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Review

Recommendations arising from an analysis of changes to the Australian agricultural research, development and extension system

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ABSTRACT

The business of agricultural research, development and extension (RD&E) has undergone considerable change in Australia since the late 1980s, moving from a domain largely dominated by government departments to a situation of multiple actors, and where rural industries now directly contribute funds towards RD&E efforts. However, the transition has not been without impacts on the overall agricultural RD&E agri-food capacity of the nation, and there are now indications of reduced capacity and slowing productivity gains in certain sectors. If not addressed, there is the risk that the future resilience of industries could be threatened, affecting parts of the Australian economy and compromising Australian contributions to global food supply on export markets and a slowing of agricultural innovation. There are also comparable divestment trends and the loss of capacity and risks to future resilience of agricultural systems in other developed nations. Importantly, research and extension are discussed as interdependent partner disciplines, and that the separation of the two has deleterious effects on capacity and resilience building. The authors investigate, through six case study institutions, organisational innovations that may provide direction towards the future restructuring of agricultural RD&E effort in Australia. These insights have application to both the Australian and the international reader, warning about the consequences of reduced investment in agricultural RD&E, and learning about how research and extension can transition from traditional public sector models to systems that have greater flexibility and, importantly, ownership by the industries themselves.

Introduction

This paper reflects on the journey of the research, development and extension (RD&E) sector in Australian agriculture since the late 1980s. It provides an insight into the transition from a system dominated by public sector agencies to a position where rural industries partner with government via legislative arrangements and through which they then manage investments around RD&E effort. It analyses those changes and reflects on their impact on the capacity and resilience of Australian agriculture, and then discusses the current and future repositioning of RD&E. The authors approach agricultural research and extension as interdependent partner disciplines. In Australia, government policies have resulted in continuous and cumulative reduction in the role of public sector RD&E since the late 1980s. RD&E has also become the domain of a variety of actors from the private sector and non-government institutions, e.g. universities and farmer agencies.

The Australian agricultural sector is a key employer and export earner for the Australian economy. In 2009–10, the gross value of agriculture, forestry and fisheries was $43.6 billion, or 3.0% of Gross Domestic Product (GDP) (Australian Senate, 2012). Approximately 327,000 people or 3.0% of the workforce are directly involved in the agriculture, forestry and fishing industries. Another one-in-six Australian jobs (around 1.6 million) are involved in ancillary occupations arising from agribusiness e.g. food processing and manufacturing (Australian Senate, 2012). Australian agriculture, forestry and fishing industries contribute substantially to the economies of rural communities and to environmental stewardship of regional Australia (Australian Government, 2013). It is now also being appreciated in Australia that agricultural RD&E investments are critical drivers for achieving productivity gains essential for agricultural industry viability and the ongoing production of safe and affordable food both domestically and internationally (Australian Government, 2013).

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International drivers

RD&E in Australian agriculture cannot be discussed in isolation from what has happened in agriculture globally. Australian agriculture has become increasingly internationalised since the 1980s and has become inextricably linked to the influences of globalisation, international trade agreements, and international politics (Josling, 1998; Skogstad, 2008; Vanclay, 2003; Vanclay and Lawrence, 1995). Consistent with these trends, agricultural policy in Australia has undergone a paradigm shift, changing from a situation that involved a high level of government intervention and support, to a more competitive market-based model (Botterill, 2003; Vanclay and Lawrence, 1994). Australian agriculture in the 21st century operates in the sphere of what can be described as both competitive and globalised market paradigms, i.e. where governments restrict their roles to assisting farm businesses that are competitive in the market place; and where agriculture must function in an internationally politicised environment, on a global playing field amidst agreed rules and regulations around food quality, safety standards, intellectual property rights and negotiated access arrangements (Josling, 1998).

Since the 1980s, Australian agriculture has transformed from a principally dependent model characterised by single-desk marketing arrangements, set prices for commodities, tariffs, production quotas, and restrictions on entry; to a relatively deregulated environment with limited government support and intervention (Balderstone et al., 1982; Botterill, 2003; Vanclay, 2003; Vanclay and Lawrence, 1995). This paper will argue that even though the reforms of the 1980s and 90s were defensible, and have delivered to Australia a more competitive agricultural sector internationally with lower burdens to taxpayers (Australian Government, 2013; Botterill, 2003); there has been a detrimental impact on agricultural RD&E, and this issue requires review and reform.

Past reforms to the RD&E system in Australia

Australia is a federation of States and Territories and the governments in these various jurisdictions have traditionally shared the investment burden in agricultural RD&E with the Australian Federal (Commonwealth) Government (Core, 2009). In the decades after World War 2 up until the early 1990s, agricultural development was a public policy priority in Australia, and agricultural institutions and RD&E effort grew, both in terms of scale and professional expertise (Cary, 1998; Williams, 1968). In addition to research, the period from the late 1960s through to the late 1980s also saw significant expansion in State and Territory Governments providing agricultural extension services. Over these two decades innovations in extension practices emerged and looked beyond simply production attempting to resolve more complex natural resource and socio-economic issues within rural industries (Bawden, 1992; Ison et al., 1997; Packham et al., 1988; Packham, 2011; Pannell et al., 2006; Prager and Vanclay, 2010; Van Beek and Coutts, 1992; Vanclay, 2004; Vanclay and Lawrence, 1994, 1995).

The economic and structural reforms of the 1980s moved Australian agriculture from a complex array of government interventions (e.g. price support, subsidy and quota systems) to one of the least supported farming sectors in the world (Botterill, 2003). Australian Government policy persuaded rural industries to begin to invest in their own RD&E as opposed to relying solely on State Governments or the Commonwealth. In the early 1990s, the Australian Government instituted various agricultural "Research and Development Corporations" (RDCs) (Core, 2009). These agencies collect industry levies which are matched dollar-for-dollar with Commonwealth funds, up to a defined limit of 0.5% of gross value of industry production for agricultural RD&E. They were instituted to deliver tangible outcomes to industry and the nation, which was a shift from an outputs focus that was centred on scientists previously directing where research and development was undertaken. The new aim was to pass the priority setting and fund allocation to industries (Kerin and Cook, 1989; Wallis, pers. comm., 3 October 2012). In addition to the RDCs, industry centres of excellence in research – Cooperative Research Centres (CRCs) – were also created, and were aimed at bringing together the best in their fields from both the public and private sectors to work on priority scientific issues (Core, 2009).

As industries and the Commonwealth took a greater role in RD&E, the State Governments saw an opportunity to divest from these services and began to withdraw as traditional providers of production-orientated RD&E services to agriculture (Core, 2009; Hunt and Coutts, 2009; Marsh and Pannell, 2000; Mullen, 2010a; Mullen and Orr, 2007; Vanclay, 1994; Watson, 1996). Recent estimates indicate that public investment in agricultural RD&E in Australia has been static for around two decades, and declines in the rate of gain in agricultural productivity are beginning to be observed as a result (Australian Government, 2013; Mullen, 2010a; Hughes et al., 2011; Mullen, 2012; Sheng et al., 2011).

With State Government investments in continual decline, the rural sector has seen the appearance of multiple actors in the agricultural RD&E landscape. It has led to opportunities for private enterprise with some former state departmental officers establishing their own advisory services, especially in more densely populated farming regions (AHRSCAFF, 2006). Several farmer-based agencies (e.g., the Kondinin and Birchip groups) have also established themselves in providing agricultural RD&E services in different regions of the country (Hunt et al., 2012a). However, an assumption held by policy makers that the private sector would sufficiently fill the gap left by the public sector exit across Australia's farming regions has proven to be over-optimistic, with evidence of failures in service provision of RD&E services (Cary, 1998; Fulton et al., 2003; Hunt and Coutts, 2009; Hunt et al., 2011; Vanclay, 2003). Governments in some jurisdictions still provide production orientated expertise in RD&E, but these are largely diminished in terms of capacity across almost all industries compared to previous decades (Hunt et al., 2012a).

It must be remembered that agricultural industries are dynamic entities, they ebb and flow with changes in prosperity, sometimes expanding, and other times contracting. The conversion from a dependent to a market-orientated paradigm facilitated major changes in the fabric and disposition of farming enterprises in Australia. Prime examples of this are the contractions observed in the wool and dairy industries since the 1990s. The wool industry's price stabilisation scheme failed, and the dairy industry was deregulated, providing exposure to genuine market forces for both of these sectors (Davidson, 2001; Vanclay, 2003). Consequently, these industries no longer exist in many regions where they previously dominated. Maintaining specialised RD&E services in regions that have transitioned into completely different agricultural industries, or where the former industries have regressed to isolated pockets, is not defensible.

In response to the rationalisation of RD&E resources nationally, interstate cooperative frameworks on agricultural RD&E are currently being developed for the different sectors of Australian agriculture (PIMC, 2010). Many jurisdictions are reducing their support for RD&E in industry areas where there is no corresponding co-investment. The exception to this is where there might be additional public benefit outcomes (Barlass, pers. comm., 5 September, 2012, National Horticulture Research Network meeting). This means that many small or developing rural industries may not have RD&E support from State or Territory governments as they are simply too limited in size to undertake co-investment. Declines in public sector investment in agricultural RD&E have also been

experienced in many of the world's developed nations as governments shift their investments into other areas of their economies. However, there are other formerly developing nations who are taking a different path (Alston et al., 2010); these will be introduced in the next section.

International trends with agricultural RD&E

The trends in public sector agricultural RD&E investment in Australia have also been evident in numerous western economies (Alston et al., 2010; Ameur, 1994; Bloom, 1993; Cary, 1998; Milburn et al., 2010; Rivera, 1993, 2000). In the 1981 to 2000 period, Alston et al. (2010) quoted an average annual negative growth rate for Australian agricultural RD&E at 0.53%. In the US from 1900 to 1970, agricultural RD&E investment grew by an average of 4.99% per annum; however, from 1970–1990 it reduced to 1.74% annually, and from 1990 to 2007 to 0.99%. From 1981 to 2000, French investments in RD&E declined by nearly 7% annually, Japanese 2.43% and British 1.36% (Alston et al., 2010).

In 1987, New Zealand ceased its responsibilities for agricultural extension leaving it entirely up to the private sector (Cary, 1998). Britain, France, the Netherlands and Germany have also largely devolved their extension responsibilities to the private sector (European Commission, 2012; Fulton et al., 2003).

In the UK, Alston et al. (1997) and Leaver (2007, 2010) cite a shift from applied science and extension towards basic science research, as government has directed public sector funds towards universities and away from the former departmental structure of service delivery. In a 2010 report of the All-Party Parliamentary Group on Science and Technology in Agriculture, Leaver advises that "the agricultural (including horticultural) R&D pipelines in the UK necessary to deliver innovation and new technology have been successively weakened over the last 25 years" (Leaver, 2010, p.5). He also warns that the consequence of concentrating public sector funding on basic research has led to a substantial loss of scientific expertise in applied agricultural research. Government, universities and research institutions became focussed on research indices that saw them target research that would have the best fit at the high-end of academic league tables, and thus would deliver increased funds and reputational gain to the respective institutions. This has led to research with no particular application or use in view, and created 'silos' of research activity which tended to look increasingly inwards. This, combined with the loss of the UK's publicly funded Agricultural Development Advisory Service (ADAS), was very damaging to research pipelines (Leaver, pers. comm., 2012). Similar lines of fragmentation are also being observed in the agricultural systems of many other European nations (European Commission, 2012).

In North America, specifically Ontario, Canada, the reduction in the farming population (to around 2% of the population), the resultant loss of political leverage, and incapacity to demonstrate cost-benefit, were seen as reasons for government to effectively hand over extension to the private sector in the early 2000s (Milburn et al., 2010). The same loss of political strength and influence has been observed in Australian rural industry over the last few decades as fewer people are engaged in the business of agriculture (Lockie et al., 2006; Vanclay, 2003).

All of these changes in agricultural RD&E systems occurred in an era when governments in western democracies committed themselves to economic rationalist thinking, and were assured that their nations had attained an abundance of food security. Consequently, they saw benefit in shifting investments into non-agricultural areas (Alston et al., 2010; Skogstad, 2008). Conversely, other nations, for example China, India and Brazil, have since the 1990s expanded and enhanced their agricultural research and extension sectors with annual growth rates of 6.7%, 6.95%, and 1.66% respectively (Alston et al., 2010).

Understanding the consequences of under investment in RD&E

The value proposition associated with justifying the investment of public funds in agricultural RD&E remains a challenge – it is not a convenient and closed experiment. It remains a complex environment where the combined impact of research and development inputs, and the lag times in adoption of different technological or systems innovations are not always immediately understood (Alston et al., 2010; Evenson, 2001). In Australia, there is a plethora of literature (some published and much unpublished reports held within RDCs), around the impact of specific RD&E projects, but there are few longitudinal economic assessments on the net benefit of agricultural RD&E to the nation. Mullen and Orr (2007) assessed the combined public and private investment from 1918–2003 and determined a benefit to cost ratio of 12.2:1, an internal rate of return of 16%, and a sustained productivity growth of 2%. However, perhaps the most appropriate place to look for further evidence of impact of investment and the downstream consequences is the global engine room of agricultural RD&E, the USA, a nation which individually accounts for nearly 20% of the total global RD&E investment in agriculture (Alston et al., 2010).

Alston et al. (2010) explain the longitudinal benefits of RD&E investment at numerous levels. They discuss how agricultural RD&E effort, in accompaniment with associated engineering developments; and demand pull from other sectors, has since the 19th C freed up the relative proportion of the US population directly engaged in agriculture. This has allowed that workforce to be used to develop other areas of the economy. RD&E can also be demonstrated to have reduced operational costs within farm enterprises and lifted overall national agricultural productivity, adding to the national terms of trade, reducing food costs, and providing many flow-on benefits in technologies and scientific advances to many developed and developing nations globally. They discuss how from 1949–1990, US agriculture has delivered average annual productivity growth rates of a little over 2% annually, and returns on investment of around 18:1.

However, since the 1990s US agriculture rates of productivity gains have slowed down to the order of 1% (1990–2002) (Alston et al., 2010). Alston et al. (2010) demonstrated that the slowdown in rates of productivity growth was linked to declining growth in public sector RD&E investment which first started in the 1970s. Slowdowns in rates of productivity gains in certain Australian agricultural industries have also been observed recently, and is being linked to the declining investment story that began in the late 1980s and early 1990s (Core, 2009; Mullen, 2010a, 2010b; Mullen and Orr, 2007). This brings into discussion the issue of lag times in the realisation of the benefit of RD&E investment. The dividends from agricultural RD&E are not always obvious in the short-term but have a delayed impact and an often extended legacy in an economy (Alston et al., 2010; Mullen, 2012; Mullen, 2010a, 2010b; Mullen and Orr, 2007; Productivity Commission, 2011). Alston et al. (2010) cite a number of well-documented US examples that indicate lag times of perhaps 15–35 years before the full dividend of technical or systems innovation is achieved. The Productivity Commission has similarly reported in relation to Australia (Productivity Commission, 2011). Conversely, the results from divestment in RD&E will have sustained negative consequences decades onwards emphasising the need for ongoing effort to enhance agricultural productivity gains given future global challenges around increasing world population, increased food demand from a rising middle class in Asia, pressures on natural resources (especially access to affordable water and vital crop

nutrients such as nitrogen and phosphorus); and the yet to be fully understood effects of climate change (Alston et al., 2010; Australian Government, 2013; Cribb, 2010; D'Occhio, 2011; Foresight, 2011; Leaver, 2010; Moir and Morris, 2011; Mullen, 2010a, 2010b; OECD-FAO, 2012; Van Braun, 2007).

The Australian Federal Government is now recognising the issue of reduced rates of productivity gains in certain sectors of Australian agriculture (Australian Government, 2013), and that productivity gains are critical if Australian rural industries are to remain competitive in often distorted global markets, especially since 2009 with a relatively high Australian dollar on world currency markets. Productivity gains are therefore being seen as essential for the survival and progression of rural industries and their communities, for providing affordable and safe food domestically; and as a consequence of Australia being a significant exporter of various agricultural commodities, also having an influence on the price of food in the global market place. Affordable food in global markets translates into alleviating suffering in developing nations and promoting international stability and security. It has been estimated that Australia (which has a population of 23 million) is currently producing enough food to sustain over 60 million people (PMSEIC, 2010).

Approaches for understanding the construct and function of RD&E systems

The analysis of RD&E systems is not simple as there are many variations upon structure, participants, funding, and benefit outcomes i.e. whether public, industry (sometimes called 'club' interests), and private. The following two frameworks will be used to aid in a discussion of both the current state of the Australian agricultural RD&E system as well as to assess a set of case studies which provide insights into what has occurred in both Australia and other developed nations in agricultural RD&E systems, and to discuss possible reform options.

Innovation structures

A model to explain the construct of agricultural RD&E systems was developed by Röling and Engel (1991) and expanded by Rivera et al. (2005) (Fig. 1). Agricultural Knowledge and Innovation Systems (AKIS) help to describe the various stakeholder blocks, and interactions between them in the "generation, transformation, transmission, storage, retrieval, integration, diffusion and utilisation of knowledge and information, with the purpose of working synergistically to support decision making, problem solving and innovation in agriculture" (Röling and Engel, 1991). Imbalances, blockages or excision of capacity at any of the points in the system, will have consequent effects on innovation and adoption outcomes. The discussion will use AKIS as the foundation for understanding the different interests involved in the innovation system.

Fig. 1. Agricultural knowledge and innovation systems. (*Source*: Rivera et al. (2005)).

The seven features of effective innovation systems

Delving further into innovation systems, any proposed reorganisation of the agricultural RD&E in Australia requires creation and application of effective knowledge development and adoption systems. Bergek et al. (2010), describe seven features that effective industrial innovation systems exhibit:

1. *Knowledge development and diffusion:* This is the heart of the innovation system and has an outcome with either the learning or adoption of practices, and technologies by industry stakeholders. Any influences that either positively or negatively impacts knowledge creation, development and diffusion of advances into industry will either enhance or degrade the innovation system.
2. *Search and identification of opportunities:* Opportunities rarely present themselves in a clear and transparent way, especially with technologies that disrupt existing technological knowledge or paradigms. Identification and pursuit of viable opportunities is central for innovation. Having the right people and processes in place to identify opportunities, support investment in research and development, and advance them through to fruition is pivotal for innovation.
3. *Entrepreneurial experimentation and management of risk and uncertainty:* Entrepreneurial uncertainties are a fundamental feature of technological and industrial development and are not limited to early phases in innovation, but are also a characteristic of later phases as well (Rosenberg, 1976, 1996). Particularly with the sciences, not every investigation can be guaranteed to yield benefits, let along findings that can be progressed and applied in industries. Effective communication channels between end-users and researchers is therefore essential in minimising the risks associated experimentation and eventual adoption.
4. *Market formation:* Innovations may initially be poorly adapted for fitment when first introduced. Effective innovation systems possess adequate development and refinement processes to modify practices or technologies to a stage where they are accepted in the market place. This includes not just the acceptance of technological innovation, but also ideas, or systems innovations.
5. *Resource access and mobilisation:* This area includes issues such as the ability to finance investments or to create efficient production systems and to recruit appropriately trained staff. This could be a significant limiter in smaller economies or industries.
6. *Legitimation:* This is effectively the social licence to operate and embed new knowledge, systems or technologies. Legitimacy also influences the function and influence on the direction of search for new opportunities.
7. *Development of positive externalities:* This constitutes the positive 'spill-over' effects from the innovation, in terms of produced, human, social or natural capital values.

Used by the European Commission in its own analysis of the EU's agricultural RD&E sector, Bergek et al. (2010), provide a credible way forward to systematically analyse and evaluate the state and trends of innovation systems.

Selected organisational models for delivery of agricultural RD&E

The legacy paradigm of Australian public sector RD&E services is well understood, though today many of these older, service delivery models are now either dismantled, or severely altered. Since the 2000s the RD&E effort has increasingly been resourced

under the auspices of the RDCs. However, it must be understood that the RDCs operating in Australian agriculture/horticulture do not directly carry out RD&E activities. They are brokers of industry levies and matched government funds. They allocate funding to private organisations, government agencies and universities according to determined priorities and the capacity of those entities to deliver. By and large, RDCs do not possess their own research or extension staff, though they do employ professionals with skills in these areas to assess, oversee and coordinate projects awarded to different agencies. The RDCs have generally acted via public or private providers to deliver RD&E services. Changes in public sector organisations or the viability of private sector providers can therefore have an influence on the effectiveness of the operations of the RDCs. RDCs often rely heavily on State departments of agriculture to deliver their programs, as this is where the residual expertise and infrastructure has historically lain.

The CRCs must also be considered in their role in the RD&E mix. Their nature and construction has meant that they generally possess little front-line extension capacity, and generally rely more of passive means associated with science communication activities, e.g. published material, scientific papers, websites and media releases. Like the RDCs, the CRCs have also relied heavily upon extension assets within the State government departments or private providers to extend their findings. The generation of new science and technologies in isolation of effectively-linked extension infrastructure can mean potential returns on research investments are reduced (Anderson and Feder, 2004).

To construct future vehicles for creating, sustaining and delivering agricultural RD&E, industry and public policy makers may need to look beyond traditional government departmental or commercial private sector models. This paper will not evaluate the US Land Grant Universities system, known as the US Cooperative Extension Service as this is widely documented elsewhere (USDA, 2012, 2005; Williams, 1968); however, some aspects of the system will be discussed in Case study 2: The Tasmanian Institute of Agriculture. There will be a focus on selected desk-top case studies drawn from Australia, New Zealand, Britain and Demark – principally of non-government RD&E institutions, such as industry-funded organisations, quasi-government agencies, as well as specific institutes established in universities. These selected case studies are being used as they reflect real-life examples that demonstrate a suite of agricultural innovation structures, with differing functions, from a range of cultural and political backgrounds. Through understanding how these institutional RD&E agencies are resourced, organised and operated; ideas for the formulation of effective and sustainable structures for agricultural RD&E in Australia may be possible.

Case study 1: The Australian sugar industry – Sugar Research Australia

For over 100 years, the Australian sugar industry has invested in and largely directed its own RD&E capacity. The Bureau of Sugar Experiment Stations (BSES) was established as a statutory body under the Queensland Government in 1900 and remained as such until 2003 when it was corporatised to become an industry-owned company, BSES Limited. This agency has historically received a portion of its finances from levies on sugar growers and millers, with the remainder from the Queensland and Australian Governments. Its initial inception was to resolve difficult pest management issues in the industry, but over the decades it evolved to undertake plant breeding, agronomy, bio-technologies and until recently engineering-related RD&E (Hunt et al., 2012b). In the early 2000s, BSES employed over 300 personnel but adopted a leaner business model over the last decade and in early 2012 had 180 staff (Armistead, 2012; Hunt et al., 2012b; Welsman, 2011). Other agencies until recently in the sugar RD&E complex were the Sugar Research Limited (SRL), which historically worked with mill engineering, and the industry RDC - the Sugar Research and Development Corporation (SRDC).

For much of the 2000s, BSES was unable to negotiate sufficient voluntary levy arrangements with industry, putting it under serious financial pressures (Hunt et al., 2012b; Welsman, 2011). Recent reforms have seen a consolidation of the various sugar RD&E bodies into a single industry-owned corporate entity, Sugar Research Australia (SRA) (Sugar Poll, 2013; Welsman, 2011). This has been done to reduce costs, streamline administration, and enhance stakeholder direction of research and extension work (Welsman, 2011). SRA is registered as an industry-owned company (IOC), backed by a compulsory levy of 35 cents per tonne of sugarcane, to be paid equally by growers and millers (i.e. a total of 70 cents per tonne).

This laudable advance does have some shortfalls. Restructuring saw the new entity shed much of its extension arm (Armistead, 2012). The agency's extension capacity is being reduced to a largely non-field entity within the new research body, and will be dedicated to specific training of industry stakeholders and general science-communication activities (Hunt et al., 2012b; Welsman, 2011). Most of the extension effort will now be conducted by mill-associated Cane Productivity Services (CPS) officers – which had previously been a form of locally-supported extension in the industry. Arguably, there has long been a costly over-servicing of the Australian sugar industry with two tiers of extension agencies in the industry, i.e. BSES extension staff and individual mill CPS field officers. Ironically, many of the retrenched BSES extension personnel are now working with the CPS's in extension service roles – thus there have been no net savings to industry. The new model will however, see R&D centred in one agency and in-field extension services spread across local CPS agencies, or attained using commercial consultants where they are available. Concerns have been expressed about the weakening of linkages between research and extension in Australian sugar (Hunt et al., 2012b; Wallis, pers. comm., 26 September, 2012).

Case study 2: The Tasmanian Institute of Agriculture

Tasmania is an island state of Australia and lies around 300 km south of the Australian mainland in the 41–43°S latitude range. It is highly rural and regionalised with around 60% of its population of a little over 500,000 living outside its capital, Hobart (DHHS, 2008). Dominant agricultural industries include dairy, annual and perennial horticulture, beef production, wool, and sheep meats. Compared with other Australian states, it is characterised by a dispersed population and a proportionally greater reliance on revenue from rural industries, approximately 7% of gross state product (TIA, 2012). The Tasmanian Institute of Agriculture (TIA) is a joint venture of the University of Tasmania (UTAS), and the Tasmanian Government's Department of Primary Industries, Parks, Water and Environment (DPIPWE). In 1997 reform measures in the State Government, and rationalisation pressures with the School of Agriculture in the University of Tasmania, resulted in the development of a joint venture partnership to service the research needs of Tasmanian agriculture. Since 2009, TIA has also incorporated the former government DPIPWE extension staff into its ranks (Hamilton and Hamilton, 2010; TIA, 2012).

TIA has around 140 staff members as well as around 100 postgraduate students and a range of honorary academic staff, and manages a research portfolio in excess of AUS$14 million, the majority of which is sourced from external funding providers, including the RDCs (Hamilton and Hamilton, 2010; TIA, 2012). Its RD&E capacity is organised into six specialist centres, Dairy, Vegetable, Perennial Horticulture, Extensive Agriculture, Food Safety, and a School of Agricultural Science (TIA, 2012). It also has

expertise in thematic areas of Value Chains, Climate Change, and Science and Society (Hamilton and Hamilton, 2010; TIA, 2012). The fact that Tasmania is an island state makes UTAS not just a state university, but also effectively a regional hub of education and service delivery. It has three main campuses (Hobart, Launceston and Burnie), and several associated research facilities inherited from DPIPWE (TIA, 2012).

TIA is the only Australian institution that resembles aspects of the US Cooperative Extension System. Like the US system, TIA undertakes integrated functions of teaching, training, extension and research. Hamilton and Hamilton (2010) assert that TIA has been able to establish a degree of independence from both university and government whilst continuing to satisfy the needs of both. The evidence that TIA has endured and its business has grown demonstrates the success of the model. They also suggested that farmers, competitors and collaborators consistently expressed goodwill towards TIA, indicating that it has a strong and positive reputation in the Tasmanian agricultural sector, but emphasise that it will need to build on this reputation, continue to secure financial resources, and maintain strong services delivery to create a successful future (Hamilton and Hamilton, 2010).

Case study 3: The McKinnon Project

Based at the University of Melbourne's Veterinary School at Werribee on the outskirts of Melbourne, the McKinnon Project is a recognised leader in sheep and beef consultancy both in Australia and internationally. The McKinnon Project was established in 1982 with the specific aim of improving the productivity and profitability of sheep flocks and beef herds for southern Australian production regions. Its core functions include education, research and whole farm consultancy for the extensive livestock industries. McKinnon has been involved with investigations into the live sheep export business, as well as various productivity programs funded by the animal industry RDCs. The project also offers fee-for-service consultancy services to agribusiness. It has been instrumental in establishing new scientific findings related to livestock production, and cementing in place new production doctrines via their extension-consultancy efforts (Hunt et al., 2008). Larsen et al. (2002) in their work with Australian wool growers felt that McKinnon was able to successfully develop participatory models of research that identified important problems and research priorities. McKinnon have also established strong linkages between researchers, program consultants and innovative farmers. As a consequence they were able to deliver properly designed and relevant research and extension packages that improved the profitability of participants. McKinnon has proven to be a sustainable program that has been, for the most part, revenue positive through their paid consultancy arrangements. McKinnon's presence has ensured the retention and availability of high-level intellectual property to southern Australian animal industries by maintaining a small multidisciplinary team at a time when many State Governments were withdrawing from service provision. It has played a vital role in keeping production system knowledge alive and up to date (Counsell, pers. comm., 2008).

Case study 4: The UK Agriculture and Horticulture Development Board (AHDB)

The Agriculture and Horticulture Development Board (AHDB) in the United Kingdom describes itself as an evidence-based agency dedicated to RD&E for subscriber industries in agriculture and horticulture. Rural industry stakeholders established the organisation in 2009 to resolve issues around market failure in public and private sector RD&E to agricultural and horticultural industries in the United Kingdom (Leaver, 2010). They undertake research and development and farm-level knowledge extension. They also provide market information for producers, assist in supply chain transparency, undertaking product branding, delivering marketing activities and working to maintain and develop export markets. The organisation is funded by statutory industry levies, and supports throughout the different jurisdictions of the UK, the meat and livestock industries, dairy, horticulture, and in vegetables – potatoes. Its limitation is that it has a modest budget of around £20 m and not all producers are satisfied with the payment of statutory levies (Leaver, 2010; Leaver, pers. comm., 2012).

The AHDB is organised around sector-specific advisory committees comprised of industry stakeholders that set strategic priorities and recommend levy rates. Leaver (2010, p. 13) states that:

> "The AHDB has an important role in providing leadership to the industry in the coordination of agricultural research; firstly at policy level by working together with public and private sectors to develop R&D policies aimed at improving agricultural productivity and competitiveness; secondly at the implementation level in ensuring the individual levy bodies are collaborating with public and private sectors in funding relevant applied research; and thirdly at knowledge exchange level by continuous monitoring of the R&D pipelines between research and practice to identify weaknesses and develop collaborative solutions."

However, Leaver (pers. comm., 2012) has reservations about the efficacy of the system:

> "Whilst the formation of AHDB and its board has led to a more strategic approach to RD&E the six advisory committees still operate somewhat independently, each with its own board which does not appear to be an efficient way of operating. Each sector body differs in the emphasis given to R, D and E and consequently are staffed differently."

Despite its shortcomings, the agency does appear to be partly addressing apparent service failures subsequent of the retreat of publicly supported applied RD&E.

Case study 5: The Agricultural Crown Research Institutes (AgResearch, and Plant and Food Research) of New Zealand

The New Zealand Crown Research Institutes (CRIs) consist of eight scientific bodies formed in 1992 as a consequence of major reforms in the country's science and agricultural sector. They were created from the elements of the former government Department of Scientific and Industrial Research (DSIR) and sections of various other government departments. The two agricultural production-focussed entities are AgResearch, and Plant and Food Research. AgResearch deals with livestock-oriented science, whilst Plant and Food Research provides research and development that adds value to New Zealand's fruit, vegetable, broadacre and food processing industries. These, like the other science CRIs, are quasi-government corporatised research entities. To support them, the New Zealand Government passed the Commodity Levies Act under which industry groups were given authority to impose mandatory levies to fund sector-specific research and market development activities (Alston et al., 1997). The CRIs became centres of science excellence and would be forced by government policy to develop a public market for their R&D services (Alston et al., 1997).

CRIs were effectively given a charge to become financially viable and to operate on commercial lines. According to CRIT (2010), in a review of the CRIs, this past policy imperative of government for the CRIs to be economically sustainable has had some negative impacts upon the nature of the science generated and

affected the net benefits to client industries. In the review it is stated:

> Currently, it is not clear if a CRI's objective is to create value for itself, as a company, or to generate value for New Zealand. Current ownership arrangements seem to place undue emphasis on research and development that produces outputs that individual CRIs can capture in their statements of revenue and balance sheets, rather than on research that contributes to the wellbeing and prosperity of New Zealand (CRIT, 2010, p. 7).

These commercial drivers also led to the pursuit of competitive contracts that were short-term, relative to the time frame in which science can be expected to produce results. This has had a detrimental impact of CRIs to operate strategically. Furthermore, the existing funding and governance arrangements for CRIs inhibited collaboration with universities and the private sector and effectively made them competitors in what should have been a collegiate function of government in enabling industrial advancement. The reviewers upheld that contestable, open access funding should remain an important element of the system that allocates science sources, albeit on a smaller scale, because it was recognised as vital for generating competing ideas and to capture new entrants into the knowledge system (CRIT, 2010). The system needed to be financially viable, and effective in its responsibilities to rural industries, as opposed to creating the growth of financially profitable R&D companies.

The CRIs have had little in the way of extension capacity. New Zealand discharged its public sector involvement in extension in 1987 (Cary, 1998) and consequently R&D generated by the organisations relies on industry service providers or private consultants to undertake many active extension works. The function of extension, or as articulated in the review 'technology transfer', also came under scrutiny. This role was seen to have been undervalued by the agricultural CRIs and was highlighted as a core responsibility with an emphasis to develop, invest in and manage intellectual property or innovation with the intent of expediting its passage into outcomes for stakeholders (CRIT, 2010). The New Zealand government has only recently begun to reinvest in the publicly funded R&D as a consequence of the shortcomings identified in the 2010 review.

The Danish Agricultural Advisory Service (DAAS)

This agency is owned and managed by farmers, through their membership of subscribing farming organisations. The partnership employs around 3500 professionals. The agency dates back to around 1875 when farmers' organisations started to employ their own advisers (DAAS, 2013). Today, DAAS is one of the leading agricultural advisory services in Europe. DAAS supports Danish farmers with extension services relating to both production and business management aspects of farming (European Commission, 2012). It provides technical know-how and client advisory services on production methods including farm planning, tracking and processing of technical and economic data for the everyday management of the individual holdings and conduct of farmer education courses. The agency also prepares accounts and tax returns, and provides farm business management advice to clients. DAAS functions as a link between farmer members and the research and experimental institutions of the Danish government and universities. Its organisational structure consists of 31 independent local advisory centres throughout the country, and one national knowledge centre, which provides the local centres with the latest information from both Danish and foreign research (European Commission, 2012). The service thus bridges the gap between agricultural research and farming, and ensures that new know-how is put into use on the farm and in the field as quickly as possible (European Commission, 2012).

Discussion

As indicated in Approaches for understanding the construct and function of RD&E systems, Bergek et al.'s seven features of effective industrial innovation have been used to analyse the status of Australia's agricultural innovation system, and compare and contrast the different case studies, and determine what they can contribute to future reform.

Knowledge development and diffusion

State and Territory Government departments of agriculture are either in decline with regards to their RD&E services, having already lost a good deal of their human and institutional capital through staged redundancies; or they have exited the business completely and have confined their engagement with rural industry to regulatory roles around biosecurity, food integrity and natural resource management, as well as broader agricultural policy agendas.

Some of the reforms undertaken by various Governments, particularly as seen in the Australian sugar industry and the New Zealand CRIs, is the separation of research from extension activities, or even in some instances the abdication of responsibilities in either one or both of these disciplines. A similar development in the state of New South Wales is the merger of its different quasi-government agencies in natural resource management and biosecurity, with that of agricultural extension assets from its Department of Primary Industries (Hodgkinson, 2012). This new structure will reallocate responsibilities to new quasi-government organisations known collectively as 'Local Land Services', which will have regional governance arrangements and local control of service activities. This restructure will effectively separate extensionists from researchers across their different production sectors.

Anderson and Feder (2004) are critical of situations where research and extension efforts are conducted via separate entities. Based on studies over several decades across a wide range of RD&E programs in both the USA and the developing world, Evenson (2001) asserted that technologies or practices will be adopted earlier when extension is integrated with research. These authors argue that extension services function best when strong links exist between extension agents and knowledge generation systems. The US Cooperative Extension services have historically demonstrated a strong connectivity between researchers, extensionists and end-users in agriculture (Evenson, 2001; Williams, 1968), though even this capacity is under threat given the recent years of fiscal tightening (Milburn et al., 2010). Therefore, extension and research disciplines must be closely associated with each other in organisational structures, and in the design and delivery of programs, to be able to sustain capacity building over time.

The case of the industry-owned Danish Agricultural Advisory Service demonstrates a situation of how to adapt to withdrawal of public sector extension. It also offers a way forward by having deliberate structural arrangements to formally link the extension service with research institutions. In Australia there are examples of structural failure, where the relationship between an industry's research centre and its' RDC can break down, thereby creating a disconnect that adversely affects industry advancement. One such example is the public schism that has occurred between the wool industry's RDC (Australian Wool Innovation) and the Sheep CRC which has resulted in cessation of significant amounts of research funding from AWI to the Sheep CRC (Jeffery, 2013). Thus the case for integrated RD&E institutions could be tendered as a more viable

proposition than fragmentation into separate funding bodies, and research, and extension service providers as is the case in numerous industries in Australia.

There is sufficient evidence in Australia, New Zealand, the UK and other European nations, of a fragmentation of the flow of information from research to farmer and vice versa in the AKIS RD&E loop, largely because extension agents no longer exist in certain parts of modern agriculture (Botha et al., 2007; European Commission, 2012; Fulton et al., 2003; Hunt and Coutts, 2009; Leaver, 2007, 2010; Leaver, pers. comm., 2012; Marsh and Pannell, 1998; Stone, 2005). The increased pluralism in extension provision has impinged on the influence that extension may exert on research (Botha et al., 2007; Carney, 1998). Hunt and Coutts (2009), in a study of the Tasmanian sheep industries, also discuss how, as a consequence of an increased involvement of the commercial sector in extension type activities, some farmers have expressed concern about the lack of independence, or potential bias in the advice they receive. Furthermore, Hunt and Coutts also identified evidence of knowledge and skills gaps of proven technologies and practices that had either not been taken up or had been let go, and ascribe this to the retreat of government extension services since the 1990s. These gaps, suggest that an alternative structure, perhaps industry-owned, (e.g. DAAS), might be productive. A client group that loses touch with existing best practices will certainly struggle to innovate. Capacity can be lost if knowledge and skills are not revisited or reinforced, and innovation will not be sustainable if the component AKIS institutional arrangements are compromised (Macadam et al., 2004).

The adoption of innovation requires the building of human capital in the client base. In spite of the increasingly complex and demanding value-chain structures of modern agriculture, Australian rural industry has the lowest number of workers with post-secondary qualifications compared to other sectors. The Australian Senate in a review into higher education and skills training to support agriculture and agribusiness, found that in 2009 only around 7.8% of agricultural industry had tertiary qualifications, compared to 25% for the wider Australian community (Australian Senate, 2012; Pratley, 2012). This situation adds to the argument for retaining suitably qualified adult educators working in extension capacities in both production oriented agriculture and along the agri-food value chain.

If knowledge development and diffusion/adoption is the engine room for innovation, then the sustained divestment trends and fragmentation of knowledge generation, implementation, and feedback pathways must have deleterious effects on the overall innovation system.

Search and identification of opportunities

The advantage of agencies that have increased industry steerage or even ownership in their construct is that they subsequently have higher levels of control in identifying where research and extension should be directed. This was one of the driving forces behind the initial creation of the RDCs, as well as one of the key tenants upon which Australian sugar research development and extension has be structured for over a century. It is also the premise on which DAAS and the UK-based AHDB models have been predicated. It inserts a reality-check in the RD&E process and removes the sole responsibility of RD&E away from research and extension agents; they instead need to share this space with true industry stakeholders. Increased industry ownership equates to a greater likelihood of relavent science and extension being pursued. However, this needs to be tempered with sufficient critical challenge and oversight; else the risk of introspective ideas and moribund industry attitudes could stymie the innovation system. With a retreat of government supported RD&E services an opportunity exists for industries to establish their own RD&E institutions beyond that of the funds brokerage roles of the RDCs and the research focus of the CRCs. Industries should aspire to possessing their own research and extension personnel to enable the AKIS model to function more effectively.

Entrepreneurial experimentation and management of risk and uncertainty

The identification and management of uncertainty and risk with new technologies or practices is a perennial issue for innovation systems. Arguably governments have traditionally been tied to a role in agricultural RD&E as there was perceived risks in the R&D process and its outcomes, or that there was market failure in delivery of RD&E services. Selecting the right ideas to pursue in terms of RD&E is the first step in reducing risk in ill targeted research, languishing development, or stalled adoption. Much research risk could be reduced if projects and programs were adequately coupled with effective development and extension efforts. The New Zealand CRIs, as well as that articulated by Leaver in the UK, are relevant cases that tell of how basic research has not necessarily translated into industry. The likes of DAAS, TIA, SRA and the MacKinnon project all have more cohesive and integrated structures that allow research findings to be developed and delivered into industries. Again the absence or fragmented channels between research and application appears to be the problem.

Industries should take the lead in their own interest; else they could be left bereft or moribund because of declining funding.

Market formation

Practicality and fitment of technologies in the market place is paramount for the efficiency of innovation systems. Extension has traditionally played an important role in refining and then facilitating the swift transfer of new innovations into the market place. The degradation of the Australian agricultural RD&E system is now being recognised by industries as affecting the "speed to market" of new practices, and the commercialisation of new technologies (Industry Skills Council, 2013). The Industry Skills Council argue that the productivity halo effect from industry and government investment in the Agrifood industry is not being realised as optimally as other nations – market formation is being compromised. They cite that Australia is ranked 107th out of a 141 countries in terms of innovation efficiency (Industry Skills Council, 2013). Our rural industries are not empowered to seize initiative which will lead to more innovation. New models that allow for freer flow of ideas and elimination of silos, and which facilitate better functioning of production and resources should be supported.

Resource access and mobilisation

Succession of the corporate memory of industry experience and skills and expertise in agricultural research, education and extension – has been recognised as an issue for the rural sector to address (Australian Senate, 2012; Industry Skills Council, 2013; Productivity Commission, 2011). The reduced involvement of government departments in agriculture has meant fewer employment opportunities for those graduates in the agricultural fields. This is translating into fewer graduates and creating a scarcity of suitably skilled professionals to work in parts of Australian agriculture. It is also causing a serious contraction of the higher education infrastructure and skills required to produce suitably qualified graduates for agriculture (AIA, 2012; Australian Senate, 2012; Hamilton and Hamilton, 2010; Pratley, 2012; Pratley and Copeland, 2008). Similar outcomes are being reported in the UK (Leaver, 2007, 2010). Therefore, if industries want to secure locally

developed expertise, then they probably need to consider increased "buy-in" in the creation of suitably trained agri-food professionals, possibly by entering into partnership arrangements with universities. The TIA model succeeds in producing a specific set of Agricultural Science graduates with skills and knowledge for operating in a cool-temperate environment. This model may be appropriate in other agro-ecological zones.

Legitimation

The advantage that the farmer-based or industry resourced agencies discussed in the case studies possess, is that they have a level of brand legitimacy that other public or private organisations cannot achieve. Their close contact with the sector in providing direct tangible assistance to producers increases the acceptance of their messages, and a willingness to support them. Milburn et al. (2010), argue that authoritative knowledge and skills, and quality service delivery are critical drivers for farmers to unquestionably and generously fund research and extension on an ongoing basis. By having in-field RD&E personnel, agencies can also better refine or modify practices as a consequence of being in close and unfettered communication with end-users. Where research and/or extension elements are separated or withdrawn, the AKIS system of connectivity and information flow that allows for innovation improvements and ultimately adoption will begin to falter.

Sugar Research Australia, Mackinnon, TIA, ADHB and DAAS are service institutions that possess grass-roots legitimacy, though they must continually perform, else client members will be inclined to change their support for funding them.

Development of positive externalities

Agricultural RD&E investment has delivered many ancillary benefits to individuals, industries, communities and nations that far exceed simply achieving changes in on-farm agricultural production or natural resource management practices. Alston et al. (2010) explain the wider trans-national spill-over benefits of agricultural RD&E investments, how what is learned in one centre of research is picked up by other countries and applied in their rural sector with commensurate rewards. They also explain how it has led to labour efficiencies in rural industries that have allowed nations to develop other sectors of their economy. At a micro-level Hunt et al. (2011) demonstrated other positive attributes to RD&E effort. In the Tasmanian sheep industries an industry-funded extension project not only built capacity in farmer and grazier on-farm skills and the adoption of new systems; but it also aided in the development of pyscho-social support services for rural communities, and played a catalytic role in drought policy innovation with State government. The authors go on to provide evidence from a range of Australian rural industry case studies of how similar programs have delivered a raft of public good benefits in social and natural capital development.

Developing a way forward for sustaining agricultural RD&E capacity in Australia does not necessitate reinventing the past. Returning to legacy public sector models will not have the support of State governments which are already under considerable fiscal challenge in a post-global financial crisis world. There are some important messages to be learned from the reforms of the 1980s and 1990s; the existing RDC and CRC models; and the case studies we presented. Consideration of what innovations might now be possible in a globalised agri-food environment should be at the forefront of the agricultural RD&E discourse as agriculture production, processing and science moves beyond the control of state and even national governments. This paper will not attempt to present a recipe or a single model of reform, but instead propose a series of recommendations worth considering in the development of a future system to address RD&E requirements in Australian agriculture.

Some recommendations for Australia and similar middle-sized market economies

Develop industry-owned RD&E institutions

With a retreating level of State and Territory Government investment, industry-owned RD&E institutions offer the best prospect for building and retaining long-term human capital in the agricultural research and extension sciences for industries. Moving beyond an RDC framework that simply brokers projects on a competitive basis, to agencies that possess research and extension staff and preserve RD&E capacity on behalf of their industries is critical. The new institutions would understand the importance of capacity building. They would not fund at the margins but contribute to the whole RD&E effort of the industry, i.e., investing in core activities that underpin industry success. Such institutions could ensure succession of knowledge and skills over time. This is vital for ongoing industry development. Institutions can also build and better sustain social capital between themselves and their client base by having staff that are in periodic contact with them. Where there are multiple agencies involved in particular industries' RD&E efforts, rationalisation into single corporate entities for the purposes of efficiency must occur. An example of a longstanding and successful model has been the Australian sugar industry's former Bureau of Sugar Experimental Stations, now known as Sugar Research Australia. Other industries should consider the utility of this model as it represents integrated self-contained RD&E capacity owned by an Australian agricultural industry.

Swann (2003) discusses the tensions associated with shifts in research and development investment from public, to industry (also referred to as 'clubs'), and private streams. The balance of public, club and private benefits with a change to industry-owned agencies will require adequate checks and balances, especially where public funds supplement RD&E efforts. We attempt to address these issues in points 9.12 and 9.14 by recommending appropriate representation and governance arrangements in the construct of these new institutions.

Further expand producer, processor and government co-investment in RD&E and agri-food industries

This will require negotiated statutory investment levies which may surpass the existing level of contributions under the current RDC scheme. If the Australian Government is attesting to the value of R&D investment (Australian Government, 2013), grower and processor funds should continue to be matched by the Commonwealth. An expanded role for extension must be embedded in these new agencies to ensure that new knowledge, systems and technological innovations proceed more efficiently. Processors of agricultural products have long benefited from advances of agricultural RD&E but in the case of many industries, they have contributed limited amounts to the investment and advancement of RD&E. This was argued strongly by several high-profile submissions to a national review of the RDCs in 2011, however, it did not receive the support of the Commissioners. Producer, processor and government co-investment arrangements have been demonstrated in the Australian sugar industry for many decades (BSES, 2010; Hunt et al., 2012b), and remains the central plank for its ongoing RD&E capacity. This position is defensible in industries where field-based factors have a significant impact on factory performance, and importantly factory throughput, which drives the processor's profitability – a clear case of mutual dependence that is often forgotten

by those in the processing sector. Having the funder and provider in the one organisation as argued in this proposal may be an issue, though such conflicts can be managed, but this must be achieved through a completely transparent model.

Avoid total deregulation of RD&E

Findings from a review of New Zealand's Crown Research Institutes indicate that a completely deregulated RD&E competitive framework should be avoided. Formed in 1992, CRIs were effectively given a charge to become financially viable and to operate on commercial lines (Alston et al., 1997). According to CRIT (2010), in a review of the CRIs, a past policy imperative of government for the CRIs to be economically sustainable has had some negative impacts upon the nature of the science generated and affected the net benefits to client industries. It stated that there were inconsistencies between creation of value for the organisation as opposed to the greater good for New Zealand. These commercial drivers also led to the pursuit of competitive contracts that were short-term, relative to the time frame in which science can be expected to produce results. This has had a detrimental impact of CRIs to operate strategically. Furthermore, the existing funding and governance arrangements for CRIs inhibited collaboration with universities and the private sector and effectively made them competitors in what should have been a collegiate function of government in enabling industrial advancement.

The CRIs have also had little in the way of extension capacity. New Zealand discharged its public sector involvement in extension in 1987 (Cary, 1998) and consequently R&D generated by the organisations relies on industry service providers or private consultants to undertake many active extension works. The function of extension, or as articulated in the review 'technology transfer', also came under scrutiny. This role was seen to have been undervalued by the agricultural CRIs and was highlighted as a core responsibility with an emphasis to develop, invest in and manage intellectual property or innovation with the intent of expediting its passage into outcomes for stakeholders (CRIT, 2010). On these observations a radically deregulated agricultural RD&E system is unlikely to deliver the outcomes Australia needs.

Integrate research and extension capacity within institutions

Extension services must not be considered as add-ons, they must be fully integrated into the process and delivery of research, and be active in providing feedback from industry stakeholders to research elements, as well as in identifying farmer innovation which can be tested through science. Extension agents should function as credible technical experts in their specific roles, and be present in the field. An absence from the field results in a decline in support for extension services (Milburn et al., 2010). Appropriate planning, provisioning, and skilling of extension in adult education skills and process should be used to complement and not be a substitute for technical competency. The failures discussed by Leaver in Britain and the CRIT review in New Zealand flag that a separation of research and extension capacities is detrimental and should be avoided.

Reduce bureaucracy

Any new institutional arrangements must eliminate excessive management hierarchies common to the former public sector 'Departmental' models. Less complex management structures allow for more flexibility, increased responsiveness to resolve issues, and reduced cost structures.

Create a new focus for State Government Departments of Agriculture

Should industries and Commonwealth take full responsibility for mainstream agricultural industry RD&E, State and Territory Government Departments of Agriculture will be able to be realigned as development support agencies for new and emerging agricultural industries. Presently many State Governments are focussed on working with the larger established industries as they can more easily obtain matched commonwealth funds through which the States and Territories can then supplement their Departments. The larger and established industries should be encouraged towards greater independence. Subsequent to these changes State and Territory Government RD&E entities could focus on longer term strategies for increased industry diversity and greater value-adding to enhance gross state agricultural product. Because of collective public benefit outcomes, State and Territory governments must maintain ongoing commitments to biosecurity, product integrity and policy functions.

Embed a consumer focus within RD&E effort

RD&E effort should be considered in reference to its contribution not just to the producer, but how the investment translates to benefiting consumers. RD&E institutions will require systems that ensure organisational awareness of the needs and wants of consumers so as to facilitate better targeting of RD&E efforts. This will reduce the risk of diversions along interest lines of professionals within agencies, or with industry stakeholders involved in decision making that might have separate and even selfish agendas. It is essential that a balance be maintained in effort dedicated to the various resource management, production, and value-adding streams along the value chain, else there will be a risk to industry capacity to resolve different bio-physical or market orientated eventualities.

Positive externalities outcomes must be considered

Planners and implementers of RD&E efforts must consider issues in the context of economic, environmental and social responsibilities and outcomes. Rural industries operate within communities, and their impacts and benefits cannot be evaluated in isolation of these component parts. This is where the public investment component can be further justified in terms of collective public good benefits.

Ensure that rural industries partner more closely with universities

The possibilities of universities partnering with industries, and functioning as learning and service hubs for agriculture should be further explored. This concept could be focussed around universities strategically positioned to service rural industries in formalised service partnerships. This could translate into situations where industries invest in university faculties in order to guarantee both RD&E services, as well as ongoing skilled technical professionals.

Ensure strategic use of private sector actors

There will be ongoing utilisation of private sector capacity where industry-owned institutions require additional expertise or geographic positioning of RD&E capacity. Private sector actors will continue to act as instruments of institutions to undertake certain research or extension functions particularly in areas where an institution's service delivery is absent.

Further develop international collaborative arrangements

Further international and agency agreements between sister industries in other nations, and increased sharing of personnel and interchange of skills and innovations will further enable potential maximisation of productivity gains.

Maintain professional diversity in governance of institutions

An increased commitment to ensuring a level of professional diversity in the governance and management of industry-owned RD&E institutions is critical to avoid conflicts of interest, and any potential aversion to innovation amongst industry decision makers. The Productivity Commission (2011) encouraged the movement of industry RDCs towards skills-based as opposed to representative selection of board members.

Focus on industry and national outcomes

Strengthening of performance monitoring and enforcement, both at the micro-level with specific projects conducted by the institutions, as well as at the macro-level over individual organisations, is essential to ensure sustained confidence in the institutions by contributors of funds.

Ensure proper oversight over the use of public funds

A reformed RD&E system requires system oversight by an independent umpire (e.g., an ombudsman or commissioner). This is to oversee the collective institutions framework and ensure probity with the use of public funds. This will provide additional rigour to the Australian agricultural RD&E system. Prior to when many RDCs became corporatised, Government Directors were appointed to RDC boards, and a Parliamentary Secretary oversaw the different bodies and acted as a conduit between the RDCs and the Minister of Agriculture. This structural arrangement has since been abandoned by most corporatised RDCs, and has been blamed for the emergence of some contentious governance issues within them (Productivity Commission, 2011).

Local action in a global context

Agriculture now functions in a global context. Skogstad (2008) highlights the sometimes negative impacts that globalisation can have on a nation's agricultural interests in terms of market power and processing. The proposal to raise and invest in national industry-owned RD&E institutions offers an assurance that future innovations in Australian agriculture are not gradually accumulated and centralised in an oligopoly of globalised agribusiness and food corporations. Externally-based stakeholders will not necessarily always have the Australian national good as their first priority. Should there be gradual centralisation of Australian agricultural science innovation in the hands of trans-national corporate agribusiness, situations could emerge where, either inadvertently or deliberately, Australian trade or national food security interests could be compromised. The approach to establish industry-owned RD&E institutions with government co-investment provides an anchor for ongoing development and innovation to remain in the hands of Australian industry. It is a paradigm of capacity and resilience building as opposed to cost shifting.

Conclusion

To suggest that the Australian agricultural research, development and extension system has failed would be incorrect. The development of a policy model that saw the implementation of the Rural Development Corporations and Cooperative Research Centres was a major step-change for the agricultural sector, and did ensure the maintenance of capacity when many other developed nations were abandoning different aspects of their agricultural RD&E. Australia took a different policy pathway, which has been largely successful. The model achieved a milestone in persuading rural industries to contribute financially to their own RD&E needs. While not on a full cost basis, it did achieve that important goal of getting industries to 'buy in'. However, the initiation of RD&E levies and matching Australian government funds sent signals to State and Territory Governments that they could divest and redirect funds to other sectors. The authors' premise is that the RDC/CRC model has only been as effective as it has because of the legacy RD&E capacity remaining in Departments of the different jurisdictions, which have effectively supplemented the efforts of the RDCs. The effects of State and Territory Government public policy decisions to reduce or discontinue services because of fiscal or ideological drivers is now resulting in a situation where expert RD&E capacity available to agricultural industries in Australia is under threat. The AKIS system is not functioning as effectively as it could as it has a number of points where capacity has been fragmented. This will impact upon the future resilience of rural industries. It will also exacerbate the ongoing decline of enrolments and graduations of professionals into the agricultural RD&E fields via tertiary institutions.

The case exists for discussing alternative structures for organising and delivering agricultural RD&E, and new systems to fund investment to prevent existing Australian export industries from becoming uncompetitive against other nations who are investing more heavily in the agricultural sciences. Australia is not developing significant tracts of new arable lands for food production; in fact numerous valuable agricultural zones have already been subsumed by urban expansion. Therefore, increases in productivity must be made using the existing land and water resources. This requires increasing investment in agricultural RD&E.

This paper proposes not an overthrow of Australia's current market-orientated agricultural paradigm, but a restructure of the RD&E system to deliver further autonomy and responsibility to the rural sector in terms of the steerage, resourcing and carriage of services. However, there remains a role for federal government oversight given the importance of the sector to the national economy, the environment, and other nations that rely on Australian food production. This paper emphasises that industries must further take up the mantle to ensure their own longer-term capacity and resilience. It is time for the Australian Government and rural industry stakeholders to revise and reform how RD&E is organised, resourced and delivered.

The current RD&E model is not likely to be supplanted until there is sufficient stimulus to drive that change. The Australian Government is indicating at least empathy to bolster public sector investment into the RDCs model, because it now recognises the multiple advantages to Australia in regard to economic and social and environmental outcomes.

As a final reflection, Hunt et al. (2012a) argue that agriculture is a subset of society, and the business of agriculture is subject to the moods and trends within it, and that crisis is the primary instigator for change. Crisis will drive the overturning of existing institutional life and structures, and the subsequent rebuilding of new systems in response to a perceived threat or threats, which may be either internal or external in origin. Essentially, the current complex of the RDC/CRC and State and Territory Government services will need to fail, or at the very least, been seen to be insufficient to respond to a future crisis before change will occur. Increasing fiscal pressures both at the state and at the federal levels may hasten the passage to a tipping point. So too may the pressures of global

population growth and demand, increases in food scarcity, price hikes, impacts from climate change, and other unforeseen drivers act as stimulus for policy change.

This paper delves into the successes and failures of the Australian agricultural RD&E system over several decades. It offers a discourse around the state of the agricultural RD&E system in Australia, its trajectory, and what might be the future features that leaders and policy makers in industry and government might deliberate over. Finally, it also provides to the international reader an insight into agricultural RD&E organisational models beyond that of many traditionally-recognised systems, and will hopefully encourage public policy makers, industry representatives, researchers, and extension people in the business of agriculture to seriously contemplate how they meet the future capacity and resilience needs of their agricultural industries.

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