”.

If you really want to evolve the RDCs from 15, it could be that we'll get merged into some mega protein RDC or mega something. Who cares? If it's more efficient and effective and delivers to my customer.

The solution isn't necessarily to change the structure. It may lie more in clear strategy, with structure adapting overtime. The solution is to take an interactive approach that combines:

- RDCs being part of the framework that develops a *Rural Industry Strategy* that guides government, the research sector, and business in delivering outcomes and results.
- Providing incentives for RDCs, particularly the larger ones to take a lead role in cross sectoral initiatives
- Empowerment of growers, farmers, producers to drive their own R&D and that means that the R&D corporations have got to become demand driven rather than supply driven.
- Leading from the Boards, with long term strategies based on foresight, global industry analysis and trends, and new approaches and technologies that will make a difference.

Policy should facilitate structural changes where structure stands in the way of achieving strategic outcomes.

6.8 Maximizing the returns from public research investment

It is often claimed that the returns from research will be greater if the research enterprise is more focused on applied rather than basic research. However, a recent report for the US National Academies, *Furthering America's Research Enterprise*, (Celeste et al., 2014) argues that the best way to boost economic returns from research is to focus on "three pillars":

- A talented and interconnected workforce
- Adequate and dependable resources
- World-class basic research in all major areas of science.

In other words, America will gain the concrete benefits of applied science and technology by fostering a broad portfolio of basic research.

The *Furthering America's Research Enterprise* Report confronts the popular mantra that basic science is driven purely by intellectual curiosity (and maximising scholarly publication output), without regard for practical applications and argues, and argues that for the most part, this perception is wrong:

Scientists want to solve important problems. In basic research, importance is defined by more than just intellectual appeal; two other factors are also crucial: the potential impact of the result and the realistic possibility of a solution. Science is the art of the soluble, and well-trained, well-connected, and well-supported scientists working on the bleeding edge of our understanding are in a good position to recognize the most promising opportunities for progress. By trying to force our research system to produce a specific practical result, we risk turning scientists' attention away from problems that are ready to be solved toward ones that may not be.

In an Australian context, former Minister for Agriculture, John Kerin recently made the point that –

If it is seen as necessary to define research in separate ways, it is quite simple to work out where the bulk of basic or blue-sky research should be carried out. In Australia's case this should be by the CSIRO and in some of the more capable universities, but not exclusively. For the universities this is dependent on establishing adequate resources (human and capital) to maintain a post-graduate train of professorial supervisors and students. For the rest, I believed in pursuing whichever direction the researchers are led, subject to strong, accountable peer review. I have never believed that politicians, agri-politicians or accountants should determine research expenditure or choose research programmes and projects on a day to day level (Kerin, 2017).

The National Academies report recommends a focus on evaluating the overall quality of our basic research institutions. Australia has been undertaking this task through the ERA, but there is also a need to address questions such as:

- Do we have a capable, well-connected scientific workforce?
- Are we adequately funding research and training institutions over the long term?
- And do we have a balanced portfolio that doesn't neglect major areas of science?

The Report suggests that "right now, we have a hard time answering those questions because the U.S. 'lacks an institutionalized capability for systematically evaluating the nation's research enterprise, assessing its performance, and developing policy options for federally funded research.' If we want to get more practical benefits from our research dollars, we should focus on measuring and supporting our system of basic research.

This Report has contributed to understanding Australia's rural research enterprise and exploring the opportunity for developing a balanced portfolio for research investment suggested by the National Academies and in the Performance Audit for this Review.

7. Conclusion: Aligning the RD&I System with Rural Industry Policy

Key Points

- Innovation systems analysis does not of itself create a strategy. Innovation policy must be connected to rural industry policy to provide context and direction and allow effectiveness to be determined.
- Innovation effectiveness is maximised by 'braiding' together science and innovation capability with a range of complementary business capabilities (strategic marketing, knowledge and systems integration, supply chain management etc.).
- This 'braiding' is what determines the nature and extent of participation in GVCs – this participation is key to economic growth and prosperity because it both determines levels of domestic value added and the ability to leverage other nations' capabilities and markets in generating that value added.
- These policy objectives are best met by transitioning from a focus on innovation strategy and towards a broader Industrial Strategy, in which innovation plays an integral role.

7.1 The rural innovation system as a foundation for rural industry strategy

From a policy perspective, the concept of the innovation system *per se* is of very limited value. Innovation policy came into vogue in the late 1990s as an alternative to *industrial* policy which was at that time associated with providing subsidies for declining industry sectors and 'picking winners'. However, it is very difficult to develop policy around relationships and connections. Policy requires a strategic dimension – what we want to do, achieve, and how we are going to do it.

Countries and policy makers now talk again about *industrial strategies*. In the recently released *UK Industrial Strategy White Paper* innovation is a part, albeit an important one of a broader set of investment initiatives and actions. These were canvassed in a *Green Paper* published a few months earlier (UK. Prime Minister, 2017a, 2017b). The *White Paper* sets out "a long-term plan to boost the productivity and earning power of people throughout the UK". It has a "vision for a transformed economy" based on five ideas:

... the world's most innovative economy; people: good jobs and greater earning power for all; infrastructure: a major upgrade to the UK's infrastructure; business environment: the best place to start and grow a business; places: prosperous communities across the UK. The strategy is the basis to set Grand Challenges to put the UK at the forefront of the industries of the future.

The *Australia 2030 Plan for Australia to thrive in the global innovation race* reflects a resurgence of this strategic approach (Innovation and Science Australia, 2017b). The Plan identifies five imperatives: Education; Research and Development; Industry; Government; and Culture and ambition. These are depicted in Figure 112 below.

Australia 2030 provides a vision for the National Innovation System through an approach that is clearly strategic and outcomes-oriented – rather than an approach based on the extensive descriptions in the *Performance Review* released a year earlier (Innovation and Science Australia, 2016). The *Australia 2030* vision is framed in the following terms:

Innovation and Science Australia's vision for 2030

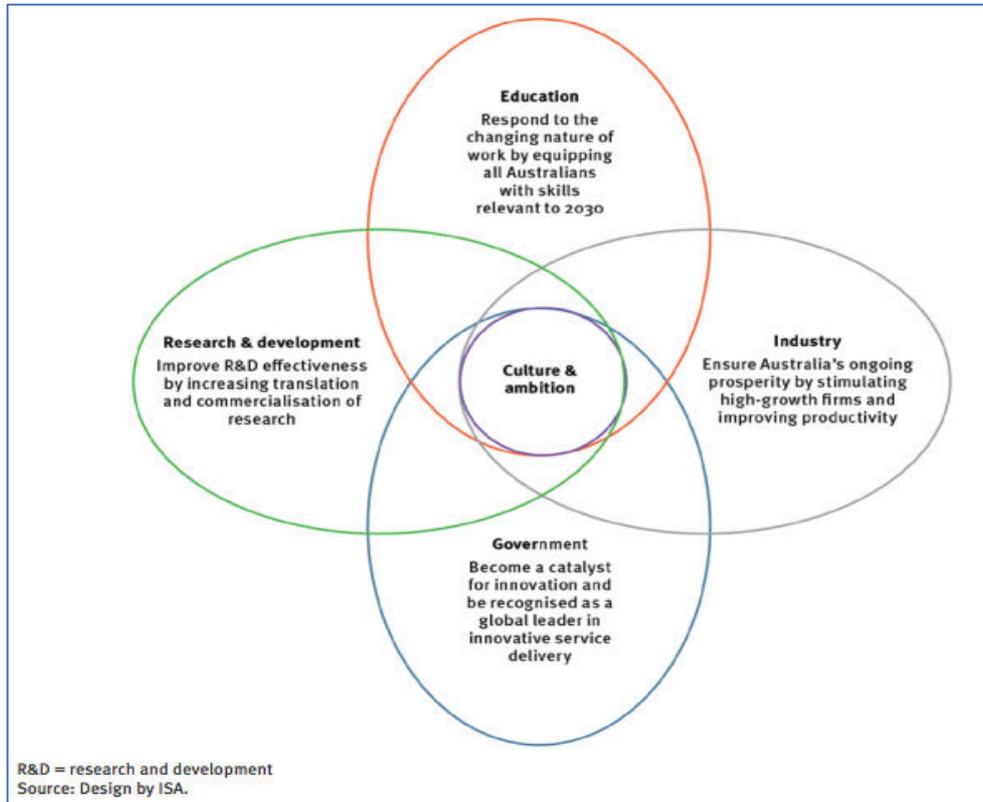
Australia will be counted within the top tier of innovation nations. We will take pride in our global reputation for excellence in science, research, and commercialisation.

Our world-leading strengths in innovation, science and research will benefit all Australians through:

- strong economic growth

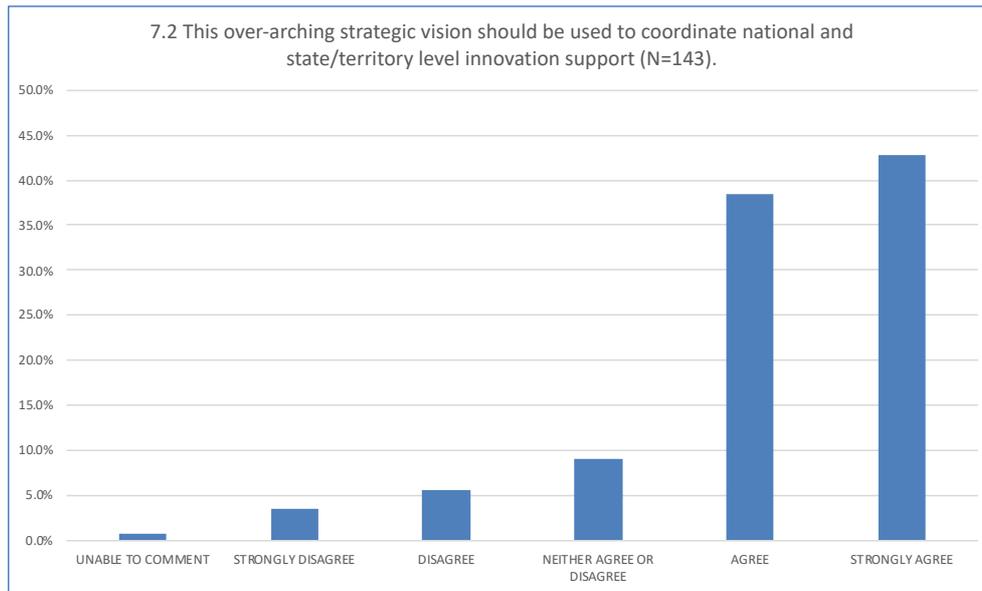
- competitive industries and companies, and collaborative education and knowledge institutions
- plentiful jobs that are meaningful and productive
- a fair and inclusive society with a high quality of life.

Figure 112: Australia 2030. Five Imperatives for the Australian innovation, science, and research system



The Consultations for this Review provided very clear feedback about a strong desire for an overarching “rural innovation system strategy”. The apparent absence of a strategy, and who should be responsible for its development and implementation was one of the more contentious issues raised in the Review.

Over 80 per cent of Innovation Experts saw a role for the strategic vision for rural innovation to guide national and state territory innovation investments, as indicated in Figure 113 below.

Figure 113: Expert Opinion Survey – Application of a Vision for Rural Innovation

Source: Howard Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

To be meaningful, an innovation system strategy must link to an industrial strategy for the rural industries, and guide development and actions in the many systems that impact on overall innovation performance. It does not make sense to talk about an outcome unless there is a strategy that sets out what it might be and how to get there. Creating a vision is the first step in strategy development.

An understanding of the rural innovation system is a *platform* for the development of rural industry strategy. This is provided in the accompanying document, *Performance Report of the Rural Innovation System* (Document C).

Developing strategy is only the first part of the exercise: a more difficult and complex exercise is working out ways to implement the strategy, with clear responsibilities and accountabilities, over what time period, the resources required, arrangements for reporting progress, and provisions for review and updating. Strategy papers are living documents and should be amenable to adjustment as situations and circumstances change.

7.2 Braiding together Science, Research, and Innovation Capability

Research on Global Value Chains (GVCs) undertaken by Dr Mark Matthews for the Review concluded that the Australian rural economy's participation in GVCs is (as would be expected from studies of international trade) is sensitive to the 'tyranny of distance' and, as a result, unusually dependent on domestic upstream and downstream value chain linkages and on domestic final consumption over international final consumption.

This structural consideration highlights the importance, to the Australian rural economy, of innovations that mitigate distance from market. This, in turn, suggests that the return-on-investment from innovations that focus on ways of lifting GVC participation are likely to exceed the return-on-investment from rural production per se – the latter is a dominating aspect of current rural innovation efforts.

This conclusion is aligned with the basic, and well-known, innovation strategy principle that primary production activities, such as occurs in the rural economy, are the lowest value-added stage in value chains. Hence, value added (and associated productivity gains) can be increased by innovations that will allow Australia to benefit from participation in both upstream and downstream value chain segments. These tend to be the intangible segments of value chains.

For example, developing and exploiting rural innovation intellectual property and know-how as *itself* an export that lifts GVC participation (something that technologically sophisticated nations like Israel have been prioritising).

This does not mean that policy should ignore or play down the importance of rural production: it does mean looking at the value chain as the smallest unit of analysis.

In terms of the mind-sets that shape strategy (whether innovation specific or in broader industrial strategy terms), these findings highlight the importance of using an understanding of GVC participation *itself* to set objectives, rather than setting objectives too narrowly around traditional 'farm' and other rural industry domains. However successful production-based innovation is, the payoffs will be limited by geographical challenges in translating what is grown on land and in water into downstream GVC participation.

In terms of the evidence-base, the potential therefore exists to build on this approach by generating an updated profile of the rural economy's GVC participation and using this profile to both define opportunities for pursuing a Rural Economy Industrial Strategy for Australia, and for tracking progress achieved by this strategy over future years.

There are major advantages to 'braiding' together science and innovation capability with a range of complementary business capabilities (strategic marketing, knowledge and systems integration, supply chain management etc).

The dividend to public and private investment in innovation is maximised when this braiding is effective but is constrained when this braiding is not effective. The combined innovation and industrial strategy outcomes that result are reflected in increased participation in Global Value Chains.

7.3 Reframing Rural Innovation Systems Analysis as Rural Industry Strategy

In Section 1.2.3 above (page 192) several deficiencies of the Rural Innovation Systems approach to Strategy were identified. Outlined below are four characteristics of a Rural Industry Strategy built on innovation:

7.3.1 Ambition

An explicit focus on the generally accepted three "strategic horizons"-

1. defending and extending existing lines of activity, notably around efficiency, productivity, quality, security, traceability, provenance, marketing, automation, robotics, analytics, and AI
2. developing new lines of activity to exploit in the future, particularly around new and emerging areas of science and technologies, meeting new regulatory requirements.
3. creating new options for possible future exploitation arising from (for example) global shifts in consumer tastes and preferences, end user requirements, social and community values, and mass urbanisation.

Such a focus would re-balance the current dominating emphasis on 'tactical' concerns (notably productivity) by adding longer-term strategic considerations.

Without this strategic imperative there is a risk that the current policy framework will simply lock Australian rural industries into the current status-quo – limiting the ability to exploit the higher value added and skill profiles opened up by stronger GVC participation.

7.3.2 Translation

The translation of this more balanced strategic focus into a general *Strategic Investment Framework* (SIF) for the rural industries.

The SIF would articulate the different pathways via which Australian rural industries can increase their value added (hence productivity by identifying and exploiting opportunities to increase participation in the system of GVCs that comprises much of the world economy).

The SIF would, by design, not restrict actions and support to activities that are easily appraised and evaluated. Rather, it would recognise that the best strategies are aspirational and motivational and are at their strongest when not bogged down in Key Performance Indicators and other empirical justifications.

7.3.3 Evidence-informed but not evidence constrained

The SIF would be grounded on the sort of comprehensive evidence-based assessment deployed in this Review: a thorough mapping of the nature and extent of current Australian rural industries participation in GVCs and the trends in this participation to date.

7.3.4 Integrative

Finally, the SIF will adopt an integrated stance regarding the links between R&D, innovation, and business strategic and practices. Rather than examining how well R&D and innovation efforts and converted to business success, the emphasis will be on how business strategy formulation and delivery can be assisted by R&D and innovation.

This approach calls for “system integrators”, a role that traverses the whole value chain. It could be a role for the Rural Industries Research and Innovation Committee.

7.4 Concluding comment

There are strong empirical and conceptual grounds for re-framing Australia's approach to maximising the effectiveness of the rural innovation system as a broader *Industrial Strategy* challenge. Innovation is a necessary but not a sufficient component of an Industrial Strategy.

An Industrial Strategy brings together a range of complementary public policy concerns in a way that has a greater likelihood of success than persisting with long-standing support for innovation in a more stand-alone manner.

A major policy implication is that Australia should re-imagine ‘innovation systems’ (and associated ‘innovation strategies’ intended to lift the effectiveness of these systems) as Industrial Strategy objectives. Strategies for a rural innovation system (per se) are not required, rather a more focused and forthright Industrial Strategy for Australia’s rural economy is.

This strategy would be most effective if it started by considering how Australia’s participation in Global Value Chains could be improved (the ‘ends’) and then moved on to consider how best to deliver on these strategic aspirations (the ‘means’).

Other important dimensions of this strategic approach would be to avoid making risky trade-offs when lifting participation in Global Value Chains: these Industrial Strategy pathways should be environmentally sustainable (crucially not running down our stocks of natural capital in the process).

Research undertaken for this Review demonstrates that it is now possible to provide empirical evidence on rural industries’ participation in GVCs and, also, to start to link that analysis to the value of the natural assets that drive and facilitate that participation.

The Review has concluded that the availability of new data on GVC participation, combined with the potential to formulate a more ‘rounded’ approach to innovation grounded in a broader Industrial Strategy, creates the right conditions for a sea change in rural industry strategy.

It is also in this context that Governments must be clear about what they expect from our national research organisations, including government research institutions and universities, in terms of their contribution to the delivery of an industrial strategy.

The Partnership between Government and Universities is under stress as governments seek to achieve budgetary savings by reducing grants, exert more detailed process accountability, and universities become lobbyists for additional funding.

Appendix 1: Trends and Outlook for Rural Production

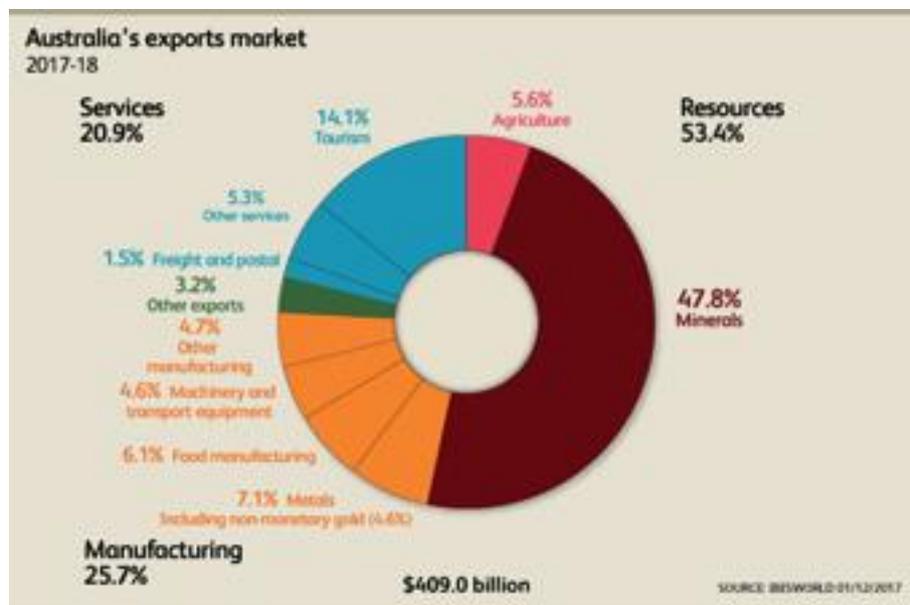
IBIS World

A key export sector

Exports generate income and wealth for Australians. Agriculture makes up 5.6 per cent of exports, but when combined with food processing, food and agriculture makes up 11.7 per cent

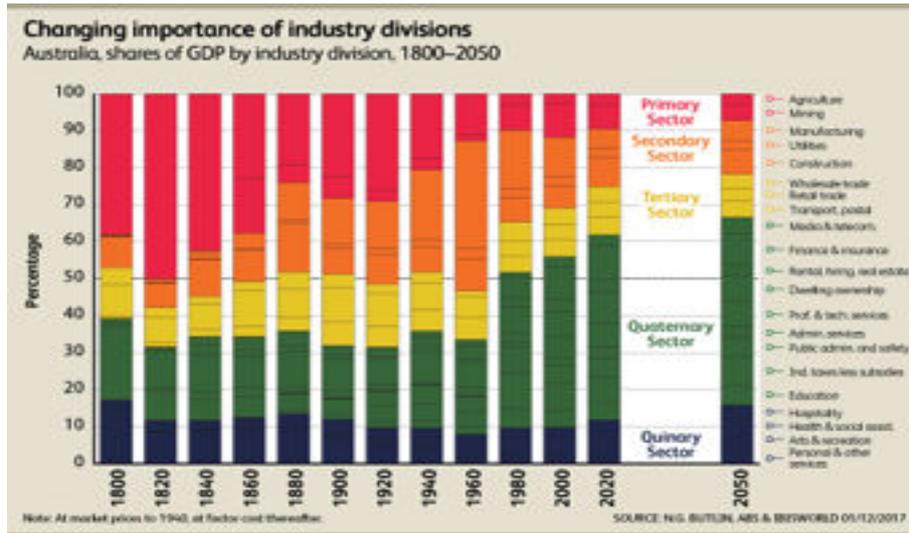
IBIS –

The world still believes that Australia has a resource-based economy, even though that ceased to be true well over 50 years ago. However, given that our exports are more visible to the world than our domestic economy, the perception is understandable. After all, our natural resources currently make up over half of our total exports, as seen below.



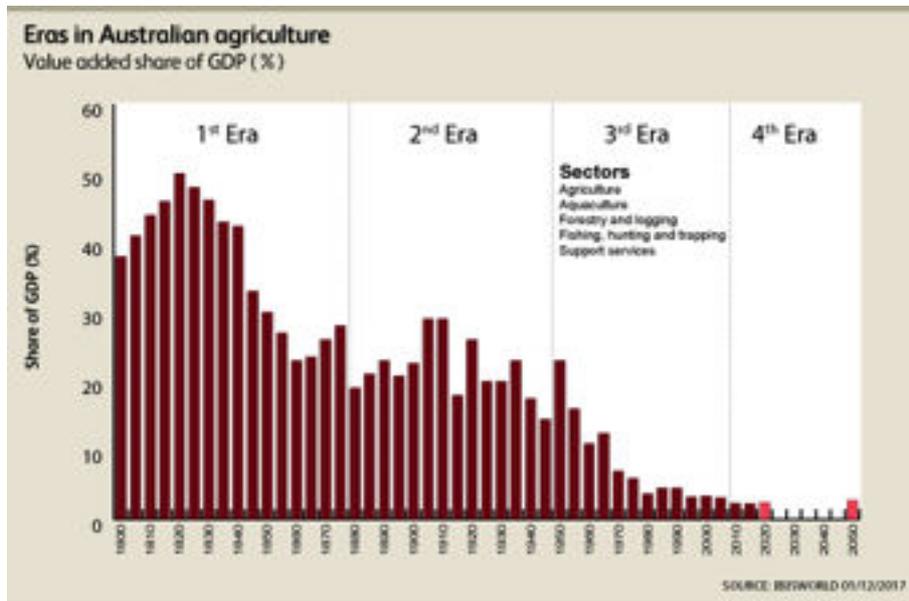
However, when it comes to our total economy, our natural resources of agriculture and mining account for just a tenth of GDP, a far cry from their once-dominant share. But statements in terms of proportions can be misleading, as actual; volumes are increasing.

But there is a lot of potential.



In the USA, their natural resources contribute just 2.3% of their GDP.

Eras of Australian rural production



ABARES projections

From *Agricultural commodities, March quarter 2017* (Australia. Department of Agriculture and Water Resources, 2017)

Table 19: Actual and estimated gross value of production (\$m, current prices)

	2014-15	2015-16 s	2016-17 f	2017-18 f	2018-19 z	2019-20 z	2020-21 z	2021-22 z
Farm	54,431	58,907	63,791	61,296	62,711	63,967	65,257	67,070
. Crops	27,438	28,175	33,866	30,049	30,225	30,766	31,564	32,649
. Livestock	26,993	30,732	29,925	31,248	32,486	33,200	33,693	34,421
Fisheries products	2,761	2,967	3,028	3,000	3,036	3,079	3,152	3,247
Forestry products	2,034	2,271	2,272	2,275	2,280	2,287	2,254	n/a
	59,226	64,145	69,091	66,571	68,027	69,333	70,663	70,317

a. Base 16-17 Australian dollars. c For a definition of the gross value of farm production see Table 13. d Chain-weighted basis using Fisher's ideal index with a reference year of 1997-98 = 100. e Gross value of farm production less total cash costs. f ABARES forecast. g Gross value of farm production less

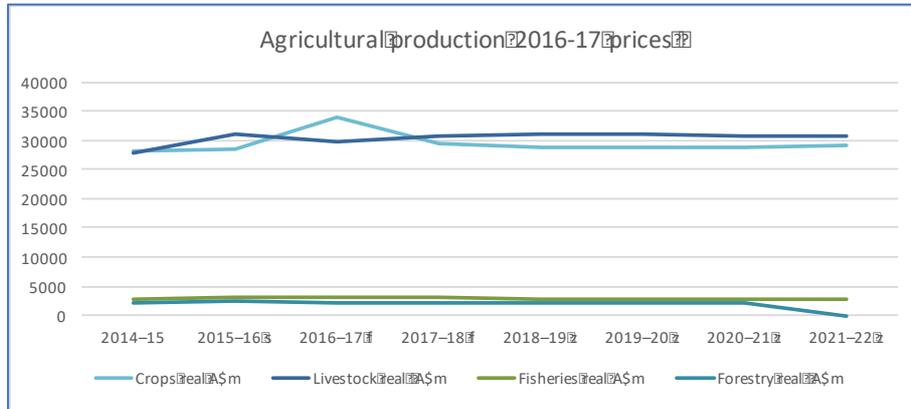
total farm costs. h Ratio of index of prices received by farmers and index of prices paid by farmers, with a reference year of 1997–98 = 100. s ABARES estimate. z ABARES projection. na Not available.

Sources: ABARES; Australian Bureau of Statistics; Reserve Bank of Australia

Estimated to grow to over \$70 billion by 2021-22, from \$69 billion in 2016-17.

Forecast in real terms much more pessimistic perspective.

Table 20: Actual and estimated value of agricultural production, real terms



From the Report:

The real value of agricultural production increased over the three years to 2015–16, at an average rate of 5.3 per cent a year. This period of solid growth coincided with strong demand for Australia’s exports, favourable global market prices for livestock, a depreciating exchange rate and subdued growth in input costs.

Poor seasonal conditions early in the period detrimentally affected crop production and returns to producers. However, lower crop production was more than offset by increased returns from livestock production. This was the result of higher slaughter rates, as producers responded to reduced pasture availability caused by dry conditions.

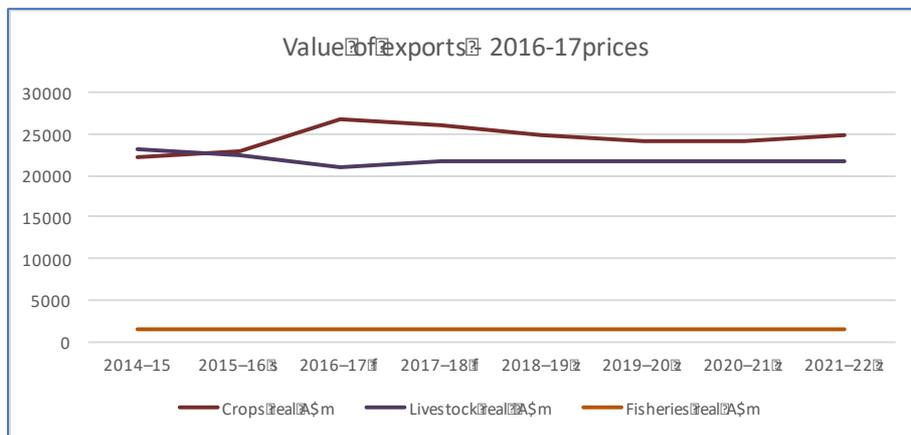
Returns to producers continued to increase in 2015–16 as a result of a rise in crop production nationally and ongoing high cattle turn-off in major cattle-producing regions of Queensland.

But the outlook for next few years doesn’t look good. The export outlook is also not strong:

The total real value of Australian agricultural exports increased for seven consecutive years from 2008–09 to 2014–15. This growth can be attributed to domestic and foreign factors. Global demand for food, particularly from Asian countries, has led to a rise in Australian exports to Asia. Growth in this region is projected to remain strong.

Productivity growth in Australian agriculture has led to a rise in total farm production and an ability to compete in world markets despite being a higher-cost producer. Factors such as changes in seasonal conditions and the value of the Australian dollar have had a more temporary impact on export growth.

Table 21: Actual and estimated value of agricultural exports, real terms



Such predictions do not always take account of technological change and underlying changes in market demand. They are also relatively short term.

The outlook for commodity categories is summarised below.

Table 22: ABARES Commodity outlook summaries to 2021-22

Commodity	Outlook
Crops	
Wheat	<ul style="list-style-type: none"> Wheat prices are projected to remain low in the short to medium term because of abundant world supplies and competition from other feed grains on the global market. World production of wheat is forecast to decline in 2017–18 but increase in the medium term as average yields return to historical trends. Australian wheat production and export volumes are forecast to fall from large volumes in 2016–17.
Coarse grains	<ul style="list-style-type: none"> World coarse grain indicator prices are forecast to remain historically low in 2017–18 and over the medium term, reflecting abundant world grain stocks. Consecutive years of increasing production have resulted in record world stock levels. Australian coarse grain production and exports are forecast to fall in 2017–18 but to increase over the medium term.
Oilseeds	<ul style="list-style-type: none"> The world oilseed indicator price is forecast to average lower in 2017–18, reflecting abundant stocks at the beginning of the year and another year of good harvests in major exporting countries. Over the outlook period to 2021–22 prices are projected to fall because of a continuation of strong yield gains and area expansion in South America. Production is expected to rise over the outlook period due to growth in South America. This is despite a projected price-led drop in planted area in other key soybean- and rapeseed-producing countries. In Australia, canola plantings are forecast to rise in 2017–18, reflecting better returns to producers compared with other cropping alternatives.
Sugar	<ul style="list-style-type: none"> The world indicator price for raw sugar is forecast to increase in the short term to average around US22 cents a pound in 2017–18 as a result of world sugar consumption exceeding production. The world sugar price is projected to fall to average US19 cents a pound, in 2019–20 before rising to US23 cents a pound (all in 2016–17 dollars) in 2021–22 as world sugar consumption grows faster than production and stocks decline. In 2021–22 returns to Australian growers are projected to increase to average \$56 a tonne (in 2016–17 dollars), reflecting higher world prices.
Horticulture	<ul style="list-style-type: none"> The gross value of horticultural production is projected to increase from \$9.3 billion in 2015–16 to \$10 billion in 2021–22 (in 2016–17 dollars). Horticultural exports are projected to increase in the medium term from record levels in 2015–16, supported by new and improved market access. The gross value of Australian horticultural production is projected to increase from \$9.3 billion in 2015–16 to around \$10 billion in 2021–22 (in 2016–17 dollars). The values of fruit and nuts (excluding wine grapes) and vegetables are projected to grow in the medium term, in response to growing domestic demand for fresh produce and favourable export opportunities. The value of nursery products, cut flowers and turf is projected to remain flat in real terms at \$1.3 billion to 2021–22. Production prospects are particularly favourable for irrigated horticultural products in the short term. Macadamia production was steady at around 30,000 tonnes in the 10 years to 2013–14. More recent plantings increased production in 2014–15 to 40,000 tonnes, and production is projected to continue to expand over the medium term. Under the China–Australia Free Trade Agreement, the tariff rate on macadamia nuts is scheduled to decrease from the base rate of 24 per cent to zero in 2019.
Wine	<ul style="list-style-type: none"> The value of Australian wine exports is forecast to increase to \$2.37 billion in 2016–17, supported by strong demand for Australian wine in China and Hong Kong. Over the medium term, the value of Australian wine exports is projected to peak in 2017–18 before declining because of increased competition from Chile, Argentina, and South Africa.
Animal production	
Beef and veal	<ul style="list-style-type: none"> Australian saleyard prices to decline over the medium term as a result of rising competition in major export markets. Average seasonal conditions are assumed to support herd rebuilding. Australian beef production and export volumes are expected to expand gradually to 2021–22. Demand for Australian live cattle is projected to remain relatively robust, supported by strong income growth in major export markets.
Sheep meat	<ul style="list-style-type: none"> Saleyard lamb and sheep prices are forecast to rise in 2016–17 and 2017–18 as a result of restocker demand, reduced turn-off, and strong export demand. The Australian Eastern Market Indicator price of wool is forecast to rise in 2016–17 and 2017–18 before easing in real terms as wool production increases over the medium term.
Pig meat	<ul style="list-style-type: none"> Pig prices are forecast to increase in 2016–17 and remain high in 2017–18 in response to relatively strong consumer demand for pig meat. Pig meat production is projected to rise over the short and medium term as a result of increased slaughter and higher weights. Over the short to medium term, pork consumption is expected to face strengthening competition as beef and sheep meat supplies increase and red meat prices decline. Limited growth in pig meat exports is projected over the medium term, as producers focus on supplying the domestic Australian market with fresh pork.

Commodity	Outlook
Chicken meat	<ul style="list-style-type: none"> • Chicken meat production is projected to continue growing over the medium term, reaching 1.4 million tonnes in 2021–22. • Low retail prices for chicken meat relative to other meats are expected to lead to an increase in per person consumption over the medium term. • Exports of chicken meat are projected to grow by 3 per cent a year to 38,000 tonnes in 2021–22.
Other food products	
Dairy	<ul style="list-style-type: none"> • World dairy prices are forecast to average higher in 2016–17 and 2017–18 in response to reduced production in major exporting countries, the lifting of the Russian dairy embargo and firming demand in Asia, the Middle East, and North Africa. • World dairy prices are projected to increase each year to 2019–20 as world consumption grows faster than world supply. World prices are projected to ease in 2020–21 and 2021–22 as increases in global milk production outstrip growth in consumption. • The value of Australian exports is projected to average higher over the outlook period, peaking at around \$3.5 billion (in 2016–17 dollars) in 2019–20.
Fisheries	<ul style="list-style-type: none"> • The value of Australia's fisheries and aquaculture production is forecast to decline marginally in 2017–18 to \$3.0 billion. Forecast increases in the value of rock lobster, tuna and abalone production are expected to be more than offset by forecast decreases in the value of prawn, salmonid, and other fish. • Over the medium term, the value of Australia's fisheries and aquaculture production is projected to fall in real terms. A projected increase in the value of rock lobster production is expected to be more than offset by lower production values for several other species groups. • The value of Australia's fisheries and aquaculture exports is forecast to rise in 2017–18, reflecting an increase in the value of rock lobster exports. • Growth in Asian economies and tariff reductions from Australia's free trade agreements are expected to support export demand for products from Australian fisheries over the medium term.
Fibres	
Forestry	No outlook
Wool	<ul style="list-style-type: none"> • The national sheep flock is forecast to increase to 73.6 million head in 2016–17 and to continue increasing to around 83 million head by 2021–22.
Cotton	<ul style="list-style-type: none"> • World cotton prices are forecast to increase over the short term as a result of world cotton consumption exceeding production. • In 2021–22 world cotton prices are projected to average around US80 cents a pound (in 2016–17 dollars), reflecting continued growth in world consumption driven by strong demand from non-OECD apparel-producing countries. • Returns to Australian cotton growers are projected to rise to average \$592 a bale (in 2016–17 dollars) in 2021–22, reflecting higher world prices. • Cotton exports from Australia are projected to increase to around 1 million tonnes in 2021–22 from a forecast 774,000 tonnes in 2016–17.

ABARES has a strong production focus and tends to be very conservative. An essentially economic projections, based on economic modelling, they do not necessarily reflect opportunities through innovation and technological change.

Appendix 2: Institutional Capability for RD&I – A Summary

The Australian Rural Research and Innovation System has a very extensive capability for undertaking and delivering research outputs, outcomes, and impacts. This capability has been built up over many years and represents a very substantial national asset. The significance of this capability is often overlooked in transactional and financial perspectives of the innovation system. Detail is provided in *Research Report 3: Key Institutions in the Rural Innovation System*. A summary listing is provided below.

University capability

- Sydney Institute for Agriculture, The University of Sydney
- Ag Health Australia - The University of Sydney
- Animal Genetics and Breeding Unit (AGBU) – UNE
- UNE Centre for Agribusiness
- Cotton Hub at UNE
- PoultryHub Australia
- The Australian Centre for Agriculture and Law (AgLaw) - UNE
- The National Centre of Science, Information and Communication Technology, and Mathematics Education for Rural and Regional Australia (SiMERR)
- Graham Centre - CSU
- National Wine and Grape Industry Centre - CSU
- Southern Cross Plant Science - Southern Cross University
- Forest research centre - Southern Cross University
- Institute for Sustainable Futures, UTS
- The University of Melbourne, Faculty of Veterinary and Agricultural Sciences
- Institute for Agriculture and Food, La Trobe
- Centre for Regional and Rural Futures, Deakin
- Centre for Frontier Materials, Deakin (fibre technologies)
- Queensland Alliance for Agriculture and Food Innovation QAAFI, UQ
- Institute for Future Environments, QUT
- Institute for Agriculture and the Environment, USQ
- Centre for Crop Health, USQ
- National Centre for Engineering in Agriculture, USQ
- ARC Research Hub for Advanced Prawn Breeding, JCU
- Centre for Sustainable Tropical Fisheries and Aquaculture, JCU
- Waite Research Institute - University of Adelaide
- Australia-China Centre for Agriculture and Health & University of Adelaide
- Shanghai Jiao Tong University Joint Laboratory for Plant Science and Breeding, Adelaide
- Australia-China Joint Centre Research Centre in Grains for Health, Adelaide
- Fertiliser Technology Research Centre, Adelaide
- FoodPlus Research Centre, Adelaide
- UniSA Agricultural Machinery Research and Design Centre (AMRDC)
- Centre for Climate Adaptation and Animal Behaviour, Flinders
- Centre for Marine Bioproducts Development, Flinders
- National Centre for Groundwater Research and Training, Flinders
- University of Western Australia Institute for Agriculture
- Tasmanian Institute for Agriculture
- Fenner School of Environment and Society - ANU
- ANU CSIRO agriculture research lab

Commonwealth Government

- CSIRO Agriculture and Food
- Boorowa Agricultural Research Station

New South Wales

- Australian Cotton Research Institute, Narrabri
- Bathurst Primary Industries Centre
- Beef Industry Centre, Armidale
- Condobolin Agricultural Research and Advisory Station
- Cowra Agricultural Research and Advisory Station
- Dareton Agricultural Research and Advisory Station
- Deniliquin Agricultural Research and Advisory Station
- Elizabeth Macarthur Agricultural Institute, Menangle
- Glen Innes Agricultural Research and Advisory Station
- Gosford Primary Industries Centre
- Grafton Fisheries Centre
- Grafton Primary Industries Institute
- Narrandera Fisheries Centre
- NSW Centre for Tropical Horticulture, Alstonville
- Orange Agricultural Institute
- Port Stephens Fisheries Institute and Research Centre of Excellence
- Tamworth Agricultural Institute
- Tocal Agricultural Institute
- Trangie Agricultural Research Centre
- Wagga Wagga Agricultural Institute
- Wollongbar Primary Industries Institute
- Yanco Agricultural Institute

Victoria

- AgriBio (a joint initiative of the Government and La Trobe University)
- DEDJTR Ellinbank
- DEDJTR Hamilton
- DEDJTR Horsham
- DEDJTR Mildura
- DEDJTR Rutherglen
- DEDJTR Tatura.
- PICCC (Primary Industries Climate Challenges Centre, Parkville)

Queensland

- Applethorpe Research Facility.
- Ayr Research Facility.
- Bowen Research Facility.
- Brian Pastures Research Facility.
- Bribie Island Research Centre.
- Bundaberg Research Facility.
- Ecosciences Precinct.
- Gatton Research Facility.
- Health Food Science Precinct.
- Hermitage Research Facility.
- J Bjelke-Petersen Research Facility & Redvale field site.
- Leslie Research Facility.

- Mareeba Research Facility.
- Maroochy Research Facility.
- Northern Fisheries Centre.
- Queensland Animal Science Precinct.
- Redden Street Research Facility.
- Redlands & QCDF Research Facility.
- Salisbury Research Facility.
- South Johnstone Research Facility.
- Spyglass Research Facility.
- Walkamin Research Facility.
- Queensland Alliance for Agriculture and Food Innovation.

Western Australia

- No government research centres, or institutes entries found. Capability located under universities.

South Australia

- South Australia Research and Development Institute (SARDI)
- Northern Adelaide Food Park
- SA Food Innovation Centre
- A Modern Transport System for Agriculture: A New Partnership Approach
- Australian Pastures Genebank
- South Australian River Murray Sustainability (SARMS) Program
- Sterile insect technology (SIT) facility
- Northern Adelaide Plains Agribusiness Initiative

Tasmania

- Tasmania Institute for Agriculture – a joint venture arrangement. Identifies six centres.

Northern Territory

- Under the Department of Primary Industry and Resources. Research is at Primary industry strategies, projects, and research

Appendix 3: The Connection Between RD&I Investment and Economic Growth

Having identified the vase for public investment in RD&I, this Section addresses another set of questions that were raised continuously through the project: “What empirical proof is there that RD&I investment will drive economic growth? Does an economic model exist? Is a national strategy more important as a driver? What is the balance between science quality and science quantity?”

Key Points

- Yes, there is *some* empirical proof that science drives innovation and economic growth - *over the longer term*; there is more than one economic model
- There has been a shift in concern in focus of modelling from longer term impacts to short term productivity gains
- *Strategy* should drive the Research, Development, and Innovation (RDI) effort – otherwise it is very hard to measure performance and impact
- Science quality is important for securing and extending the knowledge base (basic research); science quantity is important for diffusion. Requires a ‘portfolio’ approach to science investment.
- Investment in R&D complements and augments, rather than supplants, other drivers of productivity and performance improvement. The results of research are cumulative, forming a ‘stock’ of knowledge.
- The results of research are cumulative, forming a 'stock' of knowledge that is applied over time. It is difficult to attribute one outcome to a specific research investment. R&D investment is therefore likely to be more effective if approached and committed on a long-term basis.
- Public funding are not the only policy levers available to address potential under-investment in rural R&D
- RDI investments should be consistent with other policies and programs designed to improve the economic, environmental, and social performance of the rural sector.

Assessments of innovation performance and innovation policy face long-standing challenges in effective *measurement*. It is far easier to measure inputs to innovation (funding, person-hours etc.) and certain science and research related outputs (patents etc.) than actual innovation *outcomes*.

Whilst these outcomes are, at a general level, widely acknowledged to appear in differential rates of economic growth and productivity between countries and regions, and in historical variations in these rates of economic growth, there is a relative weakness in measuring the factors that intermediate between economic growth and innovation. Outcomes for other objectives of innovation policies, such as environmental and social goals, face similar problems of attribution.

This limitation is of concern to policymakers because new initiatives, programmes and projects are strongest (and most likely to be funded) if they can define how their success can be measured. In particular, how their success has helped to generate useful outcomes that would not otherwise have taken place. This Review has been sensitive to these public policy and related methodological challenges and has developed approaches that enable robust assessment.

Measurement is made difficult where results and outcomes are unclear. Generally, rural research investments are expected to have distinct or multidimensional impacts on:

- Farmer income and risk
- The environment
- Health and nutrition
- Regional development and sustainable communities
- Social inclusion.

Sometimes these impacts are phrased in more nebulous terms such as food security or livelihood improvement. Impacts occur at the field, household, regional, national, and international levels.

Some research investments are completed and pay off quickly, while others require many years before benefits are realized and the benefits may last for decades. Some research results depreciate quickly and require maintenance research to forestall a decline in their impacts. The temporal distribution of benefits and costs requires careful assessment of their distribution over time and discounting at appropriate rates.

Rural research also results in both technology and institutional development, and the effects of technologies and institutions spill over geographically. They may be picked up by public and private entities for distribution.

Demonstrating the net benefits of rural research investments are of significant interest to research administrators and funding agencies, and the demand for agricultural research evaluation to estimate those benefits has grown over time. This is addressed below.

Modelling the impact of research on economic growth economic growth

The very substantial literature on measuring the impact of research, science and innovation focuses on three broad, although interrelated areas:

- Economic, social, and environmental impacts - changes in macro indicators such as change in gross domestic product, standards of living and well-being, and loss of natural capital.
- Productivity impact – changes in factor productivity (efficiency and cost reductions)
- Innovation impact – changes that result in the production of new goods and services (market impact)

Over the years there has been a discernible shift of focus from assessing broad economic impact to productivity impact, and more recently to innovation impact. This, in turn reflects a shift in policy interest from longer term national economic and social development outcomes to shorter term tactical results that might be captured from productivity improvements.

Economic, social and environment impacts

The standard model of rural/agricultural research benefits, elaborated for example in *Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting* (Alston et al., 1998) is that research causes the commodity supply curve to shift down and out against a stationary demand curve, giving rise to an increase in quantity produced and consumed, and a lower price. The benefits are assessed using Marshallian measures of research-induced changes in consumer surplus for consumer benefits and of research-induced changes in producer surplus for producer benefits (Alston, 2010).

The social rate of return to investments in rural agricultural R&D using this method has been generally high. Specific findings differ depending on methods and modelling assumptions, particularly assumptions concerning the research lag distribution, the nature of the research-induced technological change, and the nature of the markets for the affected commodities (Alston, 2010).

Agricultural economists have also used supply and demand models of commodity markets to represent agricultural research impacts and the same model is implicit in other studies that infer a rate of return to research from the parameters of an econometric model of production.

In these models the total gross annual research benefits (GARB) depend primarily on the size of the (time varying) research-induced supply shift (expressed as a vertical shift by an amount equal to a proportion, k , of the initial price) and the scale of the industry to which it applies. A common approximation is $GARB = kPQ$, where P is the commodity price and Q is the annual quantity to which the supply shift applies.

Other aspects of the analysis typically have second-order effects on the measures of total benefits but may have important implications for the distribution of the benefits between producers and consumers and others. Measures of the size and distribution of research benefits will be affected by various complications that can be introduced to extend the basic model. In all these approaches there are serious data and attribution problems that need to be addressed.

The overwhelming view of the evidence in modelling literature is that the rate of return to agricultural R&D has been generally very high, implying marginal and average benefit-cost ratios much greater than 1.0. An implication of this finding is that it would have been profitable to have invested more in research and that individual nations and the world have underinvested in agricultural R&D.

Unless we have reason to believe that the benefits from agricultural R&D are characterized by sharply diminishing marginal returns, and there is no empirical evidence to support that conjecture, the very large marginal benefit-cost ratios can be interpreted as meaning the underinvestment was substantial (Alston, 2010).

Although it is generally concluded that the evidence suggests that agricultural R&D has paid off substantially for society, there are concerns about the methods used that can lead to upwards biases in the estimates. These concern biases associated with

- (a) using research lag distributions that were too short (the results showed that increasing the research lag length resulted in smaller rates of return, as theory would predict),
- (b) "cherry picking" bias in which only the most successful research investments were evaluated,
- (c) attribution biases associated with failing to account for the spillover roles of other private and public research agencies, both at home and in other states or other countries, in contributing to the measured benefits, or
- (d) other aspects of the methods used.

In 2011 Alston produced data to indicate that the research and development lag is longer than many studies have allowed, and that misspecification can give rise to significant biases (Alston et al., 2011). But even allowing for possible measurement errors and biases, the evidence suggests that agricultural research has generated very large dividends (Alston, 2010).

Analysis also supports the view that agriculture is characterised by market failures associated with incomplete property rights over inventions and that, despite the significant government intervention to correct the market failure, nations have continued to underinvest in agricultural research.

In a paper "Evaluating Economic Impacts of Agricultural Research: What Have We learned?" (Norton, 2015) observed:

Since publication of *Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting* (SUS) (Alston et al., 1995) the types of impacts being assessed have expanded and become more complex (e.g., impacts on livelihoods), and the methods used for impact assessment have been refined. Issues identified in SUS remain important, new ones have emerged, and research impact assessment has become a growth area of research.

The body of evidence on the benefits of agricultural research continues to mount, even if the quality of agricultural research evaluations is a bit uneven. Data availability and tools for research evaluation have improved, but some studies struggle to match the appropriate method to the type of assessment needed and others cut corners with data or assumptions.

These problems are not unique to agricultural research evaluation. But research evaluation in agriculture presents challenges that other types of impact assessments do not. These cover

... the length of time needed to complete many types of research, mid-stream adjustments in agricultural research protocols for the research being evaluated, and dynamic biological environments add to the normal impact assessment challenges such as multiple goals for interventions, aggregation issues, retrospective versus prospective estimation, and identifying appropriate counterfactuals (Norton, 2015).

Moreover, as public-sector budgets tighten, many governments and donors demand increased accountability and greater care in measuring impacts of research interventions against relevant

counterfactuals – such as “what would have happened if the investments were not made? Would the private sector have taken an initiative”?

Furthermore, impact analyses must confront the simultaneous changing of many factors, such as:

- Non-random roll-out of technologies, and non-random selection of technologies by individuals.
- A dynamic environment in which structural change occurs rapidly across economic sectors
- Demographic and income changes that affect demand for food and plant-based energy
- Climate change.

In summary, impact assessment methods have expanded and been refined over time, demand for non-efficiency objectives has grown, but there are many pitfalls and analysts must be ready to match appropriate combinations of methods to given situations. However, measures of the payoff to public agricultural R&D are potentially useful for policy, and this usefulness will be greater if the measures are transparent, well understood, and credible.

Connections between research, development, and productivity impact

Over the last 10 years policy attention has shifted from broad economic impact of research and development to productivity impact. Recent Australian studies give attention to productivity measurement and change. They do not generally address broader RDE impacts.

Many studies have assumed, implicitly or explicitly, that all measured rural productivity growth is attributable to R&D (or perhaps even a particular source of R&D such as public R&D within a country).

Increasingly, however, questions arise as to how much productivity growth might be attributable to factors other than organised R&D, including evolving weather patterns, institutional changes, or economies of size associated with changing structure of agriculture. Others have argued that it is likely that organised research has been the primary contributor to the observed productivity growth and the important issue is attribution among R&D sources. [a very courageous claim]

Modelling has been able to demonstrate that the annual value of agricultural productivity gains is worth many times more than the annual value of expenditures on research. Literature reviews commonly suggest that benefits from productivity growth attributed to agricultural R&D exceed the costs by an order of magnitude of 10 or more, regardless of methods of measurement or assumptions about attribution (e.g., the shape and length of the R&D lag distribution, inter-regional or inter-institutional spillovers, or the roles of private R&D or extension).

In reporting on productivity growth and the returns from public investment in R&D in Australian broadacre agriculture, John Mullen observed (Mullen, 2007):

- Investment in R&D has long been regarded as an important source of productivity growth in Australian agriculture. Perhaps because research lags are long, current investment in R&D is monitored closely.
- Investment in R&D has been flat while productivity growth has remained strong, relative both to other sectors of the Australian economy and to the agricultural sectors of other countries. Such productivity growth, at a time when the decline in terms of trade facing Australian farmers has slowed, may have enhanced the competitiveness of Australian agriculture.
- The econometric results presented here suggest no evidence of a decline in the returns from research from the 15 to 40 per cent per annum range estimated by Mullen and Cox. In fact, the marginal impact of research increases with research over the range of investment levels experienced from 1953 to 2000, a finding which lends support to the view that there is underinvestment in agricultural research.
- These results were obtained from econometric models which maintain strong assumptions about how investments in research and extension translate into changes in TFP. Hence some caution in interpreting the results is warranted.

Mullen notes that the long lags between the generation of new information through research investments and efficiency gains in agriculture make it difficult to monitor the performance of the

public agricultural research sector. Benefit cost analysis has been often applied *at a project level* both *ex post*, as a measure of accountability, and *ex ante*, to assist in resource allocation. Additional points are made relating to:

- At a sector level, trends in productivity growth and in research investment are often monitored as proxies for knowledge about their causal relationship which has proved difficult to estimate empirically.
- Models being used have had poor time series properties, raising doubts about the existence of a stable long-term co-integrating relationship between research and productivity growth.
- In an international context, there are concerns that both productivity growth and investment in agricultural R&D are falling, particularly in developed economies, with implications for food security in developing countries reliant on technology 'spillovers', whose populations will continue to increase for several decades.
- In Australia there is concern by governments to align large public investments more closely in agricultural research with community goals and concern by the RDCs to earn adequate returns to farmers from the funds they invest.

More recently, ABARES made the strong point in a paper that *over the long term, technological progress is the main driver of productivity growth* and that "public and private investment in research and development (R&D) has contributed significantly to agricultural productivity growth in Australia" (Xia, Zhao, & Valle, 2017).

Referring to earlier ABARES research (Yu Sheng et al., 2011; Y Sheng et al., 2011) the paper concluded:

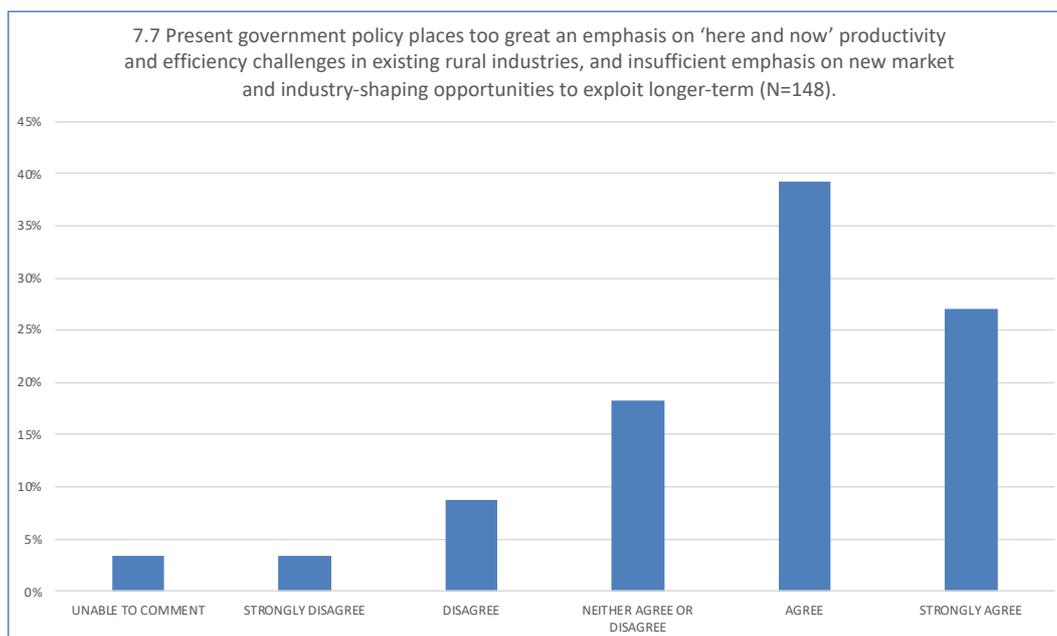
Farmers have captured developments in technology and knowledge by investing in higher-yielding, pest and disease-resistant crop varieties, superior planting and harvesting techniques, and better livestock genetics.

In the *short term*, however, and pointing to measures of productivity growth, and drawing in extensive research, the paper suggests that agricultural industries are particularly sensitive to:

- *Climate variability* - much of the productivity growth between the late 1970s and mid 1990s was the result of generally above average rainfall, which increased cropping yields and contributed to strong pasture growth. A slowdown in productivity growth since the mid 1990s is partly a result of adverse seasonal conditions, particularly during the 2000s.
- *Reforms in Australian agricultural industries* - for example, the removal of marketing and price support mechanisms has contributed directly and indirectly to productivity growth of the broadacre industries. These reforms led to structural change through the amalgamation of farms, better risk management and changes in the mix of agricultural commodities produced. They also altered the allocation of resources between farms, with more efficient producers tending to gain a greater market share over time.
- *Farm size* - which increased over the four decades to 2014–15. Individual farms have expanded, and some small farms have left the industry. Larger farms tend to have higher productivity than smaller farms, partly because they use different technologies. Large farms may benefit more from adopting innovations than small farms because they have the capacity to fund investment, and technology providers are more likely to produce solutions that meet the needs of large farms.

In a policy context, this focus on short term productivity gains appears to have taken precedence over investment in RDI over the long term. A concern with this emphasis was reflected in Consultations and in the Expert Opinion Survey undertaken as part of the Review. This is indicated in Figure 114.

Figure 114: Experts views on policy imbalance balance between 'here and now' productivity challenges vs. new market and industry shaping opportunities



Research undertaken by the US Department of Agriculture Economic Research Service (ERS) reports that the major driver of long run productivity growth is R&D (Wang et al., 2015)²³. However, the Report poses the question – *If public R&D has slowed, then why has there been no slowdown in U.S. agricultural productivity?*

The following explanations are offered:

- There is often a long lag between when a research investment is made and when the product of that research is applied to farm production and starts to boost productivity. *Many studies show that it is the accumulation of past research investment (R&D stock), and not changes in contemporary research investment, that affects productivity growth. While U.S. agricultural productivity has seemingly not slowed to date, if real public R&D continues to stagnate and private R&D fails to compensate for the shortfall, then growth in U.S. TFP is likely to slow eventually.*
- Although there is a strong long-term link between public R&D and productivity growth, spillovers from basic biological science and the rapid growth in private sector R&D over this period may have compensated for stagnant public R&D spending. Encouraging private sector investment in productivity-related science may help foster continued advances in agricultural productivity. *Still, public R&D has an irreplaceable role in developing fundamental science that does not have short-term reward and hence receives less attention from the private sector but provides much of the foundation for long-run progress.*

To show the likely impacts of public R&D funding choices on TFP growth, ERS projected future productivity growth with alternative public R&D investment scenarios, including a 1-percent increase in annual real (inflation-adjusted) public research funding (Scenario 1), constant annual public research funding in nominal dollars (Scenario 2), and a one-time 25-percent drop in public research funding followed by constant nominal funding at the lower level (Scenario 3).

This analysis found that declines in public R&D have a more pronounced effects in the long run than in the short-term. Even if public R&D investment recovers, future productivity growth (in terms of total factor productivity) would take some time to resume due to the lag between research investment and application.

In general, ERS estimates that if R&D spending is raised by 1 percent each year in real terms, the annual rate of agricultural TFP growth will increase to 1.46 percent during 2010-50, compared with

²³ <https://www.ers.usda.gov/topics/farm-economy/agricultural-research-and-productivity/>

1.42 percent during 1948-2011. This would enable the U.S. farm sector to keep pace with increasing domestic and global food demand with its current level of resource use. On the other hand, if public research funding is constant in nominal terms for the next few decades, TFP growth will slow.

Empirical assessments of connections between research, development, and *innovation* impact

Innovation systems (IS) scholars sought to develop a connection to science and innovation through *innovation systems research and analysis*. The driving philosophy of the founders and pioneers of IS was premised on the assumption that science, technology and innovation (STI) are fundamental to economic and social progress, but that one needs effective policies (and effective management strategies) to ensure the potential benefits are actually achieved (B. Martin, 2016). According to Martin:

- It was assumed that STI policy research could provide data, methods, analytical tools, conceptual frameworks and perhaps eventually theories that would help ensure better policies, and that the resulting evidence-based policies would, in turn, lead to greater benefits for humanity.
- Over the last 30–40 years, “there has certainly been some progress about providing relevant data, methods, conceptual frameworks” and some of the advances have had an evident impact on policy, “although that impact has been rather occasional, limited and accidental”.
- There is little evidence that IS efforts have resulted in substantially better policies.

Martin suggests that innovation research has not moved much from the study and understandings of innovation systems and mapping connections. Taking the next step to policy prescription has been challenging. In other words, an Innovation systems approach provides a good basis for understanding how innovation works and has been fertile ground for academic researchers.

There has been a presumption in innovation systems thinking that if system components (institutions) are healthy, connections are good, and resources available, beneficial outcomes will naturally fall into place. But as became apparent many years ago when “systems theory” was popular in scholarly work on the theory of organisation, the approaches lacked a strategic dimension – a vision, a goal, an objective – *what must be achieved, how, when, and by whom*.

There is now a growing appreciation that the innovation system does not necessarily work “systematically”. There are blockages and barriers, disconnections, sub-systems with their own drivers and goals, “off-on” switches, “no-go” zones and the “system” is undergoing constant and dynamic change. Many see this as a “system failure (Dodgson et al., 2010).

Innovation researchers have endeavoured over many years to establish connections between Intellectual Property (patent) data and innovation. Bibliometric data, reports research impact in terms of citations, which gives good indications of research strength and quality – but sheds little light on adoption and commercial outcomes. Intellectual Property has no intrinsic value as a knowledge product: it accumulates value when it is adopted, applied, and used.

Over the last 15 years there have been policy interventions to identify ‘hidden’ and potentially commercialisable IP in research organisations (the ‘treasure trove’ perspective) and to build research commercialisation capability in technology transfer offices to identify and market IP to potential adopters with a view to increasing returns to research.

In the US it was found that government encouragement to universities to patent more discoveries probably inhibited the flow of knowledge into industry by putting too much emphasis on formal (and more adversarial) channels of technology transfer, while neglecting other key ways that knowledge moves into the commercial sector. In Australia there is little expectation that university technology transfer offices will make money.

Surveys of research commercialisation provide information on income from Licences, Options and Assignments (LOAs) for research organisations, which are usually shown to be very modest, except for

the occasional 'blockbuster' (generally less than three per cent of research expenditure). Occasionally there is also a significant IPO or trade sale that generates substantial revenues. These success stories are widely publicised in science communication channels, but often find it difficult to get traction in mainstream media.

A substantial amount of policy work in the innovation systems context currently focuses on building stronger connections between institutions (particularly between research organisations and business) to shape collaborations in academic based research and applying it in commercial and policy contexts. There is strong commitment from peak business and research organisations to achieve greater progress in this area.

Business development roles in technology transfer offices of universities and research organisations have extended from marketing IP, on a transactional basis, to developing long term collaborate and joint venture research partnerships, where IP and the knowledge on which it is based provides the 'entry point' for negotiation and agreement. The business development professionals are also being appointed based on their knowledge and experience in business, as well as their scientific and technological knowledge.

For these reasons assessments of innovation impact are increasingly reliant on qualitative indicators and measures, such as survey and case study methods that demonstrate success in collaborations, partnerships, and joint ventures.

The innovation system and the broader economic system

Innovation systems scholars have tended to focus on the science and research system. In practice, the innovation system connects with several other 'systems' that constitute the nation's economic and social systems. These include:

- The education, training, and talent acquisition system – which exists for a wide range of purposes other than innovation.
- The financial system, covering the major trading/retail banks, often with specialist agribusiness divisions, global investment banks, venture capital investors.
- The international trade and commerce system - Trade and market access facilitators and other professional advisers
- A start-up and new technology-based business system – including a growing number of AgTech companies – businesses that integrate agriculture and technology and are "focused on disrupting the global food system through digital technology".
- The agripolitical system - rural representative and advocacy organisations.

This constellation of organisations and systems, the relationships among them, together with the public policies, regulations, laws, and customs that coordinate and influence them, forms the rural innovation system. The connections and interactions of the innovation system are dynamic and multi-dimensional, and relationships are constantly changing. Relationships are often socially oriented, based on high levels of trust.

It is a challenge to develop policies for the science and research system without looking to connections with these other national systems. This should be done within a national strategic framework. This is addressed briefly below and in more depth in Part B of the Review Report.

The balance between science quality and science quantity

Research organisations compete based on achieving esteem and eminence; businesses compete based on securing customers. In both cases, achieving a surplus of revenues over expenditures is an indicator of success.

It follows that research organisations are interested in reaching the highest levels of research quality (indicated in international rankings and league tables), and businesses are interested in how research can be adopted and applied to increase revenue from customers (indicated by increased market share and growth in shareholder value). Governments are interested in delivering effective policies and programmes through the application of science and research. Business and government have an interest in research quantity (output) in terms of capacity to resolve problems and capture opportunities.

There are some views that these interests are converging, reflected, for example, in the international contributions around the Triple Helix concept (Etzkowitz, 2008; Howard, 2004a; Ranga & Etzkowitz, 2013; Ricardo Viale & Etzkowitz, 2005; Riccardo Viale & Etzkowitz, 2010). It reflects thinking that science quality and science relevance to industry, government, and society go hand in hand. Indeed, data indicates that institutions that perform well in quality (excellence) also perform well around relevance in terms of industry engagement.

In the rural sector institutions have developed to build connections between research quality and relevance. They include the CSIRO, which had its genesis in 1916²⁴, and State Government Agricultural Research Institutes, and University Research Institutes. The formation of these institutes reflects the strong national development vision at the time around the rural industries.

CSIRO still maintains a strong connection to the rural sector, and the States still maintain a strong commitment to rural research. Universities also have strong rural research centres and institutes, particularly among Go8 universities and regional universities.

Academic research metrics are built around publication, and the *publish or perish* mantra still has currency. There is an incentive to maximise the quantity of publication and with increasing numbers of researchers employed in universities, the peer review system is coming under pressure. Not all publications can be of outstanding quality or contribute equally to the dissemination of new or breakthrough knowledge and insights. But in numerous ways they contribute to the stock of knowledge. This issue is addressed again in the *Performance Report* (Document C)

The Australian Productivity Commission perspective

The Productivity Commission in report on Rural Research (Australia. Productivity Commission, 2011) commented:

Past investments in rural R&D have contributed significantly to improving the productivity of Australia's primary producers (as well as providing wider environmental and social benefits).

That said, R&D is only one of many factors that have contributed to such improvements. ... farm consolidation, enhancements to the Global Positioning System and other 'non-rural' information technology, improved agricultural machinery and chemicals, better transport infrastructure, and greater educational attainment within the rural workforce have all had an impact on productivity.

More broadly, the dismantling of various trade barriers and other regulatory constraints on competition has greatly increased the incentives for primary producers to look for opportunities to improve their efficiency, including through investment in R&D. Also, because a sizeable part of Australia's rural R&D effort sensibly involves adapting core rural R&D technologies and genetic material/varieties developed in other countries to meet local requirements, much of the ensuing productivity benefit is ultimately built upon overseas research effort.

The Commission's strong impression is that the contribution of factors other than domestic research to productivity growth is frequently ignored or understated by rural policy makers. A contemporary illustration of this is the 'big vision role' for rural RD&E mapped out by the (Rural Research and Development Council, 2011) in its recently released Draft National Strategic Rural Research and Development Plan.

²⁴ The first research investment was in the 1915-16 financial year in partnership with the Queensland and New South Wales Governments to explore control measures for the prickly pear pest that was invading millions of acres of agricultural land in eastern Australia.

The Commission concluded that in these circumstances, the risk is that insufficient emphasis will be given to other policy options for improving the productivity of the rural sector — such as continuing to look for opportunities to reduce barriers to competition and encourage farm consolidation.

The Commission saw the same issue applying to rural R&D aimed at delivering better environmental outcomes. R&D is only one of several options in the policy tool kit. In the Commission's view, "it is particularly important that public investment in R&D does not deflect policy attention from exploration of instruments that would enhance the incentives (financial or otherwise) for primary producers to directly take account of any adverse impacts their activities have on the environment". The Commission noted:

- investment in R&D complements and augments, rather than supplants, other drivers of productivity and performance improvement
- public funding — and any related funding instruments such as compulsory producer levies — are not the only policy levers available to address potential under-investment in rural R&D
- R&D funding support should be consistent with other policies and programs designed to improve the economic, environmental, and social performance of the rural sector.

The PC has a focus on encouraging additional, socially valuable R&D

The key rationale for public funding for rural R&D is to address spillovers and related market failures that would otherwise mean that socially valuable research would not proceed (or would be unreasonably delayed).

The Commission recognises that the additionality concept that emerges from this does not provide a precise basis for determining how much governments should contribute to the cost of rural R&D. Predicting what impact public funding support is likely to have on the level and mix of research undertaken will not always be easy — a point emphasised by many participants in responding to the draft report (see below).

Hence, application of the additionality concept will necessarily require those determining and implementing rural R&D funding policies to exercise judgement often in the context of the likely outcomes across a program, rather than in relation to individual projects receiving support through that program.

Others would add that public investment is also appropriate to address long term "over the horizon" issues, public health, environmental, security and safety contingencies, and national challenges that individual businesses, particularly small businesses, would find too risky and uncertain to contemplate. Governments also implement policies to de-risk these investments, such as R&D tax incentives and public support for venture capital²⁵.

The Commission largely dismissed estimated benefits from rural R&D based on the results of benefit–cost studies and to the evaluation of the returns to the RDC research portfolio coordinated by the Council of Rural Research and Development Corporations (CRRDC 2010). The Commission reported:

As discussed at length in the submission from the CRRDC, the results of the latest evaluation for a sample of 59 projects indicated that for every \$1.00 invested in research by the RDCs, there was an average return of \$2.36 after five years, \$5.56 after 10 years and \$10.51 after 25 years.

... the results of such evaluations must be treated with considerable caution. In the Commission's view, the estimated returns for some individual projects seem very high — especially were account to be taken of such factors as excluded RDC overhead costs, indirect government contributions resulting from marginal-cost pricing by government research suppliers, and the 'head start' provided by previous research, both in Australia and overseas.

Further, it was put to the Commission that in some of these evaluations, the assumptions relating to the extent and rapidity of adoption and the amount of additional spending required to facilitate such adoption, are optimistic in the light of previous experience.

As several participants emphasised, most of the benefit–cost estimates do not incorporate environmental and social benefits which have instead been handled qualitatively. Such benefits appear to have primarily been a consequence of research designed in the first instance to reduce

²⁵ In Australia, CSIRO has been one of Australia's most successful venture capitalists in early stage investments. It has recently formally committed to a \$20m Innovation fund.

costs, increase productivity, or address concerns that would otherwise have undermined producers' 'community licence to operate'.

Nonetheless, if these wider benefits could be quantified, they would at least partly offset the likely overstatement of the productivity-related benefit-cost component due to the factors outlined above.

The Productivity Commission approach has been subject to much critique (Dalitz, 2016)

Concluding comment

Notwithstanding the impressive sophistication of economic models regarding connections and the *macro*-economic relationships between R&D expenditure and economic growth over the longer term, and productivity performance over the shorter term, there is a problem in using historical relationships to predict a future course of events in the emergence and adoption of technology. We know, for example, that based on pre-existing relationships, reflected in algorithms in economic models, what the employment and income relationships would be with a with a substantial increase in total R&D expenditure, *other factors remaining equal* (as economists are prone to say).

At a *micro*-economic or industry level, economic modelling is not very good at predicting the course or implications of technological change. For example, no amount of economic modelling in 1980 could have predicted employment growth in the mobile phone industry, or in 1990 the growth of employment in the Internet and 'smart phone' industry, or in 2010 the growth in employment in the 'gig' economy. Economic models are based on old relationships and data; when new or unpredicted technologies emerge, fundamental (or disruptive) change is likely to occur.

This makes policies premised on long term increases in production and employment based on current (known) technologies and relationships particularly hazardous. It is possibly for this reason that it is easier to focus on short term productivity change as a policy focus. As indicated above there are risks in withdrawing from longer term research commitment, and potentially missing out on disruptive change.

Thus, based on experience and economic modelling we know that R&D investment will lead to and production and employment growth over the longer term. As venture capital and other technology investors (including privately owned businesses) who invest on a portfolio basis over the longer term know, only a few of the investments in their portfolio will be "stars" or blockbusters, most will deliver satisfactory returns, and some will fail to deliver any results at all. Moreover, timeframes to deliver returns will vary, but the challenge is to stay with the stars and cut the poor performers loose.

Appendix 4: Dynamics and Evolution of the Rural Innovation System

Key points

- It is difficult to look at the system from one point in time; it has been evolving in a dynamic way.
- Evolution has been taking place through “cumulative evolution” across technologies and institutional change.
- Digital transformation is occurring across the sector, associated with the emergence of what is being termed "digital agriculture", and "smart" farming".
- Data, analytics, and artificial intelligence are being adopted and applied across the rural sector, in much the same way as other technology driven sectors in the economy. But investments in these areas involve risks, and must meet ROI criteria
- There has been a pattern of consolidation and concentration among global agribusiness companies, and flurry of agribusiness listing on the ASX listing in recent years. Trading and Investment Banks see opportunities in high growth agribusiness ventures
- There is a more recent trend towards disaggregation with the emergence of start-ups and new technology-based businesses, that are attracting strong risk capital investment. There are opportunities for start-ups to build businesses around IP export.
- Expert Opinion responses indicated that the future if the Australian rural innovation system will increasingly rely on best practice commercialisation methodologies that attract entrepreneurs and venture capital.

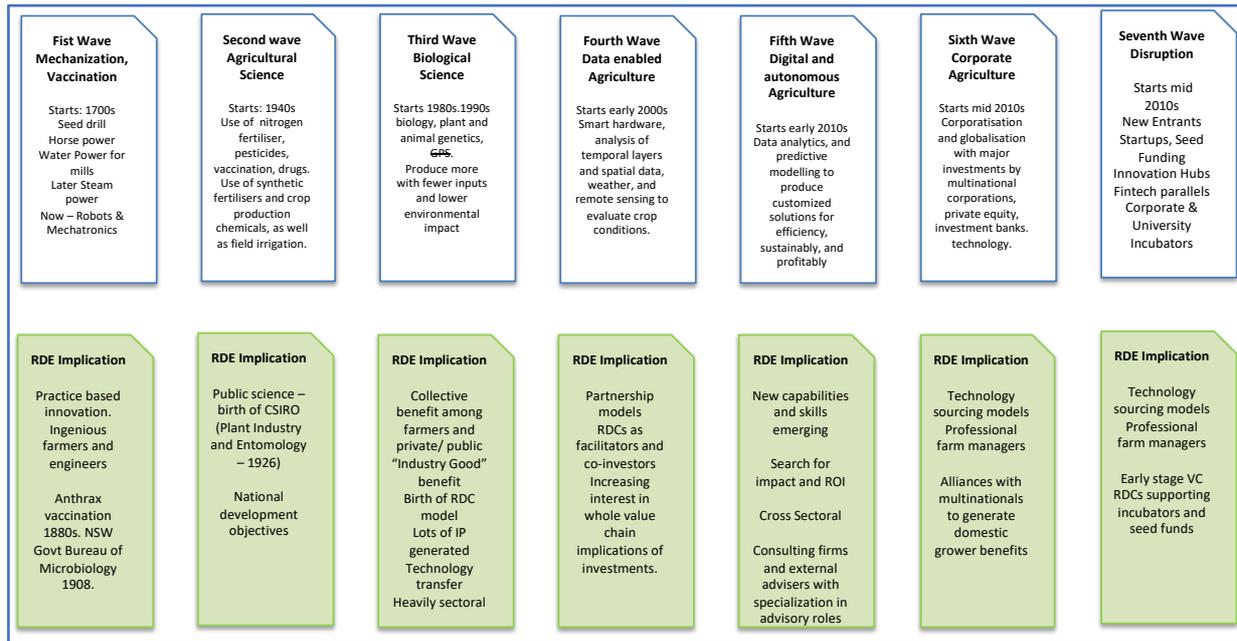
The Australian system of rural production developed through small, family businesses. Land laws were designed to encourage the "Yeoman Settler" although there was a marked increase in the size of wheat farms from around the 1870s. Dairy farming has remained predominantly a family enterprise, but increasingly large cooperatives emerged from the 1880s. The pastoral industry, always conducted on a “a grand scale”, moved gradually from the traditional ownership by individuals or great family groups into corporations. These corporations are now largely overseas owned.

The financial system had developed to facilitate the expansion of the pastoral industry, and it maintained that bias for many years. The branch banking system, which penetrated deeply into expanding areas of settlement, using deposits to expand credit, provided a mechanism for transferring British capital into rural investment. A significant financial innovation was the formation of Australian pastoral finance companies that operated between trading banks and pastoralists. They were significant supporters of innovation until the crash of the 1890s.

Waves of Innovation

To assist in providing an understanding of rural innovation and a basis for assessing performance we developed a schematic that describes the progression of innovation through various phases over the last century. The phases are intended to identify starting points for the potential application of new research, development and practices that support innovation. This is represented in Figure 115 below.

Figure 115: Waves of Innovation in Australian Rural Industries



© Howard Partners 2018

The representation is intended to identify changes in the scope and emphasis of research, development and innovation resulting from the discovery of new science and the application of new and emerging technologies.

It is intended to be represent a cumulative, rather than sequential progression of innovation. For example, breakthroughs in digital agriculture will still require knowledge and understanding of compartments in the agricultural and biological sciences. In other words, innovation progression potentially calls for more interdisciplinary approaches.

Beginnings: Mechanization, adaptation

Science historian Jan Todd has observed that while Australian innovative activity has traditionally been described as the "improvising battler against the environment", many successful 19th-century inventors had strong technical backgrounds. Immigrants included skilled artisans, but most had engineering, mechanical or some scientific education grafted onto the original training. Australians often trained themselves through mechanics institutes and associated libraries, but later in the century attended courses in technical institutes and universities (Todd, 1995).

Todd observes that Australian born inventors tended to focus on the needs of agricultural, forestry, and the pastoral industry and migrants tended to delve into fields bearing on manufacturing, such as food canning, hydraulic brakes, and even tanks. These trends resulted in clusters of Australian patents in areas closely related to the requirements and demands of Australian economic development - for example a burst of refrigeration patenting around 1867-74. However, the Australian adaptation of an anthrax vaccine in the 1890s was not patented and the formulation kept secret for many years.

Research has indicated that by the 1880s Australian engineering firms were producing machinery which reflected a mastery of 19th-century high-technology. Local foundries and engineering workshops, often in rural and regional locations, used cheaper prices, quicker delivery, better service and an equal or superior standard of craftsmanship and design earning their place in the market.

By the end of the last century universities had been increasing their commitment to science, with more science chairs, more science students, and more government funding for their teaching. Governments were also expanding their own scientific services in size and scope following from

concerned with fisheries, forests, and water, which posed new questions which science was increasingly asked to provide some answers. Departments of agriculture employed a range of scientific professions to take the benefits of science to "the man on the land".

Model farms emerged in the 1890s, beginning of the agricultural colleges. These continued as CAEs – then became universities in 1988.

By the 1880s the universities were entering into research programs in biology, chemistry, physics, and geology, but largely focused on the "puzzles" of European theory. However, the interest of government scientific services was distinctly local: there was commitment to geological surveys, surveys to assist in the eradication of the losses caused by pests and diseases, and botanical identification to facilitate the commercial exploitation of state timbers.

Agricultural science

Agriculture science has had a focus on the efficiency with which farmers use land, labour, capital, and intermediate inputs (for example, chemicals, fodder and purchased services) to produce outputs such as crops, meat, wool and milk. In terms of the innovation progression many refer to this phase as "Chemical Agriculture" involving the development and applications of chemicals, including a range of fertilisers, pesticides, and vaccines. We would like to see it as covering a bit more.

Agricultural science is also concerned with farming practices that help improve crop productivity. The research fields that relate to agricultural sciences covers:

- Agriculture, Land and Farm Management, covering Planning, Production Systems Simulation, Spatial and Systems Analysis and Modelling, Farm Management, Rural Management and Agribusiness, Farming Systems Research, Sustainable Agriculture
- Animal Production, covering Animal Breeding, Growth and Development, Nutrition, Protection (Pests and Pathogens), Reproduction, Humane Animal Treatment
- Crop and Pasture Production, covering Agro-ecosystem Function and Prediction, Agronomy, Crop and Pasture Biochemistry and Physiology, Biomass and Bioproducts, and Improvement (Selection and Breeding Nutrition, Post-Harvest Technologies (incl. Transportation and Storage), Protection (Pests, Diseases and Weeds)
- Fisheries Sciences, covering Aquaculture, Aquatic Ecosystem Studies and Stock Assessment, Fisheries Management, Fish Pests and Diseases, Fish Physiology and Genetics, Post-Harvest Fisheries Technologies (incl. Transportation)
- Forestry Sciences, covering Agroforestry, Forestry Biomass and Bioproducts, Fire Management, Management and Environment, Pests, Health and Diseases, Product Quality Assessment, Tree Improvement (Selection and Breeding), Nutrition and Physiology, Wood Fibre Processing, Wood Processing
- Horticultural Production covering Horticultural Crop Growth and Development, Crop Improvement (Selection and Breeding), Crop Protection (Pests, Diseases and Weeds), Oenology and Viticulture, Post-Harvest Horticultural Technologies (incl. Transportation and Storage)
- Veterinary Sciences, covering Veterinary Anaesthesiology and Intensive Care, Anatomy and Physiology, Diagnosis and Diagnostics, Epidemiology, Immunology, Medicine, Microbiology (excl. Virology), Parasitology, Pathology, Veterinary Pharmacology, Veterinary Surgery, Virology
- Other Agricultural and Veterinary Sciences, covering Agricultural Hydrology (Drainage, Flooding, Irrigation, Quality, etc.), Fertilisers and Agrochemicals (incl. Application)

Agricultural sciences are often taken to include soil sciences, that cover Carbon Sequestration Science, Land Capability and Soil Degradation, Soil Biology, Soil Chemistry (excl. Carbon Sequestration Science), Soil Physics

There continues to very substantial research investments in these areas, as indicated in Section 6 below.

Biological science

Biological science started to become prominent in rural production from 1980s. The research fields round biological sciences cover: Biochemistry and Cell Biology, Ecology Evolutionary Biology, Genetics, Microbiology, Physiology, Plant Biology, Zoology²⁶. It also extends into the field of biotechnology.

From an opportunity perspective, biological science creates opportunities in areas of new water/salt/pest resistant crops, nutraceuticals, health foods, productivity gains in plant and animal breeding through genetics. Australia is a world leader in many of these fields. Australia has a highly regarded capacity, developed over many years, for animal and plant breeding across CSIRO, state government agricultural research centres, and universities. These organisations collaborate, often with investments from the RDCs, and have developed a strong portfolio of international collaborations.

Australian knowledge in animal and plant breeding is also a significant element in Australia's international aid development effort and is a significant export income earner.

Taken together, the agricultural and biological sciences are the foundation for the emergence of what is being referred to as the *AgTech* and *GeneTech* sector, that applies digital technologies to foundation scientific knowledge as a basis for greater "precision" and being "smarter" in rural production that will flow through to greater productivity, reduced costs, and lower risk. But, as stressed in the consultations for the Review, digital tools and techniques are a means towards achieving these ends, not ends in themselves.

Digital transformation: "digital agriculture" and "smart" farming"

The Sydney Institute for Agriculture, and many others, see digital technology as having a major impact on the future course of agriculture (and, by implication, fishing, and forestry):

The transformative power of technology will be the major cross cutting, all pervading force of change in agriculture. This will impact the kind of research, education and outreach that is needed from universities to realise this digital transformation, but it will also change the way that research, education, and outreach are done²⁷.

Digital agriculture is not new – there have been sensor driven tractors for many years. However, over the last 10 years the concept of digital agriculture has captured the attention of a very wide range of people in research, technology, economics, and business. It has a very wide press and promotion of the potential for productivity and profit gains.

Traditionally agriculture follows a predetermined schedule of planting, maintaining, and harvesting crops. But real-time data on variables like weather, soil and air quality, crop maturity, and even equipment and labour costs now give growers a new edge in making smarter decisions

The promise

From early 2000s, smart hardware, analysis of temporal layers and spatial data, weather, and remote sensing has been used to evaluate crop conditions.

Technologies have taken many shapes, forms, and sizes - from cloud-based software tools to hybrid hardware/software products that are "smart" in that they can communicate with all other connected devices wirelessly and digitally, with minimal human intervention.

²⁶ For more detailed descriptors see

<http://www.abs.gov.au/Ausstats/abs@.nsf/Latestproducts/0E8E43D6F852712BCA257418000462C8?opendocument>

²⁷ <https://sydney.edu.au/agriculture/outreach-engagement/institute-launch-and-research-showcase.html>

The promise of Digital Agriculture

Digital agriculture offers the promise of greater income and lower volatility, utilising data, mathematics, and logic to add value to file decisions by removing human emotion and bias.

In crop farming the "promised value" for growers consists of optimal financial risk-adjusted returns on capital used to farm. The idea is that improved agronomic practices, coupled with more precise field decisions (for example, the timing and type of nutrient applications) tailored to local field and intra-field conditions, can create the promised value through: higher crop yields and lower input costs (for example lower and more precise nutrient and ag chemical applications); operational efficiencies and time management (automatic, rather than manual collection of helpful data to drive decisions that can allow farmers to complete tasks which cannot be automated).

Another consideration is better growing quality and consistency, which results in additional value to midstream and downstream buyers.

Rabobank, *Bungle in the AgTech Jungle*, 2017

Interviewees referred to some potential dangers in the drive towards digital agriculture because "the digital economy and the digital analysis ... is still reliant on base understanding of biological systems". Many organisations claim "that they are cutting edge leaders in digital analysis and machine learning" but without the basic biological understandings. An interviewee pointed out:

... you can have some really funky digital platforms that will tell you how many of a certain pest is going to be present and model that. But, without a biological understanding of population dynamics, when the pressure will hit something that's economically worth doing something about. That's, you don't glean that out of a whole stack of machine learning without first putting the whole stack of biological data

Digital agriculture is seen by interviewees as a means to an end, not an outcome in itself. It is important to look at digital applications are going to make economic impact. "In our case, we're driven by grain growth, and our purpose is to invest in R&D to create enduring profitability". Then the question is how to leverage this great opportunity to drive profitability. Digital agriculture is just one potential, in certain areas has a lot of potential, in other areas it has zero. It's not an outcome, it's a tool.

Some applications of digital agriculture are summarized below.

Field robotics

Australia leads in field robotics at the Faculty of Engineering and Information Technology at The University of Sydney.

Australian Centre for Field Robotics (AFCR)

The Centre is one of the largest robotics research institutes in the world. It focuses on the research, development and application of autonomous and intelligent robots, and systems for use in outdoor environments.

The Centre has been instrumental in developing breakthrough technologies, conducting world-renowned research, and developing field robotics principles and systems.

The centre's mission is to undertake research to develop new field robotics and intelligent systems theories and methods, and apply them in industrial, social, and environmental settings. It is committed to developing technologies in four core areas:

- sensors, fusion, and perception
- movement, control, and decisions
- modelling, learning, and adapting
- architectures, systems and cooperation of robotics and intelligent systems.

The Horticulture Innovation Centre for Robotics and Intelligent Systems (HICRIS) jointly launched with Horticulture Innovation Australia in October 2016. Part of our Australian Centre for Field Robotics, HICRIS is Australia's first horticultural robotics learning and development hub with a focus on robotics to increase farm efficiency and productivity for the vegetable and tree crop industries.

A major research project under HICRIS uses autonomous systems to guide farm decision making. Predictive tools allow growers to achieve greater crop uniformity and quality, while forecasting input cost and planning optimal harvest time.

<https://sydney.edu.au/engineering/our-research/robotics-and-intelligent-systems/australian-centre-for-field-robotics.html>

The Centre receives funding from a wide portfolio of investors, across a wide range of industry concerns, including, Meat and Livestock Australia, Horticulture Innovation, Dairy Australia, NSW Department of Industry, DAF Innovation Resource Facility, Museum of Applied Arts and Sciences, The Council of Australasian Weed Societies, NSW Department of Primary Industries, VIC Department of Economic Development, Jobs, Transport and Resources (DEDJTR), QLD Department of Agriculture and Fisheries, Department of Agriculture

Smart farms

There is global interest in 'smart farms'. Reference is often made to the UNE Smart farm, which is described below.

About the SMART Farm
'Our farming future starts today.'

The University of New England has transformed 'Kirby-Newholme', a 2,900-ha commercial farm located 10 km northwest of the campus, into a SMART Farm (Sustainable Manageable Accessible Rural Technologies Farm). Kirby-Newholme is part of the university's Armidale commercial farms.

The SMART Farm showcases the latest technologies aimed at improving productivity, environmental sustainability, safety, workflow, and social/business support networks on Australian farms.

With our \$2 million SMART Farm Innovation Centre perched atop a knoll in the middle of the farm and linked via AARNet and the national broadband network (fibre, terrestrial wireless, AND satellite), the predominantly grazing SMART Farm is a national demonstrator site. Building on the university's international leadership in Precision Agriculture, Education, Rural Health and Environmental and Rural Science, SMART Farm also serves as an 'instrumented' research laboratory, a

With broadband connectivity and serving as a test-site for new technologies, the SMART Farm is a connected classroom where the community as well as students of all ages can access the latest data streaming in from a range of field, animal, and machinery sensors. Research projects include:

- Biomass Business II: Developing applications for mobile devices such as smart phones for farmers to monitor and manage pasture biomass.
- Multi-scale monitoring tools for managing Australian tree crops — industry meets innovation: National tree project to develop technology that audits the type, location, and number of trees.
- Determining the potential of virtual fencing for application to grazing livestock: Virtual fencing for flexible, real-time control of livestock distribution.
- Optimum N — Nitrogen sensing and management: Nitrogen sensing and management using automatically-coordinated measurements to generate a growth strategy for cropping.
- UAV automated surveillance of in-field hotspots for improved management: Low-cost, high quality 3D crop monitoring using drones.
- SMART Farm Landscape Laboratory: Establishing the UNE SMART Farm as a 'landscape laboratory'.
- UAV platform for testing new sensor technologies in precision agriculture: Building applications for unmanned aerial vehicles (UAVs) to support field data collection, new sensor development and image-calibration work involving satellite and aerial images.

<https://www.une.edu.au/research/research-centres-institutes/smart-farm/about-the-smart-farm>

Major partners in the project are CSIRO, Grains Research and Development Corporation (GRDC), Boeing Defence, Australian State Governments — Queensland, Victoria, New South Wales and South Australia Department of Agriculture and Water Resources; 9 universities.

Drury farms, a milk production by robot, is often provided as an example of good application of robotics. It also reflects ingenuity in application, by getting cows to voluntarily go into dairy.

Improved technology to attract staff. Internet and tech savvy. Studied the machines to build technical expertise. Unskilled electricians who like computers. Get right people with the right training and motivation. Hunter TAFE trains robotic technicians²⁸.

The space for Australian digital innovation

Precision agriculture software and hardware providers are global in their orientation, and the market is highly contested. A selection of current international providers is listed in Table 5.

²⁸ <http://www.abc.net.au/news/rural/2016-12-02/robotic-dairy-delivers-increased-milk-production/8082764>

Table 23: Sample list of precision agriculture software providers

Company	Focus	URL
CropMetrics	focused on advanced agronomic solutions while specializing in precision irrigation management.	http://cropmetrics.com/
Agribotix	Offers a complete ag. drone system with a year of unlimited data processing	http://agribotix.com/
apitronics	an open platform for farm data collection	http://www.apitronics.com/
Granular	farm management software and analytics platform	http://www.granular.ag/
AgSmarts	offers moisture-sensing technology, predictive analytics, and farm equipment automation	http://www.agsmarts.com/
Edyn	tracks light, humidity, temperature, soil nutrition and moisture, and then cross-references this information with plant, soil science, and weather databases	https://edyn.com/
FarmLogs	platform includes yield maps, field rainfall, soil maps, automatic activity recording, crop health monitoring, growth stage analysis	https://farmlogs.com/
AquaSpy	Aquaspy's Vector Probe is the first multi-sensor probe in the world to accurately separate moisture from conductivity	http://www.aquaspy.com/
Agerpoint	technologies involve data acquisition, analysis, and translation for growers, giving personnel at all levels access to mission critical data	http://agerpoint.com/
CropX	uses a combination of three wireless sensors and a mobile app, to determine exactly how much water needs to be applied to each part of the field	http://www.cropx.com/

Source: <http://blog.initialstate.com/precision-agriculture-companies/>

The global orientation of providers makes it difficult for Australian start-ups to enter the field around digital software. However, many people are quite bullish and see a trajectory like the Fintech and Mining technology sectors.

Innovation through application

Australian agribusiness can benefit through smart adoption and application, and the emergence of trusted consultants and advisers. This is already beginning to emerge.

Data and analytics: towards precision agriculture

Fifth wave – from early 2010s. Data and analytics: algorithms, artificial intelligence, and machine learning, which combines mathematics, data analytics, and predictive modelling to produce customized recommendations designed to help growers farm more efficiently, sustainably, and profitably.

Technology and digital disruption

During consultations, several interviewees mentioned how they tier their producer and processor groups:

- The big guys - always be there because it's bespoke large capital foreign ... so it's your Japanese integration, it's an American big protein company what have you, so they can take care of themselves
- The medium guys -They're the hardest area. Because you have guys in there that are aspiring to be big, and they're progressive and they're investing in themselves. And the ones that aren't are talking about costs and they're getting smaller and they're going out of business
- The small micro guys - they'll continue ad infinitum, because they're there for geographic and lifestyle reasons - thousands of little, tiny businesses, dad and son just eking out a living but they don't really care. The value's in the land.

So, the mid-tier guys, they're the tricky ones, because they're the ones that are getting smaller and don't know it, and the ones that are aspiring to get bigger, but they don't know how to do it.

The impact of “big data”

With big data in the picture, the world has witnessed an automatic increase in information storage and seamless processing and analysing, which were difficult to achieve due to technological limitations. This, in turn, has paved the way for precision agricultural techniques. Now, the data has a wide array of benefits install farmers and reshaped agriculture in the following areas:

- Analysing soil types and fertility levels, to predict which seeds and fertilisers to use, with the help of sensors of fuels and devices installed machines.
- Predicting climate conditions and enabling act weather forecast by satellites and devices. Aerial and ground levels.
- Analysing the crop providing spoiled preventing spoilage and potential diseases by providing accurate information via unmanned aerial vehicles, like drones.
- Monitoring and evaluating supply chains via RFID tracking systems.
- Increasing crop yield and optimising resource use by integrated information like weather conditions, soil types, and market opportunities.

However, as one interviewee commented

... big data is great provided your data's relatively uniform, but if you use big data to draw a conclusion and everything changed in the last five years, but you're using 20 years, you're going to skew the results that you get.

Data and analytics are, again, a means to an end and should be used in the context of the problem or opportunity that us being confronted.

Precision agriculture

The underlying technology for precision agriculture is big data itself. Precision agriculture uses GPS technology that enables a farmer or researcher to locate the position on the field, measure fluctuations in factors like drips, irrigation, nitrogen, moisture levels, and topography. Through satellite imagery it is possible to make better soil, water, crop management decisions and consequently minimise input to maximise yields.

Tools for analysis of data and its applications offer valuable insights and opportunities for farmers and agriculturists to understand consumer needs and increase overall profitability. The challenge, however, is for governments, farmers, and data specialists to come together and form a sturdy ecosystem that can innovate in the existing agricultural landscape.

There is a concern that automation will eliminate the workforce. But high labour costs have substituted for high robotics cost to keep the machines going. That requires high value people with technical skills to maintain and program the very complex software. Whilst service and maintenance can be done remotely, it can very time consuming – entering the cost equation. This is, of course, consisted with automation in other industries.

Our complexities are many but the opportunities for efficiency are coming from the pork side. Particularly in the boning room. The greatest one for us is traceability. Because if you go to a supermarket you should be able to get a QR code, scan it with your phone, link it straight to a YouTube video of that bull. I think we're very close to that.

In this area we have gone past the phase of innovation in terms of application of new ideas. The ideas are mature, and the technology – hardware and software – is developing rapidly and potentially reducing on cost. However, as in other industries, businesses will not invest unless they are comfortable in dealing with the risks and a positive return on investment. Many people are still mindful, with good reason, of Robert Solow's observation in 1987 that “You can see the computer age everywhere but in the productivity statistics”.

Delivering the economic and innovation benefits of technological progress requires a strategic business-oriented approach and is too important to be left only to technologists. Our consultations

indicated that rural production is seeing a new category of manager entering the farm business, with a solid background in management and finance, rather than specifically agricultural science.

Investment in building management capacity and capability for rural based businesses must be seen as a high priority.

The Precision-to-Precision project

The Australian Government Department of Agriculture and Water Resources as part of the *Rural R&D for Profit* program funded all Rural Research and Development Corporations, to:

- Facilitate the development of digital technology in Australian agriculture.
- Foster the establishment of appropriate legal frameworks, data systems and access to critical datasets.
- Identify the data communications systems required to deliver the benefits of digital agriculture to the Australia farm and agribusiness sectors.

The project, known as *Accelerating Precision Agriculture* (Leonard et al., 2017) is currently undertaking industry stakeholder consultation on findings and recommendations detailed in a Summary Report and a series of Technical Report²⁹. The summary findings reported substantial potential benefits from the widespread adoption of precision agriculture. These are summarised in Table 24 below.

Table 24: The impact of Unconstrained Decision Agriculture to the Australian economy.

Sector	Baseline sector value (GVP) 2014-15	Estimated potential benefit to the sector to 20??		Estimated potential benefit to the economy	
		GVP Increase (\$m)	GVP Increase (%)	GDP Increase (\$m)	GDP increase (%)
Rice	260	78	30	46	0.00%
Grains	11,522	5,930	51	1,821	0.11%
Cotton	1,413	394	28	692	0.04%
Sugar	1,257	291	23	660	0.04%
Horticulture	1,018	403	40	951	0.06%
Beef	10,461	1688	16	4,219	0.25%
Sheep meat	2,988	516	17	1,316	0.08%
Wool	2,550	452	18	1,128	0.07%
Pork	1,084	55	5	429	0.03%
Dairy	3,343	497	15	1,298	0.08%
Eggs	729	180	25	128	0.01%
Chicken meat	2,084	503	24	371	0.02%
Wine	5,865	706	12	630	0.04%
Forest and wood products	14,864	5,511	37	7,484	0.44%
Livestock exports	1,601	72	4	179	0.01%
Red meat processing	14,533	2081	14	2,438	0.14%
Fisheries and aquaculture	2,132	928	44	855	0.05%
Total	75,331	20,285	25	24,645	1.46%

Source: Accelerating Precision Agriculture (Leonard et al., 2017) GDP calculation percentage added by the author.

GDP in 2017 estimated at \$1,693,457m – ABS <http://www.abs.gov.au/ausstats/abs@.nsf/mf/1345.0>

The projections are very aggressive and positive. However, almost 58 per cent of the increase is in three sectors – beef, forest and wood products, and red meat processing. And 23 per cent in four others. A timeframe for delivery of benefits is not indicated. This may reflect the way input-output multipliers work by playing out over numerous iterations.

The analysis is very supply side and production oriented. A framework for implementation is foreshadowed, but it needs to address institutional barriers and constraints as well as the digital opportunities. There are also demand side factors that place existing food and eating patterns under challenge.

²⁹ <http://farminstitute.org.au/p2dproject>

Data collection, storage, and management

Fisheries RDC has a goal to put all its electronic data into one portal which will be run by a not-for-profit and -

... then any researching University or any young kid in a backyard or any person in Bangladesh or whoever wants it, can just get deregulated data. And that will be the biggest breakthrough for our industry. ... we're of the view that we're trying to transform the digital landscape like a lot of people, and data is part of that.

But what we don't want to do, is get into the market to developing apps or hardware. We want a competitive landscape, so what I watch at the moment, is all these government departments, they want to develop this app for this, or they want to develop this hardware. I don't care. All I want to do is create an environment where those people want to create it because there's a market for them to sell their product. But the most important thing, is to make sure that the data doesn't get captured by Bayer or the tractor company or whatever.

The change to a digital environment was described as follows:

- Currently a fisherman goes fishing, they fill out a logbook, write it on paper. Some of them don't do it electronically. The information goes into a state-based agency, and the agency then keeps it. The agency does a fisheries assessment; sometimes a fisheries assessment takes two years before they finally use all that data to work out what the catch was in relationship to the biomass, and then we discuss is the catch relative to the biomass.
- In future, data will be collected electronically on boat and will go to a cloud-based company. Every night, an artificial intelligence system will redo the stock assessment, and every night we would tell them how much available biomass. And we could tell them basically by GPS coordinate where that fish is going to be. FRDC has already digitised Macquarie Harbour for fish farming.

Potentially, it is argued, digitising farm-based information will allow producers to work out not just what happens on their farm, but how the linkages between farms work, how that works in a nitrogen environment, a sunlight environment, flow environment, and so on.

Interestingly, the biggest opposition for the shift to data is seen to be in governments because people in agencies are concerned about change – and potentially losing their job. There are also likely to be potential arguments about software selection and acquisition, exacerbated by the marketing pitches of vendors. The challenge of achieving cross jurisdictional consensus is daunting.

The Australian Institute of Health and Welfare has been instrumental in standardising data across the health and welfare sector, where a substantial proportion of data is sourced from States and Territories, and the private and not for profit sector. It is an area where, potentially RDCs could collaborate to lead a rural data collection initiative.

Addressing risks in decisions to invest

Feedback from consultations was that many farmers are prepared to invest now in new technology but are concerned about the support services “for the day that it doesn't work”. There are also gaps in availability of support services to help decide whether to employ or deploy one technology over another or to make two technologies work together well. Technology must be robust enough and totally reliable to work in remote locations.

Where those services aren't readily available the risk of investment is magnified, which in turn holds back adoption of innovative solutions. It also means being able to access the right skills fit for the future, not just today. The risk is higher when there the sense of community erodes in districts and rural towns as people leave to go to metropolitan centres.

Many farmers do not have a problem investing \$750,000 or \$1.2m in new harvesting technology, and within two years the whole industry has changed how it harvests. I think it's when you buy one discrete thing, we buy a new plant variety, like a cotton variety, it's very discrete and that's seen as less risk.

But trying to implement a system on your farm for digital agriculture, for example, with sensors, and data logging and data analysis and you're trying to go across different brands of machinery and trying to get different systems to talk to each other, be interoperable, and you don't know whose got your data entails more risk, more risks in an adopter's mind, a farmer's mind, about some of most of the new digital technologies.

It was observed that there are solutions to that. But they are not inexpensive, but they are available, and the service providers for those aren't readily available either. Unless farmers know and have confidence in the service provider, again it's an elevated risk.

There is also a risk associated with the integration of farm-based production systems, management systems, and enterprise systems -

So, we might have a map of the decision points and the database, but being able to keep them at a farm level will be constrained by these other things that we've been talking about. So, how would you connect the weather data, the soil data, the crop data, and the water data to inform automated irrigation?

Digital communication availability and access is also an issue.

Concluding comment

There is little doubt that “digital” and “precision” agriculture has the potential to have a major economic and social impact.

Whilst the aim is productivity improvement, and returns to farmers, several people commented during the Review that this is “Horizon 1” thinking. The pattern of food production and consumption is undergoing fundamental change on a global scale, involving new entrants and business models, which will accelerate into the future.

Thus, it is important to embrace the promise of digital agriculture, and ensure that it works to its maximum potential, but attention must also be given to “Horizon 2” and Horizon 3” thinking, which relates to where the rural production value chain will be 10 to 15 years into the future. Some of these trends are addressed

Corporatisation

Corporatisation and globalisation of rural businesses with major investments by global corporations, private equity, investment banks. Changing ownership models, including foreign ownership (as seen in the mining sector). Associated with major changes to products and technology.

Trends towards consolidation

In many sectors, there is a rapid trend towards consolidation. In horticulture, for example, there are about 35 major industry groups. In nearly all of them now, the top five producers, account for 50 per cent of production. And in many sectors, the top two producers, account for 80 per cent production. Almonds is a good example. Blueberries, Strawberries, Raspberries, and Mushrooms are similar.

Big balance sheets, corporate style players, they may not be true corporates, but they'll be a family aggregation operating as corporates. With corporate attitudes, corporate balance sheets, and many are entirely capable of doing research and development themselves.

Many have argued that consolidation and “big agriculture” represents a “market failure”. During consultations interviewees commented that inability to compete is not a market failure – it is the market working. Unfair market practices and behaviours can be referred to competition watchdogs, such as the ACCC or Departments of Fair Trading. The Rural RDCs should not be expected to use the levy system to subsidise marginal producers.

Global conglomerates

Large global food and agribusiness companies have a strong presence in Australia. These companies are very active in research and innovation, but not so much in Australia. Research and innovation is approached on a global investment basis and Australia is a very small player. Bayer, for example, an important player in the global research and innovation landscape and has research collaborations in Australia³⁰.

Many of the global food and agriculture conglomerates own or have major holdings in Australian agribusiness companies. The largest food and agribusiness companies operating in Australia, in terms of sales, are listed in Table 25 below.

Table 25: The largest overseas owned food and agribusiness companies operating in Australia

Rank	Company	Sales (\$billion)	Parent
1	Lion	5.1	Japan
5	JBS Australia	3.6	Brazil
6	Olam Investments	3.6	Singapore
7	Glencore Grain	3.6	Switzerland
11	Cargill Australia	2.8	United States
13	Inghams	2.4	United States
14	Agrium	2.3	Canada
15	Food Investments	2.2	United Kingdom
16	Nestlé	2.1	Switzerland
17	Goodman Fielder	2.1	Singapore
18	Carlton & United Breweries	2.0	United Kingdom
21	Wilmar Sugar	1.8	Singapore
22	Asahi Holdings	1.8	Japan
23	Mondelez Australia	1.7	United States
24	Unilever Australia	1.6	United Kingdom
25	Parmalat Australia	1.5	France
		40.2	

Source: Austrade

There are also some large non-listed global companies with a major influence in Australian Rural industries include:

- Simplot: <https://www.simplot.com.au/about-simplot/introducing-simplot-australia/>
- Auscott: <http://www.auscott.com.au/>

Largest Australian food and agribusinesses

The largest Australian Food and Agribusiness companies identified by Austrade are listed in Table 26 below. The extent of their R&D commitment has not been published since the cessation of the publication of the *R&D Scorecard* prepared by AusIndustry many years ago. ABS data on research and innovation expenditure does not identify companies.

Table 26: The largest Australian owned food and agribusiness companies operating in Australia

Rank	Company	Sales (\$billion)	Parent
2	Coca-Cola Amatil	5.0	Australia
3	GrainCorp	4.1	Australia
4	CBH Group	4.1	Australia
8	Incitec Pivot	3.4	Australia
9	Devondale Murray Goulburn	3.0	Australia
10	Teyes Australia	2.9	Australia
12	Nufarm	2.8	Australia
19	Treasury Wine Estates	2.0	Australia
20	Queensland Sugar	1.9	Australia
		29.2	

Source: Austrade

³⁰ In 2015 Bayer invested €4.281 billion in research and development. This was equivalent to 9.1 per cent of sales. The number of employees working in research and development worldwide was approximately 14,700.

Several of these companies have research collaborations with the RDCs.

ASX listed agribusinesses

There are 55 companies listed in the ASX categorized as Food, Beverages, and Tobacco. Several of these rank among the largest companies identified in Table 26 above. Many are also relatively new listings.

With a difficulty in attracting patient expansion capital from banks and private equity, many firms list on the ASX to secure access to this form of finance. Summary information is provided in Table 27.

Table 27: ASX listed agribusinesses

Company Name	ASX code	Listed			Listed
Abundant Produce Limited	ABT	2015	Huon Aquaculture Group Limited	HUO	1994
Australian Agricultural Company Limited.	AAC	1989	Inghams Group Limited	ING	2013
Australian Agricultural Projects Limited	AAP	2003	Jijiafu Modern Agriculture Limited	JJF	2015
Australian Dairy Farms Group	AHF	2011	Longtable Group Limited	LON	2000
Australian Vintage Ltd	AVG	1991	Murray Cod Australia Limited	MCA	2010
Australian Whisky Holdings Limited	AWY	2003	Murray River Organics Group Limited	MRG	2016
Bega Cheese Limited	BGA	2008	New Zealand King Salmon Investments Limited	NZK	2016
Bellamy's Australia Limited	BAL	2007	Ocean Grown Abalone Limited	OGA	2011
Beston Global Food Company Limited	BFC	2014	Pacific Dairies Limited	PDF	2001
Bojun Agriculture Holdings Limited	BAH	2017	Refresh Group Limited	RGP	1997
Broo Ltd	BEE	1993	Ridley Corporation Limited	RIC	1987
Bubs Australia Limited	BUB	1993	Seafarms Group Limited	SFG	1988
Buderim Group Limited	BUG	1989	Select Harvests Limited	SHV	1969
Capilano Honey Limited	CZZ	1958	Sterling Plantations Limited	SBI	2006
China Dairy Corporation Limited	CDC	2015	Synlait Milk Limited	SM1	2016
Clean Seas Seafood Limited	CSS	2000	Tasfoods Limited	TFL	1988
Coca-Cola Amatil Limited	CCL	1927	Tassal Group Limited	TGR	2003
Costa Group Holdings Limited	CGC	2011	Tegel Group Holdings Limited	TGH	2016
Dawine Ltd	DW8	1999	The A2 Milk Company Limited	A2M	2012
Dongfang Modern Agriculture Holding Group Limited	DFM	2015	The Food Revolution Group Limited	FOD	2011
Elders Limited	ELD	1994	Tianmei Beverage Group Corporation Limited	TB8	2016
Farm Pride Foods Limited	FRM	1997	Treasury Wine Estates Limited	TWE	1957
Ffi Holdings Limited	FFI	1985	Wattle Health Australia Limited	WHA	2011
Fonterra Shareholders' Fund	FSF	2012	Webster Limited	WBA	1910
Freedom Foods Group Limited	FNP	1984	Wellard Limited	WLD	2015
Gage Roads Brewing Co Limited	GRB	2002	Wingara Ag Ltd	WNR	1984
Graincorp Limited	GNC	1992	Yowie Group Ltd	YOW	1999

Source ASX and ASIC

Nineteen of the 55 companies listed after 2010.

Disruption and transformation

In earlier Sections of the Report mention has been made of increasing 'disruption' of the rural value chain by AgTech and digital technologies. Their impact is opening many new opportunities for value and wealth creation and leading to the birth of new sub-sectors and firms.

A participant in the Expert Opinion Survey commented:

The Australian rural innovation system, underpinned by R&D orgs, will be disrupted in under a decade by user-driven innovation and other modern best practice implementation. The Australian rural innovation system would benefit by being modelled on other innovation systems that have changed the world like the unstructured Silicon Valley.

Disruption is also likely to see a greater role for the private sector, particular through investment in start-up businesses either directly or through financial vehicles such as venture capital funds. The interest is seen in websites such as [Agfunder](#), on-line magazines, and blogs. This creates a new set of issues concerning the role of public funding.

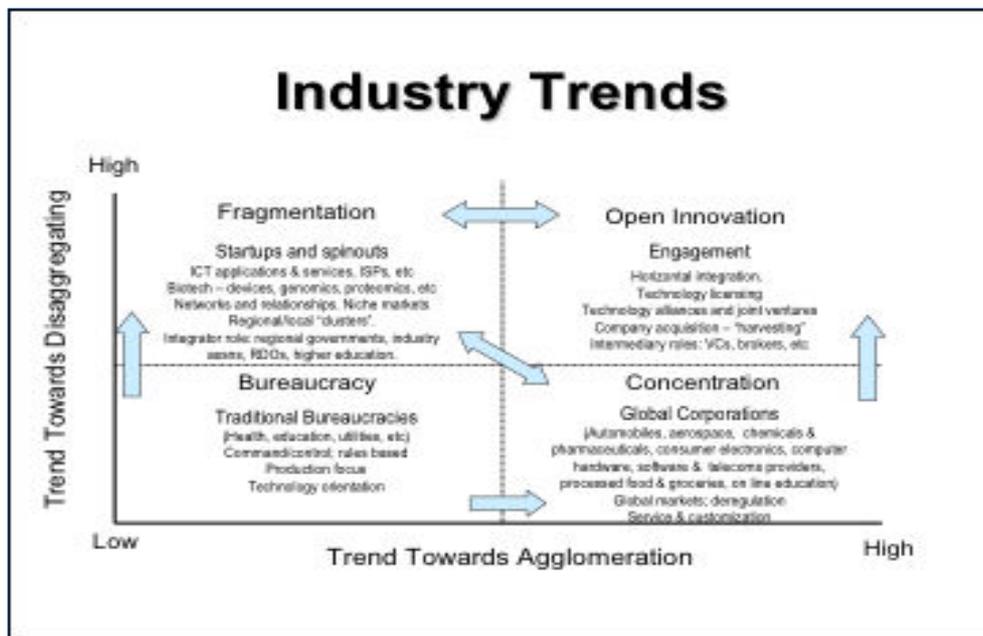
Industrial transformation trends

A range of innovations typically contribute to such transformation – digital equipment and software, new business models, innovations in organisation and in value chains and often changes in the specification of inputs. These important changes may involve some R&D in Australia, but where Australia is an early adopter of there is a higher probability of local innovations following, and related new enterprise development in sensors, equipment, and software.

A diagram that illustrates the trends in industrial structures is reproduced in Figure 116. It points to two “opposing” trends occurring in industrial structure – one towards agglomeration, and the other two disaggregation – and away from the traditional bureaucratic structure of organisations (large and small).

Concentration has been occurring over many years in the chemicals, steel, pharmaceuticals, and more recently in agribusiness. The search for global economies of scale are important drivers of this trend. Fragmentation is occurring with the emergence of new technology businesses and start-ups, where innovation around the potential of digital technologies is a key business driver. Businesses in this category can be global and profitable in new and emerging niche markets.

Figure 116: Trends in industrial structures and dynamics



Source: Howard Partners. Based on: Malone, Thomas W, Robert Laubacher, and Michael S Scott-Morton, 2003. *Investing the Organizations of the 21st Century*. Cambridge, Mass.: MIT Press.

In the rural value chain new business formation is assisted and facilitated by the growing numbers of incubators and accelerator created by enterprising business leaders, research organisations, corporations, and governments. It is also being assisted by a growing number of, incubators, accelerators, coworking/maker spaces, and seed and early-stage startup funds, and private equity players.

During consultation, and observation was made by a senior executive in a RDC that -

The role of big food companies in value chain or producing or delivering food to consumers is under huge threat. They've lost progressively over the last five years 37 per cent market share. Big food companies, in terms of food purchased and what's taking their place are artisanal fast moving small agile food companies who are listening to consumers and don't have all of the constraints in terms of responding to it and the barriers to entry. They probably still need big food companies for the moment in terms of the route to market but we're not going to get innovation from current incumbents. That's what this is about. It's about new people in food who are going to make a difference.

In fisheries small to medium businesses have a major role in the innovation system. The big businesses, like Tassals have been doing well. But the opportunity for is small to medium enterprise is to connect them as a vertically integrated company.

The successful ones don't just harvest fish, but they process it, because "we've micro-miniaturized our processing equipment. You don't have to be a big company to be a canner. Because you can buy a vacuum packager for \$15,000 and be in business and packaging your own seafood".

A prominent Australian AgTech leader observed in correspondence -

We're seeing substantial changes in agriculture globally on this front that are a far cry from (and threaten) some orgs, leaders, and their methods of so called 'innovation' we see here. These faster, cheaper, more effective, and commercially scalable methods are creeping into Singapore now which will through a top-down action affect us through the food and ag MNC's that run out of there and have investments or regional offices in Australia. Cargill, Syngenta, Olam to name a few etc. Large local companies are watching on. Already we're seeing a bottom-up action and groundswell through start-ups that use the same new-age best-practice methods.

Australian R&D investor interest in the incubation and start-up businesses

Cotton RDC have taken an interest in incubator organisations (like the Former Pollenizer) as a way of taking its research and trying, from an early stage, to get clarity about end-user interest and demand for product "and all those good questions so that we can be more effective in our commercialisation".

An Innovation Expert commented that the accelerator model is seen as a "really good thing in terms of building the skills and capabilities within the existing system".

But the power of it I see, is also reaching out to a whole new group of people and ideas, talented people and ideas that are, in that community, whether they are in Australia, in Fintech or, or in Silicon Valley or MIT.

And we can start to go, "We've got this intractable problem or this, opportunity, so how might we solve this?"

Several other RDCs have been going down this track. The MDC has arrangements with several incubators and accelerators including GrowLab at Cicada Innovations through I+E CONNECT.

To support the Australian red meat industry in making this important transition, MDC is developing an innovation and entrepreneurship platform – I+E CONNECT.

The I+E CONNECT platform will be a mechanism that enables industry participants to connect and engage with the global entrepreneurial community, as a strategic focus within their broader organisational innovation strategy. It will accelerate the identification and development of new and disruptive ideas and create commercially viable solutions which will result in unique competitive and defensible positions for our industry.

This platform will seek to tap into new forms of investment from venture capital and private equity funds, develop new partnerships within the global AgTech and FoodTech accelerator and incubator community, and attract entrepreneurs and start-ups.

MDC, through this platform, will also enable the Australian red meat industry to realise the substantial benefits of developing corporate venture activity and working with start-ups and entrepreneurs. These include the rapid development of novel solutions to specific business challenges, the ability to explore new opportunities without distracting from core operations or investing heavily in internal development, and the sourcing of products and technologies to fill or transform product pipelines.

CSIRO and some universities are also embracing this trend with their incubators, start-up and co working spaces.

Many researchers see this as how their ideas going to get traction and make a difference quicker, then that's positive. Some will feel, perhaps, threatened and it's ... they want to do the basic research.

The NFF has invested in Sprout X, a start-up business and the NSW Government and Charles Sturt University have invested in SparkLabs Cultiv8. A summary profile of agribusiness accelerators, incubators and seed funds is provided in Table 28 below.

Table 28: Agribusiness accelerators, incubators, seed funds

Name	Est.	Comment
Australian AgriFood and Wine eChallenge:	2014/16	Pitch and case competition based for a strategic business case for the development of an early-stage entrepreneurial venture pitched to the local business community https://mseq.vc/mission/
CSIRO Main Sequence Ventures:	2016?	Main Sequence Ventures is the manager of the CSIRO Innovation Fund. The Fund invests in: Start-up and spin off companies, and SMEs engaged in the translation of research generated in the publicly funded research sector, development of early-stage technology opportunities from the public research sector.
Grow Lab by Cicada Innovations:		A specialised program for deep tech start-ups looking to improve the Australian and global food and agriculture sectors http://cicadainnovations.com/growlab/
Lion Unleashed:	2017	focused on Asia Pacific and specifically backed by Lion, a leading food and beverage company in Australia, New Zealand, and Asia
Rocket Seeder:	2017	Non-profit focused on capacity building, with connections to the Monash Food Incubator at Monash University. http://cicadainnovations.com/growlab/
Simplot Ignite (in collaboration with Slingshot):	2014/16	A corporate-backed food tech accelerator offering investment and an intensive mentoring program for businesses to scale. https://www.f6s.com/simplotigniteaccelerator
Sparklabs Cultiv8 ³¹ :	2017	A tech accelerator group that mentors and thought leaders across multiple markets in over 12 countries to offer Cultiv8's program in driving ag & food tech start-ups into global businesses. https://www.sparklabscultiv8.com/
SproutX:	2017	Affiliated with Findex and the National Farmers' Federation, Sprout-X offers pre-accelerator, accelerator, and co-working space. Part of the DPI/CSU GATE initiative to fast-track adoption of agricultural R&D. http://sproutx.com.au/

Source: Ag Funder

Universities have established incubators and co-working spaces primarily as a component of the student experience in recruiting students in the highly competitive higher education marketplace.

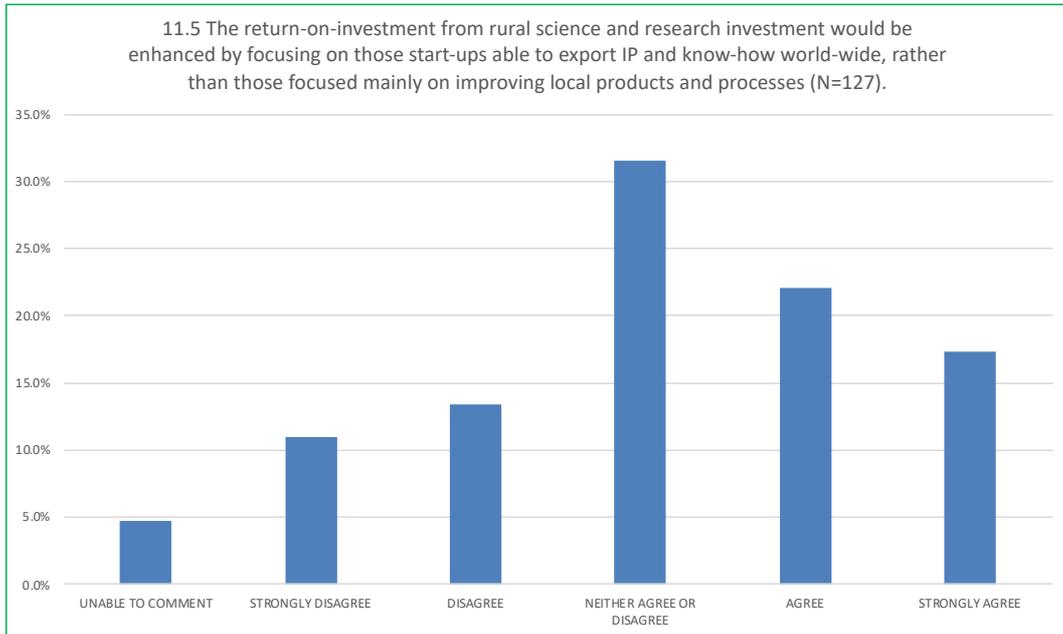
Start-ups also have potential to generate returns from export of IP and knowledge worldwide, that than specifically focus on Australia based products and processes. Rural Innovation Experts were asked to respond to the proposition:

The return-on-investment from rural science and research investment would be enhanced by focusing on those start-ups able to export IP and know-how world-wide, rather than those focused mainly on improving local products and processes.

Experts appear to be ambivalent about the question, although the balance of opinion tends towards supporting the proposition. This is reflected in Figure 117.

³¹ The NSW DPI has partnered with SparkLabs Cultiv8, the Australian arm of the entrepreneurial global investment specialist, SparkLabs, which will hasten prototyping and growth of the new services and products.

Figure 117: Expert Opinion Survey – Potential for returns from start-ups exporting IP and knowhow.



Source: Howards Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

There is a case for creating greater awareness of the opportunities for the Australian Rural Innovation in this area.

Recently formed Australian start-ups

There is a vibrant start-up sector in Australia. The scope of start-up activity across functions and activities is illustrated in Table 29.

Table 29: Recently formed agribusiness start-ups

Company	Est.	Nature of the Business
Ag DNA:		Enterprise level precision farming platform that combines data science and the Internet-of-Things (IoT) to help commercial crop producers increase yield, reduce input costs, and maximise farm profitability. https://agdna.com/about
Agersens		Developing an animal collar and phone app to help beef and dairy farmers reduce their labour costs and increase their productivity by automating the movement and control of their livestock. https://agersens.com/about/
agAlytics		Developing a smartphone enabled reader for improved soil fertility management. A system for georeferenced soil sampling, and the accurate measurement of soil nutrients and pH. http://agalytics.com.au/
AgDraft		An online marketplace for farmers post jobs to an extended network of workers that are effectively "referenced checked" by their peers, making hiring quick and reliable. https://www.agdraft.com.au/
AgWorld		Provides collaborative farm management solutions the work on iPad, iPhone and the web that aim to simplify farming solutions. https://agworld.com.au/index.php
CropLogic	2010	Provides combination of advanced research and technology devices and equipment embedded in paddocks and fields with an in-field agronomy support team. Based on IP from NZ Institute for Plant and Food Research. ASX listing 2017. https://www.croplogic.com/about.html
Dragontail Systems		Technology for the Fast Food/Quick Service Restaurants food preparation, delivery, marketing, and management processes
iPaddock Apps		Farmer-focussed Apps designed to save money, optimise yields, improve productivity, and increase profits http://www.ipaddock.com.au/
iPaddockIndustries		Manufacture of machinery specifically aimed at automation of cropping tasks. http://www.ipaddock.com.au/ipaddockindustries/
Nexgen plants	2009	Delivers non-GM solutions for a range of pathogens, production traits and consumer traits. Spin out from UQ. http://www.nexgenplants.com/
Ovass:		Provides geospatial analytics for global intelligence & insights through satellite imagery & artificial intelligence. Supported by Muru-d. http://www.ovass.com/ ; https://muru-d.com/startups/profile/ovass/
Roots Sustainable Agriculture Technologies	2012	Developing and commercializing disruptive, modular, technologies including plant climate management via root zone temperature optimisation and the shortage of water for irrigation. Supported by Israeli Chief Scientist's Office
The Yield		Provides an integrated set of AgTech solutions that sense, analyse, and predict on-farm growing conditions, and then deliver information in a usable format. Solutions can be applied across the food chain to help increase yield, reduce waste, mitigate risks and costs associated with bad weather, and address sustainability. https://www.theyield.com/

Fostering transformational impacts

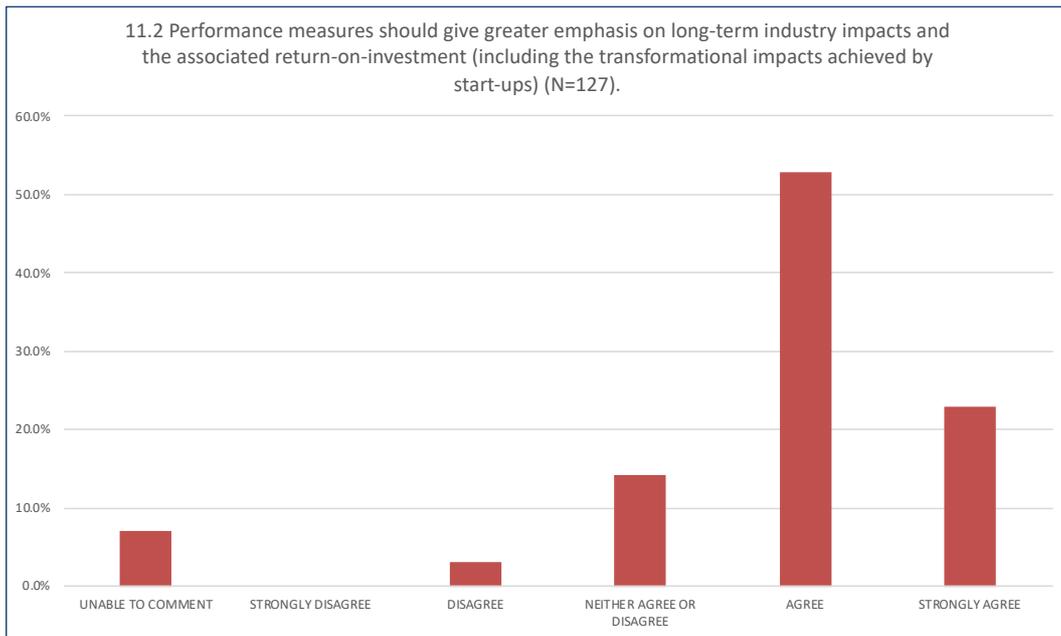
A Rural Innovation Expert commented in the Survey that –

The success of the Australian Rural Innovation System will increasingly rely on best practice commercialisation methodology which attracts entrepreneurs and venture capital. The Australian rural Innovation system in its current state is unable to attract the world's best commercial and technological talent to create, drive, implement or take to market, the most demanded technology to increase on farm or supply chain efficiency. The success of the Australian rural innovation system will see a move away from R&D to faster, cheaper, and more effective pathways of innovation, commercialisation and implementation

Rural Innovation Experts indicated broad agreement to the proposition that

performance assessments should "should give greater emphasis on long-term industry impacts and the associated return-on-investment (including the transformational impacts achieved by start-ups.

This is reflected in Figure 118 below.

Figure 118: Recognising the transformational impact of start-up businesses

Source: Howards Partners, Rural Innovation System Review, Expert Opinion Survey, 2018

Conclusion

The developments in new business creation and business models are having a major influence on the direction and performance of Australia's rural innovation system. They threaten to disrupt the position of incumbents and pre-existing relationships between producers and consumers across the rural industry.

The developments and progress of "disruption" in the Australian rural innovation system is at an early stage. But over the longer term, combined with changing consumer tastes and preferences, the impact on the system is like to be profound.

Many would argue that agriculture, fisheries, and forestry is the last major industry to be disrupted by technology and new business models.

Appendix 5: Building a more Sustainable and Collaborative Rural Research, Development, and Innovation Ecosystem – A Discussion

Key Points

- With increasing revenues and the emergence of multiple objectives and accountabilities, the university business model has evolved from the feudal community of scholars, through the idea of social contract between science and society, to an 'connected' and networked innovation systems perspective
- More recently, a view has emerged of universities as *knowledge businesses*, heavily committed to the creation and transfer of knowledge for economic and social benefit. Collaboration should reflect this "business to business" way of thinking and the commercial realities for all parties.
- That said, collaboration is moving from a transactional basis to longer-term trust-based partnership ventures reflected not only in research income/expenditure flows but also in new asset and infrastructure creation.
- A better understanding is required for institutions and organisations that facilitate and promoted collaboration and engagement
- Innovation is required in governance and organisational frameworks for collaboration where collaboration commitments involve substantial investments and risks for all parties.

Building sustainable collaboration should be addressed at three levels:

- Strengthening networks under the conventional wisdom of how knowledge is shared
- The marketing of knowledge through commercialisation – selling the outputs of a university for profit
- Building relationships around partnerships, long term commitment and trust on a 'business to business' basis.

These aspects of collaboration are addressed further below.

The conventional wisdom - networks and the sharing of knowledge

There is a popular expectation that as research organisations and universities are public funded, they should give away the knowledge they create for free. And in many instances, they do. Their core value is around the community of scholars, with academics acting independently, autonomously, and socially, with their peers in other institutions, business and in government.

But as resources available to universities come under pressure, governments have taken an interest in ensuring that universities achieve returns from their research investments through commercialisation – that is, selling the outputs of the university, in this case, Intellectual Property Rights, for a profit (Bentur & Lowenstein, 1998; Bok, 2003; Johnston et al., 2003; Lerner, 1999; Mowery et al., 2004; PMSEIC, 2001).

Except for a few blockbusters, universities do not make a commercial return in selling IPRs. They do it for a range of reasons, not least of which is to work effectively with business around collaborative research projects and extending research capability through joint projects.

Strengthening commercialisation capability

Commercialisation thinking played up the transactional nature of knowledge transfer – generating income from the sale or licensing of Intellectual property, which has created a 'transactional' culture.

Emphasis has been on establishing watertight contracts and protecting intellectual property. A Transaction focus, driven by lawyers, patent attorneys and accountants, works against building trust and forming ongoing relationships.

A transactions culture is linked to a view that scholars will be incentivized to work for a commercial return through government subsidies and incentives. But many of these incentive programs tend to be short term, involve very limited amounts of money, and find it hard to demonstrate sustained impact.

Commercialisation staff are now becoming positioned as “business development” professionals. Much more attention is being given to professional development – a high priority for Knowledge Commercialisation Australasia (KCA).

Partnership and the emergence of ‘business to business’ relationships

Context

It has been mentioned many times in the Consultations for the Review that Australia has a “transactional” culture. Success focuses on the “the sale” rather than the research and commitment that has been necessary to get there and the responsibilities and obligations that will flow from it. Success is seen only in terms of the revenues that the sale generates (or the costs that have been saved), rather than the value it creates for the purchaser and provider/supplier.

Only in recent months has it become clear that a focus on maximising sales revenues above all else can-do irreparable damage to corporate reputations and behaviours. Australian corporate Boards and senior executives should know that success is inexorably linked to generating and retaining *customers* and capable *suppliers* and delivering value to them.

Without customers and competent suppliers, businesses cannot survive. This underpins the contemporary interest in global supply chains. Many companies now see the supply chain as the critical unit of analysis. And so, it is with university business relations³².

In business the reality is that successful contractual arrangements (partnerships, joint ventures, strategic alliances, etc) are underpinned by a strong ethic of partnership and trust. These ‘business to business’ relationships often take many years to consummate and deliver results. Hastily formed ventures and alliances have a high likelihood of ending in tears – and in the lawcourts. From this perspective, university-business collaboration will only be enhanced when university-business engagement is approached on a business-to-business platform

The changing university business model

In recent years a great deal has been said and written about the low level of engagement between Australian universities and industry. Much of this commentary, which has been of a critical nature, has failed to address some fundamental changes in the university business model:

- Nearly all Australian universities are constituted as *public* organisations. They are highly independent and autonomous. Even university statutes have the force of law.
- Australian higher education has become *big business*. In 2014, revenues stood at \$27.7bn and net assets stood at \$48bn. During the year they generated a positive cash flow on operations of \$3.2bn. They also paid out \$3.1bn for property, plant, and equipment.
- This growth in revenues, together with their asset portfolios has meant that public universities are increasingly being run on a businesslike basis. This does not mean universities are being run with a profit

³² Some elements of the following comments were published in *The Australian*, 22 June 2016, “Industry engagement and the emerging university business model” <http://www.howardpartners.com.au/industry-engagement.html>

motive; but they are having to plan, budget and account for a substantial growth in their activities on a commercial basis.

- Several universities now have annual revenues more than, or approaching, \$2bn and more than 50,000 students, together with a substantial discovery and applied research portfolio. They are also investing, often collaboratively with private sector organisations, in a range of new commercial opportunities. The scale and scope of these operations is growing and diversifying, but not yet to the same extent as in the US.
- Universities compete – and they compete vigorously – for students, research income, and esteem.
- The evolving competitive model is one of a strategically driven organisations, with five to 10-year plans in teaching, research, international, campus development and industry engagement. There is a focus on performance and accountability, building competitive advantage and creating distinctiveness among students, researchers, and potential industry partners.

In this knowledge business paradigm, Vice-Chancellors (CEOs) are tending to be appointed based on their business acumen as well as academic standing. They are expected to be the external champions of the university and to have a key role in negotiating with government, business and in securing philanthropy.

At the same time, the institutional role of a university as a 'public space' and community of scholars, connected to autonomous and independent faculties and schools continues. The financial reality is that these organisational configurations are now 'business units', 'or profit centres', with strategies, plans, budgets, and performance metrics. University-business collaboration must take account of this academic and business institutional configuration.

Implications for collaboration

The evolving business model means university management is becoming more complex and sophisticated and executive teams are becoming larger, with greater professionalisation and individual specialisation. Faculties, schools, and university research centres effectively operate as business units in the emerging model that parallels that of the multi-divisional firm. Unfortunately, but not uniquely, these units can operate as silos. Better practice organisational structures are still evolving.

Power and influence is moving from faculties and schools to the chancellery, indicating a strong shift away from the community model. Key performance metrics centre on student recruitment, generating research income and investment, and scholarly publication (prestige and eminence). These developments have caused a great deal of discomfort among many academics.

It follows that new business proposals, including collaborations with industry, are assessed in terms of costs, risks and returns (benefits) to both parties. Individual academics have limited scope to enter research collaborations and consultancies — unless they do it as outside work - with, or without, the imprimatur of university management.

There is limited scope for undertaking research outside committed strategic directions – unless of course accompanied by significant investments and long-term commitment. This is evidenced by the increase scope of corporately funded and named buildings, laboratories, and facilities across university campuses.

As investments create assets, and appear in university balance sheets, the level of collaboration, indicated by transactions in the income statement, is likely to be understated.

Lingering concerns

Businesses still complain they find it difficult to work with university academic staff and faculties. The work of the faculty is heavily concentrated on teaching, and it is rare for staff to have a fulltime commitment to research.

Short-term and transactional research consultancy projects are not encouraged – unless they pay their way or are subsidised - as they tend to be difficult to manage and divert resources from research commitments. They can also get caught up in highly bureaucratic university research and financial management processes.

Short term consultancy contracts can also be high risk.

Sustaining collaboration

Increasing the scope for industry to work with universities must move from a transactions-based approach to one conducted based on partnerships, alliances, and trust in a business-to-business context. University research managers must move from a mindset of generating research income to one of value creation.

Businesses must ensure their research ideas fit with university research and engagement strategies, and that they deliver benefit to the university as well as to their own enterprises. Senior executives should take the time to get to know key decision-makers in universities, including vice-chancellors, and the fields of research excellence that their university is committed to (or could be with a substantial investment).

Similarly, university staff must ensure that their research representations to business and industry are in conformance with business missions and strategies.

At the same time, university leaders must engage effectively with the business community through involvement in business associations and organisations. This would include, for example, Vice Chancellors becoming members of the Business Council of Australia and State/Territory based business organisations.

The collaboration governance model will continue to evolve. In that process, more innovative and sustainable arrangements for industry collaboration will need to be developed, possibly around designated research centres, institutes, and controlled entities which have a specific remit for industry engagement. However, outside the CRC program, there is little guidance on best practice for formation, management, and operation of university research centres that engage with industry.

Governance and organisational models for collaboration

The university research centre is a highly regarded instrument for engagement in the US. Research centres have facilitated interdisciplinary research that has been the hallmark of knowledge-based industrial innovation. Staff in centres have advantages in relationships with industry scientists. They have time to increase their contacts and get to know the key personnel. They have become an important resource for finding employment for non-tenured researchers and postdoctoral students until they find permanent employment.

Universities are valued as sources of intellectual capital, but their roles have evolved from that of a social institution, a community of scholars, primarily focused on development of human resources to complex organisations centred on discovery, processing, transmission and application of knowledge itself. Accordingly, governance and organisational innovations will be required to ensure that universities and business can work together efficiently and effectively in this changed environment.

International practice demonstrates that research excellence and industry engagement are mutually reinforcing. But sustained collaboration requires leadership, management capacity, resources, and effective institutions for engagement designed to deliver outcomes and results. These arrangements must be incorporated into the evolving business model.

Implications for rural research

In universities, rural research is no longer the sole province of the Agricultural Science Faculties, but reflects a collaboration effort across faculties including, engineering, technology, economics, business, and management. This more integrated capability is often brought together in autonomous Centres and Institutes that draw in substantial external investment and longer-term partnerships with national and international research funding agencies and corporations.

There are continuing opportunities in developing such integrated 'mission-oriented' centres, but it requires a sustained movement away from a short-term transactional approach to collaboration ("show me the money") to one involving longer term partnerships built around clear objectives, returns on investment, mutuality, and trust. Effective governance models are emerging, but it is still an area that requires organisational innovation and scale.

University-business-government collaboration is itself a 'system' that requires, quite fundamentally, a cross-disciplinary approach to research and an end user focus – either in the immediate or longer term. It is well known that commercial or public benefit³³ research problems or opportunities are rarely confined to one academic discipline or research field.

International comparisons

Countries that perform well in collaboration appear to have strong institutional and organisational frameworks for collaboration and engagement. They promote long term commitment and partnership and appear to eschew the transactional arrangements that characterise university-business relationships in Australia.

The project brief did not allow time for detailed assessment of each country. In the following paragraphs reference is made to studies carried out as part of the ACOLA project Securing Australia's Future Project "Translating research for economic and social benefit: country comparisons" on behalf of the Australian Council of Learned Academies, located at <https://acola.org.au/wp/saf09-contributing-reports/>

Canada

Citation: *Smith, J & van Dieen, J (2015). Review of Public Research Commercialization Instruments: A Study of Canadian Public Policy and Business Partnership Mechanisms Used for Commercialization of Public R&D. Report for Securing Australia's Future Project "Translating research for economic and social benefit: country comparisons" on behalf of the Australian Council of Learned Academies, <https://acola.org.au/wp/PDF/SAF09/3%20Canada.pdf>*

The Study concluded that Canada:

- Is improving its capabilities for commercializing public research by creating new instruments such as the CCIP, Futurpreneurs and the NRC flagship programs:
- Has been investing in the revitalization and renewal of existing instruments such as SR& ED, IRAP, and SADI:
- Needs to improve the collection of performance information from the public investments in R&D; present efforts are inconsistent and insufficient to really determine the relative effectiveness of different instruments. We believe that this situation can be rectified through Executive Action, however the extent of reporting will depend upon the need for and the viability of the data for strategic purposes.

³³ The term "public good" is generally avoided in this Report. "Public good" has a meaning in public sector economics around non-excludability and non-rivalness which is hard to achieve in the real world. Defence and lighthouses come close. Natural environment and biodiversity are often referred to as "public goods," but they have more meaning in terms of outcomes (and potential measurement) when expressed as "public benefit" interventions.

- Should encourage a strategic conversation following the issues raised by James Balsillie concerning Canada's poor performance on international technology commercialization.

The Study considers that it is timely to initiate a national foresight effort directed towards identifying what Canada will require in terms of public research and national priority measures-approach to ensure that we are competitive looking to 2050.

The Study concludes that "next three decades are projected to be pivotal for the future of western civilization as it confronts enormous challenges such as climate change, global poverty, and the transition to a digital economy and society where machines are intelligent, robots are pervasive and aging and human health are central to our continued existence. A low marginal cost production base and its consequences for the future of work and finance will also create big challenges for public research".

The Study points to a reliance on a strong set of enduring instruments (E.G. IRAP, SDTC, NCE, SR&ED, NSERC, NRC, etc.) and a diversity of additional more specialized delivery tools that has enabled a strategic allocation of budgets to be applied by different administrations (2000-2015) according to their policy preferences and changes in the demand structure. Effectively the same type of measures and instruments were applied over the period 2000-2015 with sometimes minor incremental shifts in emphasis and eligibility.

Some specific points -

- Canadian R&D spending is heavily concentrated in the education sector with higher education expenditures making up 37% of Canada's R&D spending in 2009, which is considerably higher than the OECD average of 18 per cent.
- Calculation of net public benefit is not precise enough currently to permit a benefit cost/ranking of the government's R&D programs. This, however, is not a problem exclusive to Canada as Canada's peer countries of the OECD are also having difficulty measuring their innovation programs and subsequent outputs.
- Canada's commercialization record is also failing in reaching its potential. However, from an optimistic viewpoint what is encouraging about this dilemma is that Canada's lack of commercialization success is not stemming from a shortage of ideas but rather the ability to translate IP into homegrown success. Canada produces an abundance of IP and rather than reap the benefits of these ideas too many of these ideas wind up making others wealthy.
- Dan Morrison, Chief Operating Officer at Research in Motion (RIM), believes "We became collectively ineffective at moving from the idea stage to the conversion of an idea into a commercial success for anything other than devices."
- Public R&D in Canada - at least since 1916 when the NRC was created to support and develop Canadian industrial R&D capacity - has been the primary way that government has been involved in working with universities, industry, non- governmental organisations, and the voluntary sector to effect innovation in Canadian society. Over the intervening years Canada has consistently been a leader in the development of new and innovative mechanisms to provide the support, financial and otherwise, necessary to enable the economy to adapt to changing circumstances as well as the public sector to maintain its capacity to provide efficient and cost-effective services and infrastructure.
- In 2011, the NRC decided to shift its research focus toward more applied and commercial- -ready industrial level research. This shifting in priorities resulted in the creation of three flagship programs, including the Canadian Wheat Improvement Flagship, an NRC collaborative partnership with Agriculture and Agri-Food Canada (AAFC), the University of Saskatchewan's Crop Development Centre and the Province of Saskatchewan. It has budget of \$ 97 million from 2013-2018, and a goal of improving the yield of Canadian wheat crops, and on determining the use of chemical fertilizers as efficiently as possible.
- In the digital/innovation economy it has become more important than ever to be able to prove a technology application prior to it being widely adopted. Today innovative technologies need both *prototype/technical demonstration and market readiness/acceptance showcase demonstrations*. Canada has lacked a coherent approach to technology demonstration-largely because the public research enterprise does not normally include those functions (demonstration) which are thought to be associated primarily with commercial risk.
- Canadian measures to protect innovative ideas and to advance commercialization of public research have not achieved legislative prominence although many innovators have suggested that such measures will be required if Canada is to remain competitive in the Global economy. To do so will require a

concerted effort by all stakeholders to develop a coordinated integrated innovation eco-system. The training and mentorship of managers and financial personnel who are part of the innovation eco system also remains a challenge for Canada and training and mentorship of specialized groups e.g. (women, aboriginal, entrepreneurs) requires more resources.

Germany

Citation: Johnston, R (2015). A Study of Measures to Encourage the Translation of Public Sector Research for Economic and Social Benefit in Germany. Report for Securing Australia's Future Project "Translating research for economic and social benefit: country comparisons" on behalf of the Australian Council of Learned Academies, <https://acola.org.au/wp/PDF/SAF09/8%20Germany.pdf>

Key points

- A major distinguishing characteristic of the German R&D system is the existence of a broad variety of public and semi-public research institutions that complement and bridge the R&D activities of industry and universities. The most important of these institutions are the Fraunhofer Society (Fraunhofer-Gesellschaft), the Max Planck Society (Max-Planck-Gesellschaft), the Helmholtz Centres and the Federation of Industrial Research Associations.
- It is leveraged by strong links between industry and science, with a comparatively high proportion of public research funded by industry. Only 27% of the adult population is tertiary-qualified, but 37% of persons employed are in S&T occupations. It has 8.1 researchers per thousand total employed, close to the OECD median. Researchers are well integrated in international networks: 47% of scientific articles and 17% of PCT patent applications are produced with international collaboration.
- Innovation and research policies are not treated as separate within the German national system of innovation. In fact, policy makers perceive them as complementary if not inseparable. In many cases, R&D support policies target SMEs which are seen as essential drivers of innovation and the main success factor of the German economy. Consequently, almost all main political initiatives address both elements: research performed in research institutes (private or public) and innovation and technical development performed in enterprises (particularly SMEs). The clearest signal for this is the fact that most support programmes exclusively fund networks of companies and public research or higher education institutions.
- The German Federal Government continues to make targeted investments in education and research even in times of budgetary consolidation. In 2012, the budget of the Federal Ministry of Education and Research (BMBWF) was increased by 11%. In 2013 it grew by an additional 6.3% compared to 2012 (totalling about €13.75b) and, despite budgetary consolidation, was further increased in the 2014 by about €224 million, up to a total of some €14 billion.
- On 3 September 2014, the Federal Cabinet adopted a new German High-tech Strategy entitled "Innovation for Germany". The strategy aims to ensure coherence within Germany's innovation policy, and to strengthen prosperity and economic growth in Germany. It places a strong focus on speeding up the transfer of scientific findings into marketable products, processes and services, as well as on improving the overall environment for innovation. To this end, the German government invested €14 billion in both 2014 and 2015.
- Unlike the strategy of the past, this HTS is designed to promote not only emerging technologies but will also address major societal challenges. It is shaped around a model for an innovative Germany. The aim is to move Germany forward on its path to becoming an innovation leader in Europe and the world.
- Priority tasks include described as "core elements of a completely consistent innovation policy" include: Sustainable economy and its energy – energy storage, electricity grids, solar construction, green economy, bioeconomy, sustainable agricultural production, raw material supply, city of the future, future of building, sustainable consumption.

Hygiene in the agricultural sector using technologies of the Fraunhofer FEP

Hygiene is becoming ever more important and this is particularly so in the agricultural and food sectors. The Fraunhofer FEP possesses a proven method for efficiently freeing seed products, foods, and animal feed of pathogens within a matter of seconds. The method uses low energy electrons to permanently kill germs. The method is purely physical - pathogens can hence not develop any resistance. Also, chemical residues are not a problem, meaning, for example, that excess of seed can be readily used as animal feed.

Electrons also play an important role in modifying renewable raw materials. For example, by customizing the energy of the electrons the surface properties of the raw materials can be adapted for their further processing. At the Fraunhofer FEP we develop electron beam sources for a wide variety of applications. For example, a technology has been developed for agricultural machinery to detect foreign objects. The range of services we offer extends here from technology and process development right through to generating complete package solutions, including technology transfer.

<https://www.fep.fraunhofer.de/en/Anwendungsfelder/Landwirtschaft.html>

Israel

Citation: Moshe, S (2015). A Study of Measures to Encourage the Translation of Public Sector Research for Economic and Social Benefit in Israel. Report for Securing Australia's Future Project "Translating research for economic and social benefit: country comparisons" on behalf of the Australian Council of Learned Academies, <https://acola.org.au/wp/PDF/SAF09/9%20Israel.pdf>

Key points

- Any review of the governmental efforts to commercialise cannot overlook the fact that a lot of commercialisation, or to put it more bluntly, privatisation, of public R&D went on, in the absence of governmental intervention. Some would say it was part of "turning a blind eye" policy, justified by "real world practicality" and some, like the state comptroller, would point to it as negligence. Naturally there is no public information regarding the "performance" of this "measure".
- In the 1980s and 1990s, the mechanisms of research commercialization were refined, and institutions such as the Weizmann Institute and the Hebrew University had impressive success stories with commercialized patents, such as the drug Copaxone (Weizmann Institute) and cherry tomatoes (Hebrew University), which ranks them among the most successful research institutes in the field of technology transfer to this day.
- Contrary to the thriving debate in the United States, concerning the implications and potential hazards of commercialization, the issue enjoys wide consensus and almost no public debate in Israel.
- Israel's activities in research commercialization relative to the size of the higher education sector are prominent compared to the United States, Canada, Australia, and the United Kingdom.
- When total revenues from the sale of intellectual property are measured relative to R & D expenditures at universities, they are higher in Israel than in all the other countries compared. The number of patents per faculty member in Israel is more than double the average in the United States.
- Three out of the seven research universities – the Weizmann Institute, the Hebrew University, and the Technion - have developed "blockbuster" drugs, and the Weizmann Institute boasts three blockbusters to its credit. Accordingly, the Weizmann Institute and the Hebrew University are among the highest-earning universities in the international technology-transfer field.
- Another important characteristic of the Israeli case is the absence of state policy or regulations. Unlike U.S. law, before the Bayh-Dole Act of 1980, Israeli law did not limit the right of higher education institutions to register intellectual property rights for the inventions of their employees, even when such inventions were developed as part of government-sponsored research.
- Furthermore, there is no state or governmental policy concerning the principles and guidelines for research commercialization activity. The task of formulating, executing, and supervising policies remains with the management of the universities, which bear the responsibility of balancing their commercial and academic interests as well as the public interest.
- The increased involvement with industry and the introduction of financial rewards into the university system has its inherent tensions and creates an arena for various conflicts and struggles between stakeholders. The conflict between scientists and the Technology Transfer Company has several dimensions: Contested ownership of IP; Conflicts over royalties; Conflicts over the business of handling inventions.
- In 2012 and 2013, commercialization companies received 1,438 invention disclosure reports, about 1,019 from commercialization companies at universities; of all disclosures, it was decided to protect 922 cases, to reject 323 cases, and in 193 cases a decision was not yet reached.
- Compared to 2010 and 2011, there was an increase of 20% in total invention disclosures reports in all the institutions. In the companies at universities, there was an increase of 2.2%, compared to 2010-2011.

- The dominant fields in invention disclosures reports of the *companies associated with the universities* were: biotechnology, medicines, physics, electronics and electro-optics, and chemistry and nanotechnology.
- The dominant field in invention disclosures reports of research institutions and colleges was *agriculture and plant genetics*.
- The dominant fields of the active license agreements in 2012-2013 were fields which are related to life science: medicines (26%), bio-technology (20%) and *agriculture and plants genetics* (17%).
- Fields related to the Israeli high-tech industry, such as physics, electronics, electro-optics and mathematics and computer science, totalled about 12% of the active license agreements.

Netherlands

In The Netherlands, the Agricultural Knowledge System (AKS) is organised in one agricultural university (Wageningen University), a Faculty for Veterinary Medicine (University of Utrecht), a limited number of schools for higher education, and one organisation for the agricultural R&D. Knowledge on agriculture and food (processing) is also generated and nurtured in some other, more general, research institutes (for example, TNO Food & Nutrition) and numerous private sources. The extension services are provided by private enterprises. The Minister of Economic Affairs, Agriculture and Innovation is responsible for the AKS (OECD, 2013a).

Priorities in R&D are set during a (usually annual) process in which relevant stakeholders are involved. Connecting knowledge, practice and policy (the so called “golden triangle”) is considered vital to the success and innovative power of the Dutch agribusiness. To that aim it is based on a number of linking principles and connection mechanisms, different kinds of priority setting methods are applied for the different kinds of research:

New Zealand

For 25 years [AgResearch](#) has partnered with the pastoral sector to identify and deliver the innovation that is needed to create value for New Zealand. It is a national organisation, with staff spread across four campuses and 11 farms in the Waikato, Manawatu, Canterbury, Southland and Otago.

AgResearch scientists helped develop the Wool Runner, ‘the world’s most comfortable shoe’

A world-first woollen running shoe using fabrics designed by AgResearch launched for sale online in early 2016 and has been labelled “the World’s most comfortable shoe” by Time magazine.

The Wool Runner highlights the work AgResearch has done in helping create a value-added product from the under-appreciated mid-micron parts of the wool clip. This offers the opportunity to open up a new high value sector for wool, boosting demand for wool and ultimately increasing returns to sheep farmers.

The unique patent pending process, developed in a project jointly funded by Three Over Seven and Wool Industry Research Ltd, comprises a novel fabric construction technique, using wool together with small amounts of other fibre types followed by finishing using carefully selected processes to give it the characteristics suitable for use as a shoe-upper.

The advantages of being made from wool include controlling odour, temperature regulation, moisture management, and resistance to stains and dirt, all from a sustainable resource.

AgResearch senior scientist Stewart Collie worked to develop the shoe fabric after being approached by the company. “We went through a wide range of fabrics that we had created for other uses and identified a candidate that looked like it could be developed into something that would have the combination of strength, durability and comfort,” he says.

Early wearer trials of the shoe they developed came back with very positive feedback, with some even reporting they could be worn comfortably without socks.

Other success stories are located at <http://www.agresearchcareers.co.nz/our-people/science-stories/>

The Annual Report, 2017, is located at <https://www.agresearch.co.nz/assets/Uploads/AGR80298-2017-Annual-Report-finalart-Digital-6.7MB.pdf>

Singapore

Citation: Eden Strategy Institute (2015). Improving Commercialization of Publicly-Funded Research: Singapore. Report for Securing Australia's Future Project "Translating research for economic and social benefit: country comparisons" on behalf of the Australian Council of Learned Academies, <https://acola.org.au/wp/PDF/SAF09/11%20Singapore.pdf>

Some points:

- Since the launch of the first National Technology Plan in 1991, Singapore's expenditure on R&D has increased almost tenfold. The initial focus of R&D spending was on growing research manpower and building infrastructure. Subsequently, the focus shifted to developing R&D capabilities by training talent and developing technologies needed for conducting research in the long-term.
- Singapore's current emphasis is on industry partnerships and on producing economic outcomes from public research. To this end, the Research Innovation Enterprise Council (RIEC), the body that sets the strategic direction for national R&D, dedicated 70 percent of Singapore's five-year R&D budget to achieving economic outcomes in 2015, five percent more than the budget five years ago. It is evident that innovation and enterprise form the cornerstone of Singapore's strategy to remain globally competitive.
- Public research commercialization requires the alignment between Singapore's national interests and R&D strategy. As a result, research priorities are identified based on their strategic implications on the economy. Research efforts are also aimed at diversifying Singapore's economic landscape, increasing the innovativeness of its people, and presenting an attractive destination for multinationals to establish their offices.

UK

Citation: Hughes, A (2015). Review of approaches to the commercialisation of university research and support for university industry collaboration in the UK. Report for Securing Australia's Future Project "Translating research for economic and social benefit: country comparisons" on behalf of the Australian Council of Learned Academies, <https://acola.org.au/wp/PDF/SAF09/13%20UK.pdf>

Some points

- In terms of innovation outputs, the UK is not an outstanding performer. Innovation scoreboard rankings typically place the UK in a second group of 'innovation follower' nations behind leaders such as the USA, Japan, Switzerland, Korea and Germany.
- In terms of innovation inputs and, in particular, R&D in both the public and private sectors, the UK is also at the lower end of international performance.
- In terms of the academic performance of the science base, the UK has an outstanding record. Higher education sector expenditure on R&D, moreover, rose substantially in real terms in the decade prior to the financial crisis of 2008/09. By 2009 the UK ranked a little above Germany, Japan, France, Korea and the US. It has, however, lagged in commitments to the sector in the aftermath of the financial crisis. After 2005, the UK lagged Germany, France, Norway, Korea, Denmark, Finland and Sweden in growth of the ratio of Higher Education R&D to GDP.
- The concern over persistent innovation and productivity underperformance has led to numerous reviews and policy changes attempting to alter the university-industry interface. There have been a dozen investigations and reviews since 2011 alone. It has also generated multiple evaluations and investigations of policy interventions.
- In assessing the role of policy towards university industry relationships and the impact it may have on innovation and economic growth it is important to keep the scale and significance of these relationships in perspective. Only around 5-7 % of UK businesses report co-operation activities with universities, HEIs or public sector research organisations.
- If businesses are asked to indicate the frequency of use and importance of universities as a source of knowledge for innovation the proportions are somewhat higher (around 20%) *but they rank very low down the list of sources as a whole and well below customers and suppliers. This is a generic feature of the role of universities and is as true of Australia the US and other countries as it is of the UK.*

- A second generic feature of innovation activity is that *the development of innovations from the science base requires multiple complementary investments by the private sector. Without this 'demand pull' increasing 'supply push' will have little impact. **University–industry links policy must therefore be seen in the wider context of industrial policy to raise private sector investment and the capacity of the private sector to absorb and develop knowledge flows from the science base.***
- The **Agri-tech Catalyst** is delivered by Innovate-UK with support from the Biotechnology and Biological Sciences Research Council (BBSRC). It is seen as an important part of the UK Strategy for Agricultural Technologies and supports the 'proof of concept' development of near-market agricultural innovations. The Government has invested £60 million in the Catalyst, with an additional contribution of £10 million from the Department for International Development (DfID) to help in the transfer of technology and new products to developing countries. Agri-tech has been identified as a priority sector and Agri-science as a key technology.
- *Agriculture and Food Action Plan 2014-15*, taken from the Technology Strategy Board Delivery Plan, 2014-15. –
 - Crop and livestock disease challenges: effective solutions to control agricultural diseases to realise the yield potential of crop and livestock production systems; Collaborative R&D competition;
 - Agri-Tech Catalyst: to advance the sustainable intensification of agriculture and deliver economic impact for the UK agri-tech industry; Catalyst competition
 - Agriculture and the food supply chain: knowledge transfer to improve the competitiveness, resilience and responsiveness of the agriculture and food supply chain; Knowledge Transfer Partnership
 - Resource efficiency in the food supply chain: improving the use of resources and minimising post-farm-gate waste generation in food production supply chains; Collaborative R&D competition
 - Centres for agricultural innovation: working with BIS, DEFRA, and BBSRC to establish centres as part of the implementation of the industrial strategy. The first centre planned is the Centre for Agricultural Informatics and Sustainability Metrics; Collaborative proposals

USA

Citation: Roessner, D (2015). Selected U.S. Measures to Promote the Transfer and Commercialisation of Public Sector Research. Report for Securing Australia's Future Project "Translating research for economic and social benefit: country comparisons" on behalf of the Australian Council of Learned Academies, <https://acola.org.au/wp/PDF/SAF09/14%20US.pdf>

The United States has a long tradition of the land grant universities (MIT, for example) that fostered close collaboration with industry. There are also many private universities (Stanford, for example) that also have close business/industry relationships. There is also long term stability through the investments in fundamental research, such as the National Science Foundation.

Some points -

- Knowledge and technology transfer focus on application of existing knowledge to solve problems and improvement of products and processes, functions that initially (in the U.S.) were central to land grant universities but are now recognized as highly important for all research universities, public and private,
- The beginning of significant governmental concern with technology transfer and use of publicly funded research was marked by passage of the Smith-Lever Act of 1914, which created the Cooperative Extension Service (CES) in the U.S. Department of Agriculture. The Act provided federal grants to states for a growing "extension" system that provided more effective means of transmitting research results originating in state land-grant colleges (research supported largely by the Agriculture Department) via county extension agents to individual farmers (Rogers, Eveland, and Bean, 1976). The cooperative aspect of the Service involved cooperation, and financial support, from all three levels of government in the federal system.
- The most important aspect of the extension system was that it involved two-way exchange of information among numerous participants who were closely associated both geographically and culturally. Problems requiring research were identified by farmers and passed through the system to

research managers; the managers established priorities and funded research whose results were translated into the language of farmers by county agents. Agents not only translated research results into practical guidelines, they also demonstrated the payoffs from the new seeds, techniques, and fertilizers by using them in their own fields.

- The extension system in agriculture was extremely labour-intensive, and thus expensive, but it was also highly effective. Agricultural productivity shot upward through the first half of the twentieth century, largely as a consequence of the CES.
- A substantial evaluation literature indicates that passive/reactive technology transfer mechanisms and programs are generally less effective than active/collaborative ones. Successful transfer of knowledge and technology is based on relationships between suppliers and users characterised by trust and personal relations developed over time.
- Further, technology transfer is expensive and time-consuming, because it tends to require considerable adaptation and/or further development by the user. In addition, because of the need for users to further develop or adapt technology, successful transfer is more likely when the user possesses substantial technical capabilities.
- If the transfer of information and technology is to be effective, clients and users should be involved early in the process of research or technology development activity by helping to select and package information to be transferred, to set research objectives and priorities, and even to be involved in the knowledge or technology development process itself.
- Effective information and technology transfer occurs when users are closely involved with producers in an ongoing personal relationship; in other words, knowledge use and production are inherently linked. That these lessons closely match the elements of the agricultural extension model is obviously not a coincidence.
- ***Knowledge and technology transfer focus on application of existing knowledge to solve problems and improvement of products and processes, functions that initially (in the U.S.) were central to land grant universities but are now recognized as highly important for all research universities, public and private.*** The creation of technological innovations at the university frequently leads to patenting, licensing, and the formation of start-up companies by faculty and students.
- Sampat (2003) notes that the relative importance of the different channels through which university outputs diffuse (or are “transferred”) to industry has varied by industry and over time. Such channels include hiring of students and faculty, consulting relationships between faculty and firms, publications, conference presentations, informal interactions with industry researchers, university start-up companies, and licensing of university patents.
- Studies conducted over many years show that both faculty and private firms in most industries consider ***the primary channels through which learning occurs to be publications, conferences, and informal information exchange*** (Cohen, Nelson, and Walsh, 2002; Agrawal and Henderson, 2002).
- Several studies of the benefits that companies derive from membership in National Science Foundation-funded university-industry research centres (e.g., Engineering Research Centers, Industry/University Cooperative Research Centers) show that ***access to students and faculty and to new ideas and research results, rather than technology per se, are consistently the most frequently cited benefits of centre membership*** (Feller, Ailes, and Roessner, 2002; Roessner, 2000).
- The Federal Technology Transfer Act of 1986 (FTTA) made it a formal mission of all federal laboratories to transfer technology to industry. It also established the legislative authority for the Cooperative Research and Development Agreement, or “CRADA,” to be used by all federal R&D agencies to conduct R&D of mutual interest jointly with firms and consortia of firms. In the original CRADA, no funds were to be exchanged between the federal laboratory and industry; instead, both were to support their own efforts, but they could engage in joint agenda setting, could divide the specific research tasks among themselves, and could share the results with each other.
- CRADAs were intended to be real partnerships, including an expectation that all the industrial partners would contribute not just money but also technical effort to the collaboration.
- In the current era, collaborations or other forms of cooperative research arrangements are regarded as the most productive and effective forms of interaction between sources and potential users of knowledge and technology. “Technology transfer” has given way to “knowledge exchange” or “information exchange” as more inclusive phrases that portray more accurately the most effective interactions between research institutions (Bozeman, 2000).

- Large, research-intensive firms consider “idea” transfer from federal labs to have greater payoff than more tangible interactions such as those involving licensed technology. Instead, they seek access to lab expertise and facilities. They want to share research risks and leverage their investment in research (Roessner and Bean, 1994; Bozeman, Papadakis and Coker, 1995; Geisler and Clements, 1995).
- Effective interactions are wide-ranging, company-initiated, and tend to originate from day-to-day professional communication. Fruitful collaborative work comes only after considerable personal interaction. Companies report that the factors critical to success or failure of lab-industry interactions are personal contact, management support (especially middle management), and clarification of rights to intellectual property (Roessner and Bean, 1994; Geisler and Clements, 1995).
- Most interactions do not result in commercial products. The benefits reported from interactions that do not result in products are highly skewed, with a few resulting in very large benefit:cost ratios, but the typical interaction does not yield significant net benefits. For interactions that result in products, the benefits are uniformly modest but positive: about \$40,000 in a typical case (Bozeman, Papadakis, and Coker, 1995).
- What makes labs and companies interact may not be the factors that influence the success of the interaction in the form of technology transfer and commercialisation. Companies may join labs to gain access to resources and to enhance their R&D, but the success of the interaction does not depend on accomplishing these objectives. Rather, it depends on individual and organisational variables such as management support and attributes and attitudes that favour industrially-oriented objectives (Geisler and Clements, 1995).
- A carefully-done study of five CRADAs (Ham and Mowery, 1998) also found that the primary benefits from CRADAs were generic and longer-term, such as design principles, engineering techniques, and testing methods that enhanced their overall technical capabilities. The study also concluded that CRADAs, with their emphasis on intellectual property rights, may be the wrong mechanism for most laboratory-industry collaborations, for which property rights are of secondary importance. Finally, consistent with numerous results from other studies of research collaboration, the authors of these CRADA case studies concluded that firms without inhouse technical expertise, or the willingness to devote inhouse resources to the collaboration; are unlikely to benefit commercially from such collaborations.
- Early in the Reagan administration, Congress responded passed the Small Business Innovation Research and Development Act of 1982, which established the SBIR program. The new program required agencies with R&D budgets greater than \$100 million to set aside 0.2% of their funds for SBIR, with overall responsibility for the program assigned to the Commerce Department's Small Business Administration (SBA).

Conclusion

Collaboration is hard because it means traversing different forms of economic and social organisation. However, as universities become more business-like in their orientation the scope for greater collaboration is bright. Collaboration based around collective action – partnership, joint venture, strategic alliance. In business, these things happen when it makes good commercial sense to do so, subject to anti-competitive laws.

Collaboration thinking must move away from a transactional way of thinking (the merchandising of “knowledge products” to one built around partnership and the development of long term trust-based relationships.

Enduring and effective collaboration requires the development of effective “institutions for engagement” covering governance, incorporation requirements, organisation, staffing, remuneration, and systems that sit alongside the traditional faculty organisation of university or the hierarchal structures of corporate business units.

Innovation flourishes in environments that are organic, active and nimble and where there is a focus on purpose, achievement, and results. Highly structured, process oriented, and procedure driven (bureaucratic) organisations and management styles are not seen to be conducive to innovation (Burns & Stalker, 1994)

Collaboration, often meaning putting competitive pressures on the backburner, and working with competitors, governments, and research organisations, has enabled the invention, adoption and application of some pioneering and ground-breaking solutions to major economic, societal and environmental challenges and problems.

Collaboration still retains a negative connotation in many Australian institutions. For example, “collaborators working with the enemy”, “collaborators as traitors”. For many, collaboration compromises academic independence and is tainted working with businesses that set out to make a profit and return to shareholders. The objection can be moderated when the thinking is around creation of value on a wide range of platforms.

Even businesses now have to think of the value they create for people *other* than their shareholders. Smart boards will think about the value they create for the research and education system and civil society through education.

Appendix 6: People and Organisations Consulted

Peter Appleford, SA Government

Jack Archer, CEO Regional Australia Institute

Dr Lewe Atkinson, Global Partner Haines Centre for Strategic Management

Michael Badcock, Managing Director Enchanted Isle Farms

Dr Bronwyn Barkla, Associate Professor Southern Cross University

Elizabeth Bennett, Director, RDA Programs Department of Infrastructure and Regional Development

Anne-Marie Boland, Managing Principal RM Consulting Group

Dr William Brown, Charles Sturt University

Tim Burrow, Agribusiness Association

Dr Andrew Campbell, CEO ACIAR

Lou Conway Director, Regional Smart Incubator University of New England

Justin Crosby, Senior Manager Operations GRDC

Prof Heiko Daniel, DVC-Research University of New England

Dr Charlie Day, CEO Innovation and Science Australia

Rob Delane, Department of Agriculture, WA

Anthony Dona, Solution consultant Clarivate

Prof Tim Driscoll, Professor, Epidemiology and Occupational Medicine The University of Sydney

Prof Annabelle Duncan, Vice-Chancellor University of New England

Dr Philip Eberbach, Associate Prof, Soil Hydrology Charles Sturt University

Kathy Evans, Senior Lecturer Tasmania Institute of Agriculture

Duncan Ferguson, Commercialisation Manager CSIRO

Dr Bruce Finney, CEO Cotton RDC

Prof Michael Friend, Centre Director Graham Centre for Agricultural Innovation

Andrew Hall, Senior Principle Research Scientist Agri-Food Systems Innovation, CSIRO

Wayne Hall, Executive Director, Agri-Science, Queensland Department of Agriculture and Fisheries, Queensland

Justin Hardstall, Business Development CSIRO

A/Prof Greg Harper, Honorary, Agriculture and Food, The University of Melbourne

John Harvey, CEO Agrifutures

Richard Heath, General Manager, Research Australian Farm Institute

Lionel Henderson, Business Development CSIRO

Dr Patrick Hone, CEO Fisheries RDC

Peter Horvat, GM Communications, Trade and Marketing Fisheries RDC

Dr Kim Houghton, General Manager, Policy and Research Regional Australia Institute

Adrian James, Land Program Manager, Northern Tasmania Natural Resources Management, Tasmania

Dr Steve Jefferies, CEO GRDC

Ian Jensen, Manager, market access science and technology MLA

Brian Keating, Fmr Division Chief CSIRO

John Kerin, Adviser Minister for Agriculture (past)

Prof Graham King, Director, Southern Cross Plant Science Southern Cross University

David Lamb, Director, Smart Farm University of New England

Wesley LeFroy, Agricultural Analyst Rabobank

Dr Peat Leith, Senior Lecturer Tasmania Institute of Agriculture

Dr John Lloyd, CEO Hort Innovation

Mike Logan, Chair Cotton RDC, Agri Business

Maxine Loynd, A/g General Manager of the Local Government, ACT/NT and RDA Department of Infrastructure and Regional Development

Arthur Lyons, Forico Tasmania

Laura Matthews, Senior Business Development Manage Clarivate

Dr John Mawson, Professor in Food Engineering,
Project Lead, AgriTech Incubator Charles Sturt
University

Prof Alex McBratley, Director, Sydney Institute of
Agriculture The University of Sydney

Prof Holger Menke, Director, Tasmanian Institute
of Agriculture (TIA) University of Tasmania

Peter Metcalf, Government of Western Australia

Jed Metz, CEO Northern Australia CRC

Betina Moore, Simplot

Prof Bruce Mullen, The University of Western
Australia

Chris Murphy, Group Manager, Farm Profit &
Innovation Dairy Australia

Ruth Nettle, Rural Innovation Research Group
(RIRG) The University of Melbourne

Howard Nichols, AgriForce

Dr Cathy Nock, Research Fellow (macadamias)
Southern Cross University

Sarah Nolet, CEO Agthentic

Toni Nugent, Partnerships and Engagement
Manager Graham Centre for Agricultural
Innovation

Manuel Palazuelos-Martinez, Team Leader, Smart
Specialisation Platform European Commission

Dr Tony Peacock, CEO CRC Association

Dr Caroline Perkins, CEO Regional Universities
Network

Dr Christine Pitt, CEO MLA Donor company

Prof James Pratley, Secretary Council of the Deans
of Agriculture

Mirjana Prica, CEO Food Innovation Australia

Steve Radeski, State Agribus Manager ANZ

Keith Rice, Chief Executive Poppy Growers
Tasmania Inc

Peter Rizzo, CEO Meat Processors Corp

Michael Robertson, Deputy Director, Agriculture
and Food CSIRO

Terry Rose, Primary Industries Liaison Officer
Southern Cross University

Mike Ryan, Assistant Secretary Department of
Agriculture and Water Resources

Catherine Sayer, CEO Food South Australia

Peter Schutz, Chair Food Innovation Australia

Peter Sharp, Director, Plant Breeding Institute The
University of Sydney

Prof Kadambot Siddique, The University of
Western Australia

Ric Sinclair, CEO Forest and Wood Products
Australia

Ariana Sippel, Adviser - Agribusiness and Food
Austrade

Prof Leigh Schmidtke, Director National Wine and
Grape Industry Centre

Neville Stevens, Chair NSW Innovation and
Productivity Council

Ben Taylor, GM Corporate Affairs Rabobank

Steve Thomas, Deputy CEO GRDC

Robin Thompson, Manager, Agricultural
Development and Policy - Aggrowth DPIEW,
Tasmania

Charlie Thorn, GRDC, WA

Steve Tiley, CEO Growcom, Townsville

Leslie Weston, Charles Sturt University

John Wilson, FAS, Commercialisation Policy
Department of Jobs and Innovation

Appendix 7: Participants in the Expert Opinion Survey

List below are participants in the Expert Opinion Survey. The list excludes 25 people who indicated that they did not wish to be identified as a participant.

Name	Position	Organisation
A/Professor Jason Able	Head, Department of Agricultural Science	University of Adelaide
Aaron Birkby	CEO	Startup Catalyst
Adam Kay	CEO	Cotton Australia
Adrian Egan	Chair	South West Science Council Inc
Adrian James	Land Program Manager	NRM North
Alex McBratney	Director, Sydney Institute of Agriculture	University of Sydney
Alex Scandurra	CEO	Stone & Chalk
Alexandra Macvean	Senior Strategic Planner	MidCoast Council
Andrew Campbell	CEO	ACIAR
Andrew Kelly	Exec Director	BioPacific Partners
Andrew Vann	Vice-Chancellor	Charles Sturt University
Annabelle Duncan	VC	UNE
Anne-Maree Boland	Managing Principal	RMCG
Anton Kriz	Associate Professor	ANU
Associate Professor Helen Thompson	Director Centre for eResearch and Digital Innovation	Federation University Australia
Barbara Howlett	Professor (Honorary)	the University of Melbourne
Barry Westlake	Director	Baad Concepts Pty Ltd
Ben van Delden	Partner, Head of AgTech	KPMG
Brian Weir	Lecturer	University of Canberra
Bruce Finney	Executive Director	CRDC
Bruce Mullan	Director	Dept Primary Industries Western Australia
Cameron Begley	Managing Director	Spiegare
Carl Germanos	Research Graduate	RMIT University
Carol Bracken	Owner	Tamar Valley Hazelnuts
Caroline Hauxwell	Associate Professor	QUT
Caroline Perkins	Executive Director	Regional Universities Network
Catherine Sayer	CEO	Food South Australia
Charles Thorn	Senior Regional manager	GRDC
Chris Lafferty	Manager - Research Development and Extension	Forest and Wood Products Australia
Chris Murphy	Groyp Manager Farm Profit & Capability	Dairy Australia
Christopher Mayne	Director	Westbroo Holdings
Cindy Cassidy	CEO	FarmLink
Craig Davis	GM Growth Programs	Canberra Innovation Network
Craig Shapiro	Co-CEO	Blue River Group
Daniel Rodriguez	A/Prof	University of Queensland
Daniel Terrill	Partner	Deloitte
Darren Gibson	Senior Manager, Collaboration & Innovation	Edith Cowan University
David Campbell	Director	Agribusiness Freelance
David Falepau	Professor Ag Business Management	Charles Sturt University
David Halliwell	Director, Centre for Regional and Rural Futures	Deakin University
David Pannell	Professor, Centre Director	University of Western Australia
Deborah Mead	Regional Manager	AusIndustry
Denise Colledge	Education Manager - Primary Industries NW	TasTAFE
Diana Gibbs	Director	NSW RAA
Diane Mather	Professor	The University of Adelaide
Don Scott-Kemmis	Research Fellow	USSC
Dr John Kapeleris	CEO	Innovative Business Concepts
Dr Judy Matthews	Senior Lecturer	QUT Business School
Dr Omid Ansari	Research Director	Ecofibre (ex-GRDC employee)
Dr Patrick Hone	Managing Director	Fisheries Research and Development Corporation
Dr. Mohammad Sharif Sharifi	CEO	Australian Food and Pharmaceutical Industries
Dr. William Brown	Senior Lecturer and Research Fellow	Charles Sturt University
Duncan Rowland	CEO	Livestock Biosecurity Network
Elizabeth Bennett	Director, RDA Coordination	Department of Infrastructure, Regional Development and Cities
Elizabeth Skirving	Chief Executive Officer	Rural Business Tasmania Inc
Eric Craswell	Visiting Fellow	Australian National University

Australia's Rural Innovation System

Name	Position	Organisation
George Peppou	Mentor, Agtech	Cicada Innovations
George Wilson	Honorary Prof	Australian National University
Glen Hassett	Director, Programs, Innovate Canberra	ACT Government
Hon Fran Bailey		
Ian Dennis	Executive Chairman	Pearcey Centre for Innovative Industry Economic Research Inc.
Ian Jenson	Program Manager, Market Access Science and Technology	Meat & Livestock Australia
J Phillips	CEO	BioDiem Ltd
Jack Archer	CEO	Regional Australia Institute
Jack Dan	Head of Global Foresight	Telstra
Jan Davis	CEO	Agribusiness Tasmania
Jeffrey Bourne	Managing Director	Rocket Seeder Limited
Jim Henderson	Principal Consultant	Tech to Market Pty Ltd
John Canning	Professor	University of Technology Sydney
John Hamblin	Adjunct Professor	Institute of Agriculture
John Kerin	Prone	Retired
John Tyas	CEO	Avocados Australia
Josh Ariens	Research Partnerships Manager	CQUniversity
Kadambot Siddique	Professor and Director	The University of Western Australia
Kate cini	Director, food strategy	Agriculture cixtoeia
Katherine J. Evans	Senior Research Fellow; Lead for Value Creation & Impact	Tasmanian Institute of Agriculture, University of Tasmania
Keith Rice	Chief Executive	Poppy Growers Tasmania
Kerry Hallett		
Kevin Norman	General Manager	FarmscanAg
Kim Houghton	General Manager Policy and Research	Regional Australia Institute
Laura Dan	Director Knowledge Exchange and Engagement	Charles Sturt University
Lauren Rickards	Associate Professor	RMIT University
Leigh Schmidtk	Director, National Wine and Grape Industry Centre	Charles Sturt University
Lewe Atkinson	Global Partner	Haines Centre for Strategic Management LLC
Liz Kobold	Director SME Program	CBR Innovation Network
Lou Conway	Partnerships and Business Development Manager	University of New England
Lyndall Bull	Director	Lynea Advisory
Marea Fatseas	Managing Director	Ideas Connect
Matt Brett	Director Planning	La Trobe University
Michael Friend	Director, Graham Centre	Charles Sturt University
Michael Robertson	Deputy Director	CSIRO Agriculture and Food
Mike Logan	CEO	Oakville Pastoral Co
Mirjana Prica	Managing Director	Food Innovation Australia Limited
Narelle Kennedy	Managing Director	The Kennedy Company Pty Ltd
Noel Ferguson	Economic Development Manager	Self
Paul Wood	Chair of Ag and Foodtech Committee	AusBiotech
Peat Leit	Senior Research Fellow	Tasmanian Institute of Ag
Pennie Scott	Principal Goddess	Bush Goddess
Peter Appleford	Executive Director	SARDI
Peter Barnard	Managing Director	Oliver & Doam
Peter Davies	Pro Vice Chancellor -Research	University of Western Australia
Peter Horvat	GM Communications, Trade and Marketing	FRDC
Peter Rizzo	CEO	AMPC
Peter Roberts	MD	Self-employed in agribusiness
Peter Schutz	Executive Chair	FIAL
Peter Stone	General Manager	Bureau of Meteorology
Petr Adamek	CEO	CBRIN
Phil Morle	Partner	Main Sequence Ventures
Prof Richard Eckard	Professor and Centre Director	The University of Melbourne
Professor Lindsay Falvey	1) Director 2) Chair of the Board 3) Former Dean and Chair of Agriculture	1) Hassad Australia 2) International Livestock Research Institute 3) University of Melbourne
Professor Sue Kilpatrick	Professor of Education / Deputy Chair	University of Tasmania and Northern Tasmania Development Corporation
Renata Berglas	Director Livestock Policy	AgForce
Richard Hames	CEO	Centre for the Future
Richard Harper	Acting Dean, Vet and Life Sciences	Murdoch University
Rob Lewis	Director	Science Without Bounds Pty Ltd
Rob Stephenson	Head of Campus, Bendigo	La Trobe University

Australia's Rural Innovation System

Name	Position	Organisation
Robin Fieldhouse	Snr Research & Business Development Manager	Innovation ANU
Rohan Rainbow	Managing Director	Crop Protection Australia
Roy Green	former dean, now innovation adviser	UTS
Russel Rankin	Owner & Founder	Food Innovation Partners Pty Ltd
Ruth Nettle	Leader, Rural Innovation Research Group	University of Melbourne
S.D. Tyerman	Professor	University of Adelaide
Sagadevan Mundree	Director and Professor	Queensland University of Technology
Sally Leigo	NT Project Manager	CRC for Developing Northern Australia
Sam Trethewey	General Manager	SproutX
Sara Hely	Manager	Regional Development Victoria
Steve Lacey	BMP Manager	AgForce QLD
Steve Tiley	Innovation Coach	Growcom
Steve Whan	CEO	National Irrigators Council
Steven Lapidge	Director- Food Safety & Innovation	South Australian Research & Development Institute
Ted Lefroy	Director, Centre for Environment	University of Tasmania
Terry Rose	Associate Professor	Southern Cross University
The Hon. Katrina Hodgkinson	Director	Georgton Pty Ltd
Tim Burrow	CEO	Agribusiness Australia
Tim Driscoll	Professor	Sydney School of Public Health
Tim Sides	Senior Policy Officer	ACT Government
Tom Lewis	Director	RDS Partners
Tony Bacic	Director and Professor	Institute for Agriculture & Food, La Trobe University
Tony Peacock	CEO	Cooperative Research Centres Association
Tony Stephens	Director Regional Strategy and Engagement	Jobs for NSW Dept of Industry NSW Government
Trevor John	Director of Regional Development and EO	Regional Development Australia Hunter
Vicki Thomson	Chief Executive	Group of Eight
Vinit Chand	Operations Manager	Innovation Connections
Vladimir Jiranek	Head, Dept Wine & Food Science	University of Adelaide
Wayne Fitzsimmons	Chairman	Pearcey Foundation
Wayne Hall	Executive Director Agri-Science Queensland	Qld Dept Agriculture and Fisheries

Appendix 8: Participants Additional Comments in Opinion Survey

1. Greater diversity of teams (gender, culture, locational etc) will deliver better designed and implemented innovations.
2. RDC's should listen to the farmers who pay the levies that fund them. RDC's should have overheads capped at 5 to 10% max
3. The survey would be improved if the international dimensions of rural innovation and research was emphasised more. We import a lot of technology and export somewhat less. Furthermore our investments in agencies like ACIAR bring significant benefits to Australian farmers as well as those in collaborating countries.
4. Rural innovation system should be viewed as a component of Australia's innovation system, not separate and unconnected.
5. I [Noel Ferguson] will try to confine my comments to high level strategic issues that I believe need to be considered whenever we are making strategic decisions. I am not a farmer, which is a good and a bad, but in my work I have worked alongside many producers. My comments reflect what I have learned from them.
 1. For the most part we are following in the footsteps of the early pioneers. Instead of changing what they were used to doing and working with the land, for the most part they kept on doing what they had been doing in Europe instead of developing industries that aligned with the reality of Australian conditions. Science can only get us so far - I think until we rethink our agriculture so that it aligns fully with Australian conditions, we will for the most part keep on developing band aid solutions instead developing resilient and sustainable agriculture models.
 2. The adage "We manage what we measure" has some serious implications. For the most part, farmers the world over tend to think in terms of production tonnages rather than retained profit. As a result they are mostly price takers instead of price makers - i.e. the average producer is thinking within a commodity framework instead of a product framework. A NZ example that I am familiar with - the average Fonterra farmer retains 3% in an average year, and the banks retain 28%. Yet in NSW, farmers on similar land are making 50% net profit on by doing things differently - and without compromising the environment. The net retained profit NSW is \$60k per acre. On comparable land in NZ, industrial production techniques (from memory) generate just \$1000-\$1500 per acre. A slightly related example - wine makers generate only half the net profit on turnover that grape growers do, so why make wine?
 3. We need to fully embrace supply chain / Industry 4.0 thinking. This starts with our water and our soil. First there is our water usage. The centre is heating up twice as fast as the coast yet we persist in wasteful irrigation practices and growing water-hungry crops and animals. We are treating our fers and surface water as if they were infinite current assets - which they are not. We should be thinking of ourselves as custodians, not owners. The big Ag chemical techniques that contributed to the "Green Revolution" after WW2 are failing us, or have failed us. Our topsoil is dying and disappearing. Some soil experts I have met say we will be lucky to have any topsoil by 2100 because of the way we farm. Then there is the way we distribute and market our food. Wherever possible products should be processed at the source. The counter arguments related to economies of scale work if your focus is on lowest possible cost, but for the most part they are irrelevant if a focus on superior retained earnings per acre and the impact of local jobs are priorities. The top-down corporate model does not deliver anywhere near the retained profitability per acre for regional communities that alternatives provide. For example, one desk exercise I did while working in Western Australia showed 17 times more retained net profit by processing locally and marketing local non-GMO grain brands as frozen half-cooked bread.
 4. Technology. Using the Internet of Things and using modern distribution techniques are major opportunities. Managing the entire supply chain (soil/water, paddock to plate) are not only going to provide us with the information we need to make intelligent fact-based choices, but they we can also protect our brands if we make the effort to embrace blockchain-like technologies. Blockchain can guarantee food provenance (currently not helped by our dumbed-down approach to labelling) and facilitate "whole of supply chain" branding. For example, Blockchain allows the possibility of distribution via (say) Amazon which in turn allows producers to connect directly with end users and retain higher margins via a reduction in distribution costs. And, by direct-selling branded products rather than commodities, producers can massively increase retained earnings while halving food waste, a major source of greenhouse gases, and a major drag on overall productivity/profitability. I hope you find these "framing arguments" useful.
6. Universities do research Startups commercialise innovation We need to shift funding from universities that is not directly applicable to the strategic and tactical problems and opportunities Australia faces and re-allocate it to startups and scaleups that are creating and commercialising the new innovations that solve these problems whilst simultaneously creating the businesses that create jobs and wealth for Australians. CRCs and RDCs need to be completely disrupted.

7. RDC investment benefit is impacted by the lack of a clear pathway to address regulatory issues on new and emerging technologies, ultimately delaying industry delivery to producers due to a lack of commercial investment confidence.
8. The Australian rural innovation system, underpinned by R&D orgs, will be disrupted in under a decade by user-driven innovation and other modern best practice implementation. The Australian rural innovation system would benefit by being modeled on other innovation systems that have changed the world like the unstructured Silicon Valley. The success of the Australian Rural Innovation System will increasingly rely on best practice commercialisation methodology which attracts entrepreneurs and venture capital. The Australian rural Innovation system in its current state is unable to attract the world's best commercial and technological talent to create, drive, implement or take to market, the most demanded technology to increase on farm or supply chain efficiency. The success of the Australian rural innovation system will see a move away from R&D to faster, cheaper and more effective pathways of innovation, commercialisation and implementation
9. A key issue that may be overlooked in the one dimensional question/response is that in many cases the answer is not black and white. For example some RDCs/Universities and farmers are already using cutting-edge or next generation technology; but not all. We are in a time of fast change - one system (third industrial revolution) is being left behind for the next. The biggest issue we face is navigating the transition and investing in how we make this transition. This includes funding R&D or providing incentives, opportunities to facilitate the transition.
10. Some points -
 1. Definitions used are not sufficient to tease out all the issue for the whole 'sector as a system' (either nationally or globally)
 2. Questions are biased to status quo outcomes, which favour public sector over the private sector.
 3. Insufficient recognition of the depressing effect of public sector activity on the private sector (i.e. suppressed the growth of private sector R&D)
 4. Little or no regard for competitive impact assessment of entire Australia sector vis-a-vis R&D/innovation capabilities globally, including but not limited to private sector capabilities offshore (i.e. the importance of global cost structures and capability factors significantly understated).
 5. No recognition of the depressing effect on the long-term productivity of the compulsory levy system (i.e. public sector R&D/innovation cost structures making Australia uncompetitive in global terms).
 6. Continued inability to express return on investment to individuals or companies, this frustrates proper performance assessment of the whole system (public -v- private comparisons).
 7. Australia's university sector, for all intended purposes, is publicly funded and reliant upon public funds for rural R&D/innovation (there are no private universities, for example. i.e. there is no genuine competition in the sector of any consequence (and thus, true public accountability evaded).
11. A greater commitment is required for multi-disciplinary teams to be RESOURCED to meet end-user needs (or better, 'next' user needs) (it might be a requirement but it must be resourced)
12. I strongly believe that R&D bodies as well as universities and environmental organisations are biased toward funder expectations in order to maintain cash flow and that this is guiding outcomes without balanced hypothesis or the ability to replicate findings. This in turn is guiding government regulatory responses which are now emerging as being detrimental to rural industry especially where environmental issues are concerned. Therefore, I would be concerned that any national overarching policy on the direction of R&D would have to strenuously avoid built in bias.
13. I do not feel well qualified to answer questions about national innovation projects as my work is quite stat based. In addition, some of the questions are difficult to answer as my area is very beef livestock specific. In relation to RDCs my responses only relate to MLA. In terms of producer engagement with technology there are two issues. Many producers are well aware of the technological revolution occurring around them but feel isolated from it in practical terms. Connectivity, lack of education, rural isolation, ability to fix it if it stops working IT support etc. all play a part in their suspicion. Secondly why do I need it the old way isn't broken. Valuing innovation is high as producers are very innovative but in an operational sense. The value of large scale system change is difficult to grasp. So, while there is a gap it's not a lack of knowledge that things are changing it is more things are changing and I don't feel included. Data is a big issue impeding tech change. Producers don't trust, or value the data for their business and are suspicious about why people want the data. The bank for example wants data government wants data. I am not sure I was the right person to contribute but I hope this proves useful.
14. Rural innovation system needs to more successfully integrate RD&E.
15. In some cases I disagreed with the questions because as stated they did not seem fully coherent e.g. "An over-arching strategic vision for rural innovation should emphasise the nature and extent of all biologically-derived economic activity and associated innovation - both in Australia and world-wide." - seems to me to imply our strategic vision needs to encompass the whole world which I'm not sure you can do.
16. The RDC-based levy funded Rural R&D system is flawed. It was established to enable the collection of levies in order to mitigate "free rider" effects, but one of the unintended outcomes is a "silo-based" approach to agricultural research. These "commodity R&D-silos" have a single-commodity focused mission which is biased towards productivity gain at the expense of market diversity, biosecurity and provenance as potential USPs for Australian farmers. This means that there is mis-match between the target outcomes for R&D and the needs of the multi-commodity-based levy-paying

farming enterprises that they are intended to serve. Finally, when it comes to TFP as a measure of the performance of Australian agriculture and the attribution of its contribution to productivity improvement through adoption of innovative practices, there is no recognition of the contribution of the degradation of environmental resources (e.g. soil erosion, salinity, nutrient depletion through monoculture, etc) to the denominator of the equation. This means that the growth in the output is reported without any recognition for the environmental impact of achieving the consequent growth in output. Unfortunately, because the reported productivity performance of commodity agriculture is silent on the contribution of natural resources to the denominator there is no incentive for investment (private or public) in being more innovative re: environmental impact.

17. I compliment you on the thought put into this.
18. Australian agriculture has demonstrated a good ability to find innovative ways to adapt to climatic variability over the past 200 years - research institutions should harness this ability and learn from the collective experience of farmers and land managers
19. The rural production systems could be enhanced by further attention to transparency, traceability and authenticity throughout the multiple value chains in food and fibre sectors.
20. Declines in research funding have led to declines in productivity improvement (as documented for the USA more graphically) - joint research with large research-funding nations (according to some measures, China is the largest) and with international research centres in environments similar to Australia's would provide greater impact
21. Greater emphasis should be given by regional development agencies to educational and demonstration efforts of regional not for profit organisations to extend the capabilities and innovative adoption and adaptation of known best practice principles and practices in the local environment.
22. Improved rural sector R&D would be improved by government incentivising farmers and growers to make data publicly available by partial subsidising or tax incentives for the generation of such data.
23. Some of those statement were pretty hard to unpack. They seemed like consultant-speak rather than English.
24. Unfortunately in the most cases it is a connection with the officials that would give a business something rather than how innovative and great your project/s is/are. To make the system we have in place more efficiently you need to fight corruptions (recommendation from officials is a corruption as it is based on friendship etc..... rather than a good will).
25. Declining total factor productivity in Australian broad acre agriculture is in part a consequence of declining public investment in the rural R&D system - see Sheng Y, Mullen JD and Zhao S. Has Growth in Productivity in Australian Broadacre Agriculture Slowed? A Historical View. *Ann Agric Crop Sci.* 2016; 1(3): 1011. ISSN:2573-3583
26. Public Private partnership should be encouraged to accelerate RnD outcomes to greater audience.
27. An Innovation Service Hub model is required as a new innovation service delivery platform for the Australian agri-food industry. The Agri-food Innovation Service Hub would have a specific interface for each sector (dairy, horticulture, meat and food) so that those industry participants, stakeholders, growers and companies 'engage' with the Hub through their own familiar portal. The Innovation Service Hub would be the interface to the different elements of the innovation ecosystem; connecting industry, research, government, marketing and finance. It would require seed funding then becoming self-funded.
28. Distributed and 'off grid' energy generation and storage on farm / in rural communities will transform production, regional processing and rural communities RDC focus on 'co-investment' and wrangling over dubious IP ownership is stifling research, innovation and adoption. RDC investment needs to shift to a strategic, innovation and long term research focus instead of spending money on work simply because it is on farm.
29. Good questions John! But don't overlook animal welfare, substitutes for animal exploitation etc. Must be part of the picture.
30. There is a strong missing link between hard science and future agri tech. There is no mention of global market places online. These two will determine the long term direction and future of all agriculture. For Australia its crucial to have a controlling interest in shaping this global market place and shaping global standards with it.
31. The survey questions made little sense to me
32. Please find below some comments rather than hypotheses: 1. RDCs should become more efficient by being operated by an independent board that allocates funding to applied research activities to address industry problems and capitalise on opportunities - both long term and short term. 2. There is an over-abundance of rural/agricultural industry bodies accessing both public funds and private funds (through levies and fees) that seem to diminish their impact across a specific industry sector. These industry bodies should be consolidated and refined thereby reducing the overall percentage of funding allocated towards administrative expenses. 3. Australia needs to place more emphasis on the translation and more importantly commercialisation of new agricultural research, technology and systems that drive innovation rather than falling behind of other nations such as New Zealand, that have smaller budgets.
33. Australia's rural industries are currently inadequately prepared for the disruptive effects of climate change in terms of climatic effects (acute and chronic), flow-on effects (e.g. on agricultural labour, transportation) and opportunities for renewable energy generation.
34. RDCs should continue to evolve to improve the industry government partnership for their sectors clients across the supply chain and improve the co-investment model where it makes sense to invest collectively - the rural system needs to be agile to allow for different investment approaches to reflect the operating environment for respective RDCs

35. Key to moving innovation into the hands of the growers who can turn research into application is addressing the research funding model - we should be resetting the expectation that RDCs must assess the commercialisation / adoption pathway for any research program before they allocate research funding to universities and others that undertake the research activities. Too much research time and funding has been caught up in projects that have not reached growers because the universities and RDCs have either not got the skills to commercialise (very often the case) or have been caught up in IP ownership debates that result in the research ending up stalled in labs. We need to fix this model!
36. The convergence of food, water and energy security concerns worldwide, all of which are amplified by climate change, demands much more integrated approaches to rural innovation and regional development. Climate change is a 'risk multiplier'. There is insufficient emphasis in the rural innovation on both mitigation (the ultimate adaptation strategy) and transformative adaptation as opposed to incremental adaptation and risk management. The Australian rural innovation system is overwhelmingly focused on-farm, and insufficiently focused on peri-urban and urban agriculture, and value chain innovation to create more circular economies, even around regional centres like say Wagga, Toowoomba or Ballarat. The rural innovation system is missing in action on energy - both production and consumption - and on understanding the implications of decarbonisation for Australian agriculture, fisheries and forestry.
37. That Ag R&D would be of greater benefit to the levy payer stakeholders if it was more closely driven by impact outcome than by research activities.
38. Additional hypotheses around general non-biological regional innovation should be considered. For example - rural communities and businesses and innovators would benefit from strong locally relevant education systems. We cannot expect that health systems geared towards major cities will be able to address regional issues. The innovation ecosystem in rural and regional Australia needs to have sufficient breadth of activity and localised relevance if regions are to thrive. A focus only on agri-business in research intensive institutions is not going to cut it, for example. We should consider something like a 'Regional ARC' or funding stream that supports regional research and innovation.
39. The size and scale of the RDC system can seem an impenetrable mass from the outside where the idea that R&D can provide competitive advantage can be quickly trumped by a large public good investment. This investment is focused on production (not customers) and Australian farms (not globally competitive companies). Together these forces line up an insular trap for the sector. Tax differences mean that profitable agribusinesses have head office (and profits) offshore. Once you make \$10M per year then it's time to move offshore.
40. Greater diversity of teams (gender, culture, locational etc) will deliver better designed and implemented innovations.
41. RDC's should listen to the farmers who pay the levies that fund them. RDC's should have overheads capped at 5 to 10% max

Appendix 9: Terms of Reference - Performance Review of the Rural Innovation System

Goal

The purpose of this project is to describe the performance and impact of Australia's rural innovation system³⁴. The project will collate and analyse evidence across a range of metrics in order to present a comprehensive review of the overall performance of the system, highlighting areas of strength, opportunities for improvement and gaps in our knowledge base.

Introduction

The National Research and Innovation (R&I) Committee³⁵ is seeking an analysis of evidence available through which the performance of Australia's rural innovation system can be articulated and understood. This evidence may cover issues such as how resources are allocated and utilised, how information flows and various organisations and actors interact, what outcomes are being achieved and what impacts result from the effort.

R&D plays an important role in driving the productivity and competitiveness of Australia's primary industries. The Productivity Commission estimates that the annual funding for rural research, development and extension is \$1.5 billion. About three quarters of this provided by Commonwealth and State Governments, with the private sector contributing the remainder³⁶.

The Australian rural innovation system (covering agriculture, fisheries and forestry) is highly complex with multiple funders and suppliers of rural R&D, including the Commonwealth, State Governments, Universities, Rural Research and Development Corporations, Australian agricultural industry, and international partners (public and private sector). The rural innovation system covers a spectrum of activities that drive, facilitate and support the creation, transfer and application of knowledge. In turn this knowledge enables ongoing improvement in the productivity, profitability and competitiveness of our rural industries and sustainability of social and environmental landscapes.

A major component of the rural innovation system in Australia is the National Primary Industries Research, Development and Extension Framework. The Framework seeks to improve the efficiency and effectiveness of RD&E delivery across Australia through the coordination of financial, human and infrastructure resources, and increased collaboration within the research community. This project is not focusing on understanding the performance or influence of the Framework on the rural innovation system, although it is expected that the findings may be useful for that purpose.

The research, development and extension (RD&E) system for primary industries in Australia has been reviewed extensively and is considered to have served Australia well (examples include a review from the OECD in 2015, and by the Productivity Commission in 2007 and 2011). However, the complexity of the system, multitude of participants, diffuse nature of public and private benefits and the difficulty of evaluating and attributing the impact of research effort means that articulating and understanding the efficiency and effectiveness of the system as a whole is particularly challenging. Meanwhile government and industry resources are contested as budgetary and industry circumstances change.

In 2016 the Australian Government undertook a review of the National Innovation System and developed an approach for assessing its performance using a performance model which focused on the particular aspects of knowledge creation, knowledge transfer and knowledge application. This projects seeks to test application of that model to the rural innovation system.

³⁴ The rural innovation system refers to the set of institutions and arrangements which contribute to the development and diffusion of new knowledge, technologies and practices, and which provide the framework within which governments form and implement policies to influence the innovation process. Adapted from Metcalfe, S. (1995), "The Economic Foundations of Technology Policy: Equilibrium and Evolutionary Perspectives", in P. Stoneman (ed.), *Handbook of the Economics of Innovation and Technological Change*, Blackwell Publishers, Oxford (UK)/Cambridge (US)

³⁵ The R&I Committee is an Advisory Committee to the Agriculture Senior Officials Committee (AGSOC) and is responsible for the oversight of the development and implementation of the National Primary Industries Research Development and Extension Framework (the Framework) and also provides advice on the overall performance of the primary industries research innovation system.

³⁶ Productivity Commission 2011, *Rural Research and Development Corporations*, Report No. 52, Final Inquiry Report, Canberra

Terms of Reference

The project is to implement an approach to understand and articulate the performance of the rural innovation system, identify gaps in the available evidence, and make recommendations regarding opportunities for improvement.

The project will:

- Assess the performance framework used to assess the national innovation system for application to the rural innovation system, and propose adjustments as necessary
- Identify and collate evidence against agreed metrics under the performance framework
- Identify gaps in the available evidence
- Develop a comprehensive report assessing the performance of Australia's rural innovation system in national and international contexts
- Recommend opportunities for improvement.

Project Design

The contractor will develop a project approach that seeks to identify, review, collate and analyse performance evidence that is already available against a framework based on the performance model development by Innovation and Science Australia. It is expected that this process will identify gaps in the current available evidence. The contractor is expected to identify and highlight these gaps. It is not anticipated that the project will seek to fill gaps in the available evidence, although recommendations on how the gaps could be filled would be useful.

The ISA approach is summarised in Appendix 10.

Appendix 10: Innovation and Science Australia (ISA) Approach to Measuring Innovation Performance

In 2016 the Australian Government undertook a review of the National Innovation System and developed an approach for assessing its performance using a performance model which focused on the particular aspects of knowledge creation, knowledge transfer and knowledge application. This project seeks to test application of that model to the rural innovation system.

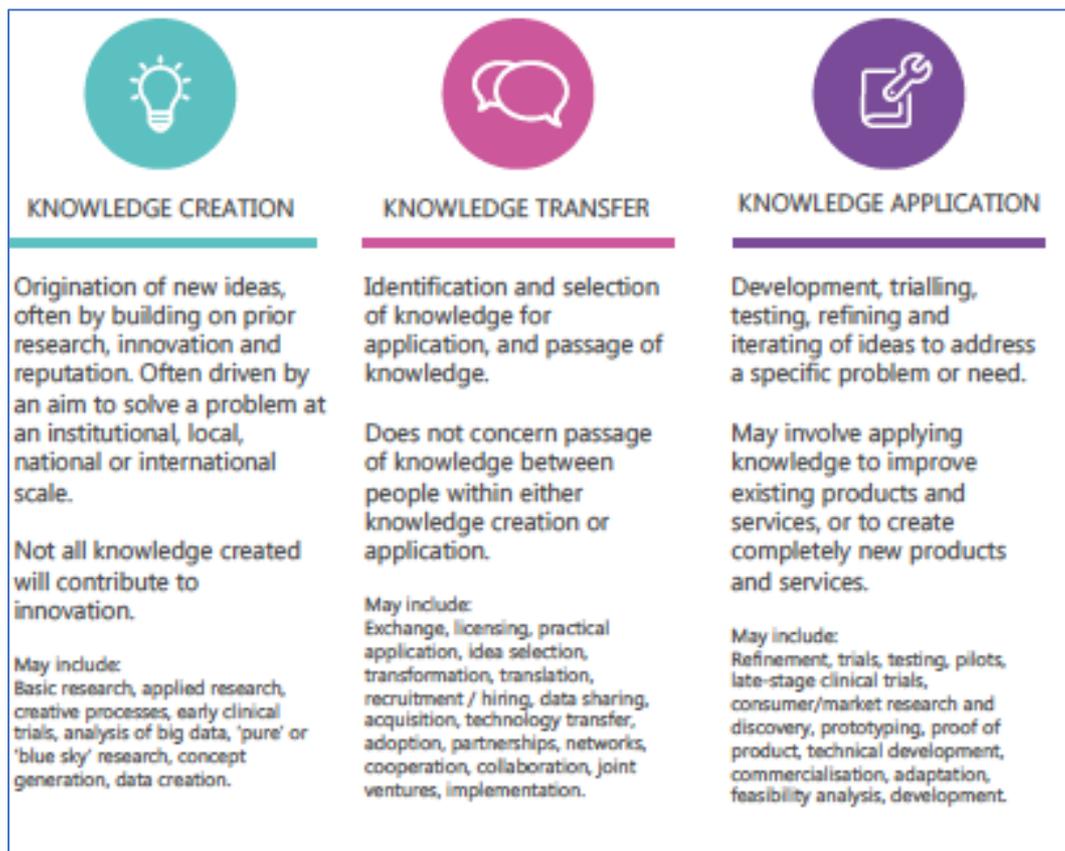
The ISA Framework

From Performance Review (Innovation and Science Australia, 2016):

The complex and dynamic nature of the ISR System makes it difficult to measure with precision or in real time. A recurrent theme in this ISR System Review is the challenge of capturing the activities and the impacts of actors in the ISR System with sufficient clarity to inform a national response.

ISA's framework identifies three innovation activities (see Figure 1): knowledge creation; knowledge transfer; and knowledge application.

Figure 119: ISA defined innovation activities, by type



These activities produce **outputs** across the ISR System, such as new and improved products or processes. The adoption of innovation outputs, including those sourced from international systems, delivers **outcomes**, such as improved productivity, longer life expectancies and a more resilient Australian ISR System.

The framework identifies six categories of **enablers** that facilitate innovation activities: policy; money; infrastructure; skills; networks; and culture. The linkages across, within and between innovation activities and enablers are of critical importance to eventual outcomes.

Figure 120: Performance framework to assess the Australian ISR System.



To capture this complexity, this ISR System Review examines the overall strengths and weakness of the ISR System's activities in knowledge creation, knowledge transfer, and knowledge application through the lens of the six categories of enablers. It also considers indicators for the outputs and outcomes that the ISR System generates from these activities.

The ISR Australian Performance Scorecard

This ISR System Review has been prepared in part to provide a baseline from which to measure future progress through the adoption of suitable metrics, recognising the limitations of existing frameworks as aids to policy. International assessments, in particular, frequently use rankings as an assessment tool, but do so with a focus on only a single aspect of the system, or try to combine disparate dimensions into a single "score" (with all the methodological challenges that might be expected).

The Global Innovation Index is one example of the advantages and limitations of this approach. It ranks the innovation performance of 128 countries and economies around the world based on 82 indicators.⁴ Australia ranked 19th in the 2016 Global Innovation Index, and our overall international position has been relatively stable over the past five years, ranging from 17th to 23rd.⁵ Whilst the Index provides a useful annual pulse check it needs to be interpreted with an understanding of our unique national context and goals.

This ISR System Review introduces a new Australian Scorecard, calibrated to the needs of Australian decision-makers through measures of particular relevance to our ISR System, and informed by the global evidence base. More than 250 available metrics gathered by domestic and international bodies such as the OECD were assessed and prioritised to identify 20 most pertinent and relevant performance indicators performance indicators (Figure 3).

Figure 121: Performance scorecard for the Australian ISR System

	Australia's performance		International comparison (OECD+)	
	Latest score & trend		Average for the top 5 performers	Australia's ranking
Knowledge creation				
Gross expenditure on research and development (GERD), % of GDP	2.12 ▲		3.66	15 of 37
Higher education expenditure on research and development (HERD), % of GDP	0.63 ▲		0.84	10 of 37
Government expenditure on research and development (GOVERD), % of GDP	0.24 ▼		0.40	15 of 37
Academic Ranking of World Universities top 200 universities, per million population	0.33 ▲		0.54	9 of 31
Highly cited publications (top 1% in the world, all disciplines) per million population	48.7 ▲		86.0	8 of 36
Government and higher education researchers (full time equivalent) per thousand total employment	6.48 ▲		6.27	3 of 36
Population aged 25–64 with a doctorate per thousand population	8.21 ▲		16.8	11 of 34
Knowledge transfer				
Population aged 25–64 with tertiary education, %	42.9 ▲		48.7	7 of 36
Universitas 21 national higher education systems ranking	10th ▼		n/a	10 of 34
Percentage of HERD financed by industry, %	4.73 ▼		16.8	18 of 37
Proportion of publications with industry affiliated co-authors, %	1.22 ▼		4.99	27 of 38
Proportion of Patent Cooperation Treaty (PCT) patents with foreign co-inventors, %	16.2 ▲		43.8	27 of 37
Knowledge application				
Total early-stage entrepreneurship activity, %	12.8 ▲		18.7	8 of 38
Venture capital investment, % of GDP	0.02 ▲		0.19	18 of 30
Number of international patent applications filed by residents at the PCT per billion GDP (PPP)	1.5 ▼		8.3	22 of 37
Business researchers, per thousand employed in industry	4.68 ▲		14.7	21 of 36
Business expenditure on research and development (BERD), % of GDP	1.19 ▲		2.78	16 of 37
Outputs				
Percentage of firms that introduced new-to-market product innovation, %	9.23 ▼		21.3	23 of 31
Outcomes				
Multifactor productivity change, five year compound annual growth rate, %	0.40 ▼		1.29	12 of 20
High-growth enterprise rate, measured by employment growth, industry, %	0.80 ▼		13.5	27 of 27

1. Australia's score is the latest available data point for the given metric.
 2. Australia's trend in each metric is shown by the upwards and downwards arrows.
 3. International comparisons are made between Australia and other OECD+ countries. OECD+ countries include all countries in the OECD, as well as China, Taiwan and Singapore (where data is available). If country data from the given reference period is unavailable, the nearest available data has been included in the analysis.
 4. The average for the top five OECD+ countries represents the simple average of the scores for the top five OECD+ countries in the given metric.

■ First quartile
 ■ Second quartile
 ■ Third or fourth quartile

Observations on the ISA approach

It is a useful representation of relationships between knowledge production, transfer and application. It is a framework for understanding the *national research system*, and has clear parallels for *comprehending the rural research system*.

But there are some limitations which would require adjustment to the Framework in addressing rural innovation system performance.

The ISA framework represents the traditional and much criticised 'linear flow' view of knowledge generated through scientific discovery and technological invention and transferred into application and use. It is attractive for its simplicity and avoidance of complex 'spaghetti' or 'hydraulic' diagrams, but it tends to encourage a 'supply side' or 'science push' focus, and can overlook important demand/market side factors that initiate and 'pull through' new discoveries, inventions and technologies.

This supply side presumption has some merit in a commodity approach to agricultural production, where farmers, farmer lobby groups, and some research providers, approach demand side issues from a commodity perspective. However, in a competitive and open trading environment consumers have choices on the basis of their tastes and preferences, for products and services (embedded and aesthetic) that satisfy their wants. The demise of the Australian auto manufacturing industry reflects the futility of a commodity and supply oriented approach to addressing customer demand.

The ISA approach also tends to neglect non-technological forms of innovation, for example in marketing, organisation, collaboration, institutions, business models. Fundamentally, it does not recognise the role of the *consumer* in driving innovation. The tastes, revealed preferences, and consumption patterns of consumers are fundamentally important in driving innovation. Some confusion arises in the area of agricultural research where the "consumers" of research, development and extension are identified as farmers.

The development of contemporary and critically important enabling technologies rarely follows the "linear flow" trajectory. These include, for example, micro/nano-electronics, nanotechnology, semiconductors, advanced materials, robotics and mechatronics, photonics, artificial intelligence and machine learning, analytics, digital imaging, visualisation, prototyping, and augmentation, biotechnology, advanced manufacturing (including 3D printing).

Bibliography

- Academy of Technological Sciences and Engineering (ATSE). (2014). Food and fibre: Australia's opportunities. *Academy of technological sciences and engineering*. <https://www.atse.org.au/Documents/Publications/Reports/Agriculture/atse-food-and-fibre-full-report.pdf>
- AgriFutures Australia. (2017). *Strategic R&D plan 2017-2022*
- Allen Consulting Group. (2012). *The Economic, Social and Environmental Impacts of the Cooperative Research Centres Program* Retrieved from <https://www.business.gov.au/~media/Business/CRC/Cooperative-Research-Centres-Programme-Economic-Social-and-Environmental-Impacts-2012-PDF.pdf?la=en>
- Alston, J. M. (2010). *The Benefits from Agricultural Research and Development, Innovation, and Productivity Growth*. Paris: OECD Publishing.
- Alston, J. M., Anderson, M. A., James, J. S., & Pardey, P. G. (2011). The economic returns to US public agricultural research. *American Journal of Agricultural Economics*, 93(5), 1257-1277. <https://academic.oup.com/ajae/article-abstract/93/5/1257/176597?redirectedFrom=fulltext> doi:10.1093/ajae/aar044
- Alston, J. M., Norton, G. W., Pardey, P. G., & International Service for National Agricultural Research. (1995). *Science under scarcity : principles and practice for agricultural research evaluation and priority setting*. Ithaca: Cornell University Press.
- Alston, J. M., Norton, G. W., Pardey, P. G., & International Service for National Agricultural Research. (1998). *Science under scarcity : principles and practice for agricultural research evaluation and priority setting*. Wallingford: CAB International in association with the International Service for National Agricultural Research.
- Australia. Department of Agriculture and Water Resources. (2017). *Agricultural commodities, March quarter 2017 Research by the Australian Bureau of Agricultural and Resource Economics and Sciences* Retrieved from <http://www.agriculture.gov.au/abares/Documents/agricultural-commodities-report-march-2017.pdf>
- Australia. Department of Industry and Science. (2015). *National Survey of Research Commercialisation 2012-2013*
- Australia. Department of Industry Science and Technology. (1995). *Cooperative Research Centres Programme Evaluation: Changing Research Culture, Australia - 1995 (Sir Rupert Myers, Chair)*. Canberra: Australian Government Publishing Service.
- Australia. Department of Innovation Industry Science and Research. (2011). *National Survey of Research Commercialisation 2008 and 2009*. Canberra: Commonwealth of Australia.
- Australia. Department of Innovation Industry Science and Research. (2012). *National Survey of Research Commercialisation 2010 and 2011*. Canberra: Commonwealth of Australia.
- Australia. Industry Task Force on Leadership and Management Skills. (1995). *Enterprising Nation: Renewing Australia's Managers to Meet the Challenges of the Asia Pacific Century*. Retrieved from Canberra:
- Australia. Minister for Agriculture. (2015). *Agricultural Competitiveness White Paper Stronger Farmers Stronger Economy*. <http://agwhitepaper.agriculture.gov.au/SiteCollectionDocuments/ag-competitiveness-white-paper.pdf>
- Australia. Minister for Agriculture and Water Resources. (2018). Supporting bold vision to grow agriculture into a \$100 billion industry [Press release]. Retrieved from [http://minister.agriculture.gov.au/littleproud/Pages/Media-Releases/nff-\\$100-billion.aspx](http://minister.agriculture.gov.au/littleproud/Pages/Media-Releases/nff-$100-billion.aspx)
- Australia. Productivity Commission. (2007). *Public Support for Science and Innovation*. Canberra: Australian Government Publishing Service.

- Australia. Productivity Commission. (2011). *Rural Research and Development Corporations, Report, No. 52, Final Inquiry Report* Retrieved from <http://www.pc.gov.au/inquiries/completed/rural-research/report/rural-research.pdf>
- Australian Academy of Science. (2016). Grow. Make. Prosper. Decadal plan for Australian agricultural sciences <https://www.science.org.au/files/userfiles/support/reports-and-plans/2017/agricultural-decadal-plan-2017-26.pdf>
- Bentur, A., & Lowenstein, A. (1998, June). Technology Transfer and the Commercialisation of Knowledge. *High-Techonion*. Retrieved from www.technion.ac.il/technion/dimontech/bentur.html
- Bernstein, P. L. (1996). *Against the Gods: The Remarkable Story of Risk*: John Wiley & Sons.
- Bok, D. (2003). *Universities in the Marketplace: The Commercialization of Higher Education*. Princeton: Princeton University Press.
- Bossidy, L., Charan, R., & Burck, C. (2002). *Execution: The Discipline of Getting Things Done* (1 ed.): Crown Business.
- Boyer, E. L. (1997). *Scholarship Reconsidered: Priorities of the Professoriate* (1 ed.): Jossey-Bass.
- Bradley, D., Noonan, P., Nugent, H., & Scales, B. (2008). *Review of Australian Higher Education* Retrieved from <http://apo.org.au/system/files/15776/apo-nid15776-54471.pdf>, <http://www.voced.edu.au/content/ngv%3A32134>, http://apo.org.au/files/Resource/higher_education_review_one_document_02.pdf
- Branscomb, L. (1998). From Science Policy to Research Policy. In L. Branscomb & J. H. Keller (Eds.), *Investing in Innovation: Creating a Research and Innovation Policy that Works*. Cambridge, MA.: MIT Press.
- Branscomb, L. M., & Auerswald, P. E. (2001). *Taking Technical Risks: How Innovators, Managers, and Investors Manage Risk in High-Tech Innovations*: The MIT Press.
- Branscomb, L. M., Morse, K. P., Roberts, M. J., & Boville, D. (2000). *Managing Technical Risk: Understanding Private Sector Decision Making on Early Stage, Technology Based Projects*. (NIST GCR 00-787). Washington: National Institute for Standards and Technology.
- Brown, T. (2013). Design Thinking. *Harvard Business Review*(June 2013).
- Bucolo, S. (2014). *Design thinking for export competitiveness: industry recommendations* Retrieved from Sydney: <http://meta.org.au/wp-content/uploads/2014/12/Design-Thinking-for-Advanced-Manufacturing--Industry-Recommendations-Dec-2014-1.pdf>
- Burns, T., & Stalker, G. M. (1994). *The Management of Innovation* (Revised ed.): Oxford University Press, USA.
- Celeste, R. F., Griswold, A., Straf, M. L., National Research Council (U.S.). Committee on Assessing the Value of Research in Advancing National Goals., National Research Council (U.S.). Division of Behavioral and Social Sciences and Education, & National Research Council (U.S.). (2014). *Furthering America's research enterprise*. Washington, D.C.: The National Academies Press.
- CSIRO, AFGC, & MLA. (2013). *National food and nutrition research and development and technology transfer strategy* . Retrieved from <https://www.npirdef.org/content/33/8700b4c8/Food-and-Nutrition-RDIT-Strategy.pdf>
- CSIRO Futures. (2017). *Food and agribusiness: a roadmap for unlocking value-added growth opportunities for Australia*. Retrieved from <https://www.csiro.au/~media/AF/Files/SMIIndustryRoadmapFoodAgWEB170710-PDF.pdf>
- Dalitz, R. (2016). Innovation and growth: The Australian Productivity Commission's policy void. *The Economic and Labour Relations Review*, 27(2), 199-214. doi:10.1177/1035304616648065
- Daly, J., Anderson, K., Ankeny, R., Harch, B., Hastings, A., Rolfe, J., & Waterhouse, R. (2015). *Australia's Agricultural Future. Report for the Australian Council of Learned Academies* Retrieved from <https://acola.org.au/wp/PDF/SAF07/SAF07%20full%20report.pdf>
- Department of Industry and Science. (2015). *Industry Growth Centres Initiative* Retrieved from <http://www.business.gov.au/advice-and-support/IndustryGrowthCentres/Pages/default.aspx>

- Dodgson, M., Gann, D., & Phillips, N. (2015). *The Oxford handbook of innovation management*. Oxford: Oxford University Press.
- Dodgson, M., Hughes, A., Foster, J., & Metcalfe, J. S. (2010). Systems thinking, market failure, and the development of innovation policy: The case of Australia. *UQ Economics Discussion Paper No. 403: Department of Economics, University of Queensland. And Centre for Business Research Working Paper 397, University of Cambridge*.
<http://www.sppm.tsinghua.edu.cn/ewebeditor/uploadfile/2011120204253847.doc>
- Etzkowitz, H. (2008). *The triple helix : university-industry-government innovation in action*. New York: Routledge.
- Florida, R. (1999). The Role of the University: Leverage Talent, Not Technology. *Issues in Science and Technology*.
- Food Innovation Australia Limited. (2017). *Celebrating Australian Food and Agribusiness Innovation* Retrieved from <http://foodbook.fial.com.au/product/celebrating-australia-food-and-agribusiness-innovations/>
- Gereffi, G., Humphrey, J., & Sturgeon, T. (2005). The Governance of Global Value Chains. *Review of International Political Economy*, 12(1), 78-104.
- Govindarajan, V., & Trimble, C. (2010). *The other side of innovation : solving the execution challenge*. Boston, Mass.: Harvard Business School Pub.
- Green, R. (2013). *The role of management in lifting productivity*. Retrieved from Canberra:
- Green, R., Agarwal, R., & others. (2009). *Management Matters in Australia: Just How Productive Are We? Findings from the Australian Management Practices and Productivity Global Benchmarking Project* Retrieved from http://worldmanagementsurvey.org/wp-content/images/2010/07/Report_Management-Matters-in-Australia-just-how-productive-are-we.pdf, <http://www.voced.edu.au/content/ngv:65677>
- Green, R., Toner, P., & Agarwal, R. (2012). *Understanding Productivity: Australia's Choice*. Retrieved from Sydney:
- Greenaway, D., & Rudd, C. D. (2014). *The business growth benefits of higher education*. New York, NY: Palgrave Macmillan.
- Hagel, J., & Singer, M. (1999). Unbundling the Corporation. *McKinsey Quarterly*, 3(3).
- Hartman, G. C., & Meyers, M. B. (2001). Technical Risk, Product Specifications and Market Risk. In L. Branscomb & P. E. Auerswald (Eds.), *Taking Technical Risks: How Innovators, Managers and Investors Manage Risk in High-Tech Innovation*. Cambridge, MA.: MIT Press.
- Howard, J. H. (2004a). *Business, Higher Education and Innovation: Institutions for Engagement in a Mode 2 Society*. Paper presented at the Triple Helix 5, Turin, Italy.
- Howard, J. H. (2004b). *Business, Higher Education and Innovation: Institutions for Engagement in a Mode 2 Society: Thesis submitted in fulfillment of requirements for PhD Faculty of Engineering* Retrieved from <https://www.howardpartners.com.au/assets/howard-phd.pdf>
- Howard, J. H. (2008). *Between a 'Hard Rock' and a 'Soft Space': The Arts, Humanities and Social Sciences in Innovation Systems* Retrieved from <http://www.chass.org.au/wp-content/uploads/2015/02/PAP20080521JH.pdf>
- Howard, J. H. (2015). *Translation of Research for Economic and Social Benefit: Measures that facilitate transfer of knowledge from publicly funded research organisations to industry Report for Securing Australia's Future Project "Translating research for economic and social benefit: country comparisons" on behalf of the Australian Council of Learned Academies* Retrieved from <http://www.acola.org.au/PDF/SAF09/1%20Australia.pdf>
- Howard Partners. (2003). *Evaluation of the Cooperative Research Centres Programme* Retrieved from <https://www.howardpartners.com.au/publications/crc-report.pdf>
- Howard Partners. (2005). *The Emerging Business of Knowledge Transfer: Creating Value From Intellectual Products and Services*. Retrieved from [https://www.howardpartners.com.au/publications/Howard Partners Business of Knowledge Transfer Report.pdf](https://www.howardpartners.com.au/publications/Howard%20Partners%20Business%20of%20Knowledge%20Transfer%20Report.pdf)

- Innovation and Science Australia. (2016). *Performance Review of the Australian Innovation Science and Research System*. Retrieved from Canberra: <https://industry.gov.au/Innovation-and-Science-Australia/Documents/ISA-system-review/Performance-Review-of-the-Australian-Innovation-Science-and-Research-System-ISA.pdf>
- Innovation and Science Australia. (2017a). *Australia 2030: Prosperity Through Innovation - Report of the Analysis of Stakeholder Consultation* Retrieved from <https://industry.gov.au/Innovation-and-Science-Australia/publications/Documents/Australia-2030-Stakeholder-Consultation-Report.pdf>
- Innovation and Science Australia. (2017b). *Australia 2030: prosperity through innovation, a plan for Australia to thrive in the global innovation race* Retrieved from <https://industry.gov.au/Innovation-and-Science-Australia/Documents/Australia-2030-Prosperity-through-Innovation-Full-Report.pdf>
- Johnston, R., Howard, J. H., & Grigg, L. (2003). *Best Practice Processes for University Research Commercialisation* Retrieved from Best Practice Processes for University Research Commercialisation
- Kambil, A. (2002). *Good Ideas are Not Enough: Adding Execution Muscle to Innovation Engines*. Boston: Accenture.
- Kelley, T., & Littman, J. (2001). *The Art of Innovation: Lessons in Creativity from IDEO, America's Leading Design Firm*. New York: Currency.
- Kelley, T., & Littman, J. (2005). *The Ten Faces of Innovation: IDEO's Strategies for Defeating the Devil's Advocate and Driving Creativity Throughout Your Organization*: Doubleday.
- Kerin, J. C. (2017). *The way I saw it; the way it was: The making of national agricultural and natural resource management policy* Retrieved from <http://apo.org.au/node/76216>
doi:<https://doi.org/10.4225/50/590fe72f12dd9>
- Leonard, E., Rainbow, R., Trindall, J., Baker, I., Barry, S., Darragh, L., . . . Zhang, A. (2017). *Accelerating precision agriculture to decision agriculture: Enabling digital agriculture in Australia* Retrieved from <http://farminstitute.org.au/LiteratureRetrieve.aspx?ID=160984>
- Lerner, J. (1999). Venture Capital and the Commercialization of University Technology: Symbiosis and Paradox. In L. Branscomb, F. Kodama, & R. Florida (Eds.), *Industrializing Knowledge: University-Industry Linkages in Japan and the United States*. Cambridge, MA.: MIT Press.
- Libert, B., & Spector, J. (2009). *We Are Smarter Than Me: Crowdsourcing New Businesses*: FT Press.
- Martin, B. (2016). Twenty challenges for innovation studies. *Science and Public Policy*, 43(3), 432-450. doi:10.31093/scipol/scv077
- Martin, B. R., & Salter, A. (1996). *The Relationship Between Publicly Funded Research and Economic Performance: A SPRU Review. Report Prepared for HM Treasury*. Retrieved from Brighton:
- Martin, B. R., & Tang, P. (2006). *The Benefits from Publicly Funded Research*. Retrieved from
- Martin, R. (2009). *The Design of Business: Why Design Thinking is the Next Competitive Advantage* (eBook Edition ed.). Boston: Harvard Business Press.
- Matthews, M. (2005). *Who Will Harvest Whom?: Identifying Areas of Comparative Strength, Weakness and Risk Associated with Economic Engagement with China. Working Draft*. Retrieved from Canberra:
- Matthews, M. (2006). Managing uncertainty and risk in science, innovation and preparedness: why public policy should pay more attention to financial and geopolitical considerations. Discussion Paper commissioned by the Federation of Australian Scientific and Technological Societies (FASTS). <https://marklmatthews.files.wordpress.com/2014/02/first-preparedness-paper-final.pdf>
- Matthews, M. (2009). Giving Preparedness a Central Role in Science and Innovation Policy. *FASTS Policy Discussion Paper*, (November 2009). <https://marklmatthews.files.wordpress.com/2014/02/second-preparedness-paper.pdf>
- Matthews, M. (2015). Coping with nasty surprises: improving risk management in the public sector using simplified Bayesian methods. *Asia & the Pacific Policy Studies*, 2(3). https://marklmatthews.files.wordpress.com/2014/02/matthews_et_al-2015-asia_the_pacific_policy_studies.pdf

- Matthews, M. (2016). *Transformational Public Policy: A new strategy for coping with uncertainty and risk* Studies in Government and Public Policy, Retrieved from <https://www.routledge.com/Transformational-Public-Policy-A-new-strategy-for-coping-with-uncertainty/Matthews/p/book/9781138824041>
- Matthews, M., & Frater, B. (2003). *Creating and Exploiting Intangible Networks: How Radiata was Able to Improve its Odds of Success in the Risky Business of Innovation*. Retrieved from Canberra:
- Matthews, M., & Lacy, C. (2017). *Innovation Strategy and Global Value Chains: Report for Innovation and Science Australia to Assist in the preparation of the 2030 Innovation System Strategic Plan*. SGD Economic Development Report
- Miles, D. (2015). *Growth Through Innovation and Collaboration: A Review of the CRC Program A Review of the Cooperative Research Centres Programme* Retrieved from <https://www.business.gov.au/~media/Business/CRC/Cooperative-Research-Centres-Miles-Review-Growth-through-Innovation-and-Collaboration-WORD.docx?la=en>
- Millist, N., Chancellor, W., & Jackson, T. (2017). *Rural research, development and extension investment in Australia. Research report 17. 11 Research by the Australian Bureau of Agricultural and Resource Economics and Sciences* Retrieved from <http://www.agriculture.gov.au/abares/research-topics/productivity/related-research/rural-rde-investment>
- Mowery, D., Nelson, R., Sampat, B., & Ziedonis, A. (2004). *Ivory Tower and Industrial Innovation: University-Industry Technology Transfer Before and After the Bayh-Dole Act* (1 ed.): Stanford Business Books.
- Mullen, J. D. (2007). Productivity growth and the returns from public investment in R&D in Australian broadacre agriculture. *The Australian Journal of Agricultural and Resource Economics*, 51. file:///Users/jhhoward1/Dropbox/COUNCIL%20OF%20RURAL%20RDCs/Articles,%20Papers,%20Reports/Mullen-2007-Australian_Journal_of_Agricultural_and_Resource_Economics.pdf doi:10.1111/j.1467-8489.2007.00392.x
- National Australia Bank. (2017). *Backing Rural Australia; Future-proffing our farmers by investing for sustainability and AgTech solutions*. Retrieved from Sydney: <https://nabnews.efront-flare.com.au/wp-content/uploads/2017/12/171213-Backing-Rural-Australia.pdf>
- National Famers Federation, & KPMG. (2018). *Talking 2030: Growing Agriculture to a \$100 billion Industry* Retrieved from <https://assets.kpmg.com/content/dam/kpmg/au/pdf/2018/talking-2030-growing-australian-agriculture.pdf>
- National Primary Industries Research and Development Framework. (2009). *Statement of Intent* Retrieved from <https://www.npirdef.org/framework-purpose>
- Norton, G. W. (2015). *Evaluating Economic Impacts of Agricultural Research: What Have We learned?* , North Carolina State University.
- O'Kane, M. (2008). *Collaborating to a purpose: review of the CRC Program* Retrieved from <https://industry.gov.au/innovation/Documents/CRCReviewReport.htm>, <https://www.archive.industry.gov.au/innovation/InnovationPolicy/Documents/Policy/NISAnnexCRC.pdf>
- OECD. (1997). *National Innovation Systems* Retrieved from <https://www.oecd.org/science/inno/2101733.pdf>
- OECD. (2013a). *Agricultural Innovation Systems: A Framework for Analysing the Role of the Government* Working Party on Agricultural Policies and Markets,, Trade and Agriculture Directorate Committee for Agriculture (Ed.) Retrieved from <http://www.oecd-ilibrary.org.ezproxy.lib.uts.edu.au/docserver/download/5113071e.pdf?expires=1501648851&id=id&ccname=ocid194662&checksum=F76D2BAF126B7128BDE8ABEBE0487DA5>
- OECD. (2013b). *Interconnected Economies: Benefiting from Global Value Chains* Retrieved from <https://www.oecd.org/sti/ind/interconnected-economies-GVCs-synthesis.pdf>
- OECD. (2015). *Evaluation of Industrial Policy: Methodological Issues and Policy Lessons. Teport of the Committee on Industry, Innovation and Entrepreneurship, Directorate of Science, Technology and Innovation* Retrieved from

- <http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=DSTI/IND%282014%293/FINAL&docLanguage=En>
- OECD. (2017). *OECD Research and Development Expenditure in Industry 2017: ANBERD* Retrieved from <http://www.oecd.org/publications/research-and-development-expenditure-in-industry-22237925.htm> doi:<http://dx.doi.org/10.1787/9789264284494-en>.
- Plattner, H., Meinel, C., & Leifer, L. J. (2012). *Design thinking research : studying co-creation in practice*. Heidelberg ; New York: Springer.
- PMSEIC. (2001). *Commercialisation of Public Sector Research* Retrieved from <https://industry.gov.au/science/PMSEIC/Documents/CommercialisationOfPublicSectorResearch.pdf>
- Radin, B. (2013). *Beyond Machiavelli : policy analysis reaches midlife* (2nd ed.). Washington, DC: Georgetown University Press.
- Ranga, M., & Etzkowitz, H. (2013). Triple Helix Systems: An Analytical Framework for Innovation Policy and Practice in the Knowledge Society. *Industry and Higher Education (Special Issue)*, 27 (4). http://triplehelix.stanford.edu/images/Triple_Helix_Systems.pdf
- Reid, G. (2014). *Why Should the Taxpayer Fund Science and Research* Retrieved from http://www.ncub.co.uk/index.php?option=com_docman&view=download&category_slug=reports&alias=180-why-should-the-taxpayer-fund-science-and-research&Itemid=2728
- Rogers, E. M. (1995). *Diffusion of innovations* (4th ed.). New York: Free Press.
- Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York: Free Press.
- Rural Research and Development Council. (2011). *National Strategic Rural Research and Development Investment Plan Department of Agriculture, Fisheries and Forestry* Retrieved from <http://www.agriculture.gov.au/ag-farm-food/innovation/national-strategic-rural-research-and-development-investment-plan>
- Shannon, C. E. (1948). A mathematical theory of communication. *The Bell System Technical Journal*, XXVII(July), 379-423.
- Sharma, A. (2013). Disconnect between researchers and national needs. *Australian Financial Review*, (16 September 2013). <http://www.afr.com/news/policy/education/universities-need-to-address-disconnect-between-research-and-national-needs-20130915-jh1ib>
- Sheng, Y., Gray, E. M., & Mullen, J. D. (2011). Public investment in R&D and extension and productivity in Australian broadacre agriculture *Australian Agricultural and Resource Economics Society*. http://data.daff.gov.au/data/warehouse/pe_abares99001784/CP11.08_Public_investment.pdf
- Sheng, Y., Mullen, J., & Zhao, S. (2011). *A turning point in agricultural productivity: consideration of the causes*. Retrieved from Canberra:
- StartupAUS. (2017). *Powering Growth: Realising the Potential of AgTech for Australia*. Retrieved from Sydney: <https://home.kpmg.com/content/dam/kpmg/au/pdf/2016/powering-growth-realising-potential-agtech-australia.pdf>
- Surowiecki, J. (2004). *The Wisdom of Crowds: Why the Many Are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations*: Doubleday.
- Terwiesch, C., & Ulrich, K. (2009). *Innovation Tournaments: Creating and Selecting Exceptional Opportunities*: Harvard Business School Press.
- Todd, J. (1995). *Colonial Technology: Science and the Transfer of Innovation to Australia*. Melbourne: Cambridge University Press.
- UK. Prime Minister. (2017a). *Building our Industrial Strategy - Green Paper* Retrieved from https://beisgovuk.citizenspace.com/strategy/industrial-strategy/supporting_documents/buildingourindustrialstrategygreenpaper.pdf

- UK. Prime Minister. (2017b). *Industrial Strategy: Building a Britain Fit For the Future*. Retrieved from London: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664572/industrial-strategy-white-paper-print-ready-version.pdf
- United States. Advanced Technology Program. (2000). *Managing Technical Risk: Understanding Private Sector Decision Making on Early Stage, Technology Based Projects*. Washington: National Institute for Standards and Technology.
- Viale, R., & Etzkowitz, H. (2005). *The Third Academic Revolution*. Paper presented at the Fifth Triple Helix Conference, Turin.
- Viale, R., & Etzkowitz, H. (2010). *The capitalization of knowledge : a triple helix of university-industry-government*. Cheltenham, Glos, UK ; Northampton, MA: Edward Elgar.
- Wang, S. L., Heisey, P., Schimmelpennig, D., & Ball, E. (2015). *US Agricultural Productivity Growth: The Past, Challenges and the Future*. Washington: USDA.
- Winchester, S. (2018). *Exactly: How Precision Engineers Created the Modern World*. London: Harper Collins.
- Xia, C., Zhao, S., & Valle, H. (2017). *Productivity in Australia's broadacre and dairy industries Research by the Australian Bureau of Agricultural and Resource Economics and Sciences* Retrieved from http://data.daff.gov.au/data/warehouse/agcomd9abcc004/agcomd9abcc20170307_0S6mp/ProdAustBrdacrDry_AgComm201703_v.1.0.0.pdf
- Xia, C., Zhao, S., & White, H. (2017). Productivity in Australia's Broadacre and Dairy Industries. In ABARES (Ed.), *Agricultural Commodities, March Quarter 2017*. Canberra: ABARES. Retrieved from <http://www.agriculture.gov.au/abares/Documents/agricultural-commodities-report-march-2017.pdf>.