Committee, Economics & Industry Standing

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To the Committee

I am scheduled to appear before the Committee on Wed Feb 17 at 9.30am. An additional submission that the Committee may want to consider is attached. It is a version of an invited paper I gave last week at the Australian Agricultural & Resource Economics Society's annual conference in Canberra.
Please note that this submission is not a submission from the Australian Export Grains Innovation Centre or the WA Department of Agriculture & Food or the University of WA. It is a submission provided in my capacity as an ex-president of the Australian Agricultural & Resource Economics Society.

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AEGIC is an initiative of the Western Australian State Government
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Widgets matter: So do people and policies

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Abstract

The profitability and productivity of Australian agriculture has been well-served by agricultural innovation that includes a wealth of useful technologies generated by local and overseas R,D&E. However, Australia's ability to maintain the flow of its R,D&E services that underpin the creation of useful technologies is being eroded. Structural change in the Australian economy has greatly reduced the relative economic and political significance of the agricultural sector. Greater economic expansion in other parts of the economy, fewer farms, labour-saving technologies, budget restrictions facing federal and state governments, and incentive systems in tertiary education and agribusiness firms; all in combination now limit employment and career prospects for many engaged in agricultural innovation. An outcome is the potential restriction of local innovation and an eventual lessening of the productivity of Australian agriculture.

To lessen the erosion and corrosion of the labour force of Australia's agricultural innovation system, and improve the effectiveness of that labour force and other components of the innovation system, change is needed. Policy and organisational changes can improve the efficiency and effectiveness of Australia's agricultural innovation system. The federal government recently has announced some helpful policy and organisational changes, but even greater change is required; especially regarding tertiary sector and business incentive structures.

Other useful organisational change involves altering agricultural R&D organisational structures and introducing or incentivising more public-private partnerships. Failure to develop and implement these sorts of useful changes will weaken the international competitiveness of Australian agriculture and disserve local consumers and agricultural producers by restricting agricultural innovation.

Introduction

Agricultural innovation is a process of invention often driven by research, but is also a process of making novel use of old ideas as well as new ones with the specific goal of adding social, economic and/or environmental value (Hall, 2012). As a process, innovation can be purely technical — making a new or better widget. But as a process, innovation involves human actors responding to a variety of market and social signals; and so in this process people and policies matter.

Agricultural Innovation in Australia: current situation

It is obvious that currently innovation, both in the agriculture sector and the wider economy, are political flavours of the month in Australia. In August 2015 the Minister for Agriculture, the Hon Barnaby Joyce MP, asked the Standing Committee on Agriculture and Industry to inquire into and report on agricultural innovation. Earlier in March 2014, the Senate of the Australian parliament asked its Economics References Committee to enquire into Australia's innovation system. The committee received 185 submissions and released its report in December 2015. In Appendix two of that report is a list of 60 Commonwealth Government ministerial policy statements, government commissioned reports, reviews, and information papers that over the last 15 years (2000 to 2014) have examined innovation system issues in Australia.

In September 2015 the Hon Christopher Pyne MP was sworn in as Minister for Industry, Innovation and Science. In early December 2015 he and the Prime Minister jointly announced a National Innovation and Science Agenda which included some funding and policy initiatives relevant to agricultural innovation. Then also in early December 2015 the Australian parliament's Trade and Investment Growth Committee initiated a further inquiry into Australia's research and innovation sector. The committee announced it would investigate how the research and innovation sector might help overcome Australia's geographic, economic, and labour challenges. It would focus on commercialisation opportunities, including how technology imports and exports could be further facilitated.

Yet before these Australian reviews were initiated much was already known about agricultural innovation, and innovation more generally (e.g. Pardey and Beintema, 2001; World Bank, 2006; Juma, 2010; Alston, 2010; OECD 2012; Hurley et al, 2014). Innovation, for example, often relies on R&D that creates disruptive, breakthrough and mostly incremental technical change. These technologies are the 'widgets' of modern-day farming and they underpin its productivity improvement and commercial success.

Widgets Matter

In the innovation process investment in R,D&E is a key pre-cursor for the creation and use of technologies ('widgets') that help drive agricultural productivity. In Australia, Grafton et al (2015) estimate that productivity growth since 1953 accounts for about half the value of agricultural production in 2013. Also, Sheng et al (2011) examine the average effect of R,D&E knowledge stocks on the total factor productivity (TFP) of Australia's broadacre sector between 1952–53 and 2006–07 and find that public investment in R,D&E had a significant and positive effect on the sector's productivity. R&D and extension generated average rates of return as high as 28 per cent and 47 per cent a year, respectively, in Australia's broadacre sector. Sheng et al (2011) also find that the relative contributions of foreign and domestic research (including domestic extension) to broadacre TFP growth were roughly equal (0.63% per annum and 0.60% per annum, respectively) and accounted for the bulk (1.23% per annum) of average annual broadacre TFP growth of 1.96% per annum over the period. Their analysis also indicates that public R&D research strategies that invested over the long-term resulted in higher returns than research strategies that invested with a sole short-term focus.

One implication of their findings is that spill-ins from foreign research should be facilitated, as they have delivered around one-third of the TFP growth observed in Australia's broadacre sector over the past 50 years. Indeed, it could be argued that in an increasingly globalized technology-driven agriculture, many future technologies and products are more likely to be first developed outside of Australia, with the

resultant innovation challenge in Australia being how to cost-effectively identify and access potentially applicable innovations and then rapidly assess and tailor those innovations to the Australian agricultural context. Their findings also imply that concentrating mostly on short-term highly applied R,D&E is probably not the best strategy for increasing returns from R&D investment.

The spill-in technologies and local research products that underpin the productivity gains identified by Sheng et al (2010&2011) are many and varied. Table 1 lists examples of those products (or 'widgets') that apply to some key industries in Australia's broadacre sector. Many of the innovations listed in Table 1 are technologies that are products of R&D undertaken locally and overseas.

When formal assessments of R&D investments in such agricultural technologies and products are conducted, often the findings are that the returns from such investments are highly variable, but mostly are strongly positive (Mullen and Cox, 1995; Brennan and Davis, 1996; CRRDC, 2010). This strong evidence of the profitability of investment in agricultural R&D, whether funded from private or public sources, however, has not prevented an erosion of those investments. For example, the Productivity Commission (2007) responded to findings about the overall relative profitability of investments in agricultural R&D in Australia by saying that this evidence, including sizeable returns to public investment in science and innovation, was by their assessment insufficient evidence to use in developing government science and innovation policy, due to the inherent unreliability of some of the methods of R&D assessment. Yet later in 2011, when the Productivity Commission (2011) reported on rural research and development corporations, the commission recommended reductions in public support for agricultural R&D. They argued that there was ample evidence of sufficient financial returns to justify producers or industries fully funding much of this research themselves. So in spite of the statements in their 2007 report about the unreliability of assessments of returns to R&D investment, the commission was saying in 2011 that those same assessments were now sufficiently reliable to justify a reduction in the overall level of public support for industry-focused research and an increase in industry contributions.

In spite of the flaws or inconsistencies in arguments forwarded by the commission, nonetheless when a prestigious review body like the Productivity Commission makes recommendations to governments for less public support for agricultural R&D, then budget-constrained governments are willing listeners. The recommendations of the commission, for example, were repeated verbatim by the National Commission of Audit (2014) with the audit review additionally recommending the abolition of sector-specific R&D programmes and arguing for greater government oversight of R&D activity of the CSIRO. The audit also recommended the abolition of Co-Operative Research Centres (CRCs) whilst curiously simultaneously extolling the virtues of industry clusters to achieve innovation outcomes. It is interesting to note that the current federal government has ignored the audit's recommendation to abolish CRCs, but has reformed their investment focus.

In Western Australia (WA), although the arguments of the commission and the audit review have not been offered as the principal rationale for budget cuts to agricultural agencies, nonetheless they implicitly form part of the supportive backdrop for expenditure cuts. The WA state government has forecast no budget surpluses until 2018-19, and WA state government debt is projected to peak at $39 billion in 2019. Hence, cost-savings have been forced on many state agencies, including agriculture. The Department of Agriculture and Food, the State's main employer of agricultural graduates and researchers, has shed 500 staff over less than a decade. Rob Delane, the Director-General of that department, announced in June 2015 that due to budgetary restrictions staff numbers would be further reduced from 950 in 2015 to only 700 in 2017.

Reductions in funding in many state and federal agricultural agencies translate into staff reductions and a lesser capacity to undertake R,D&E or commit to shared investments in R,D&E.

Table 1. Examples of technology innovations that have boosted the productivity of Australia's broadacre sector

Cross-industry	Electronic communication (faxes, mobile phones, radio, TV, computers, tablets, internet, electronic banking, decision aids, record-keeping)
	Safer, more reliable, more fuel-efficient vehicles
	Portable, cheaper power tools
	Remote power generation, remote-sensing technologies (cameras, automatic weather stations, satellite imagery)
	Soil mapping, soil monitoring and tissue testing
Grains	High work rate machinery (tractors, air-seeders, self-propelled sprayers, harvesters, chaser bins)
	Higher-yielding crop varieties (wheat, barley, canola, pulses, GM varieties)
	Pre and post-emergence herbicides
	Broad and narrow spectrum herbicides
	GPS guidance systems, variable rate technology
	Harvest weed seed control (Bale Direct System, Harrington Seed Destructor, windrow burning)
	Chemical fertilisers and soil ameliorates
	Bulk handling equipment, sealed storage and silo bags
	Deep-ripping of traffic hardpans
	B-doubles for grain transport
Animals	Objective measurement for breeding, artificial insemination, more breeds better suited to Australian conditions
	Livestock health products
	Improved shed design for dairying and shearing, improved animal handling equipment, self-feeders
	Improved and new pasture species
	Chemical fertilisers and soil ameliorates for pasture and feed grain production
	B-doubles and triples for stock transport
	Electronic ear tags, electronic weighing, condition scoring

State and federal agricultural agencies historically have been the main employers of agricultural scientists. When these departments are required to shed significant numbers of their staff, or cannot offer new employment opportunities or commit to public/private partnerships, then adverse flow-on effects to agricultural graduate and research-training institutions are inevitable. These reduced and uncertain employment prospects for many agricultural graduates and researchers affect the human capacity to undertake R,D&E in Australia. In this current environment, securing the local creation of future agricultural technologies (widgets) would seem to be more problematic, as the R,D&E staff likely to be engaged in their creation and application face uncertain and currently limited employment prospects.

People Matter

Although parlous budgetary conditions are the current principal rationale for reduced employment prospects for many agricultural scientists who normally would be employed in state and federal agencies to develop or adapt agricultural innovations, there are also structural changes underway that affect those employment prospects.

Agriculture in Australia, but also in most developed nations, is a sector, particularly in extensive industries, that continues to be characterised by technologies and business strategies that are labour-saving. Given the land constraints applying in most developed nations, applying these technologies and business strategies leads to fewer, larger farms which remain mostly owned and operated by farm families. Furthermore, the greater ease of electronic communication, when combined with the ease and capability of the electronic storage and retrieval of information, means that the farm sector can be serviced with fewer highly skilled extension and research specialists than otherwise might have occurred in previous decades.

In such an environment there is no burgeoning population of farmers, nor a strongly growing population of farm advisory and farm management workers, nor are there sustained high growth employment prospects in support industries. Ultimately, the limited employment prospects are reflected in the relatively small proportion of the student population who select agricultural science as a first career choice. When local student numbers are limited, maintaining a diverse and large group of agricultural academics deeply familiar with most aspects of local agriculture becomes no longer financially viable or justified. These trends have occurred on many campuses over the last three decades. By illustration, Professor David Pannell in replying to a blog post on tertiary agricultural education by Mick Keogh, executive director of the Australian Farm Institute, noted:

> *The demand at UWA [University of Western Australia] has fallen by about a factor of 10 since I started my agricultural science degree in 1980. I agree that the lack of students in agricultural science and agricultural economics should be a really serious concern to the industry. Given the intense financial pressures on universities, they aren't going to start subsidizing loss-making courses any time soon.*"

In his book *Conditions of Economic Progress*, Clark (1957) discusses the causes and implications of increased labour productivity in agriculture. He recounts how in the USA between 1849 and 1950 the proportion of the labour force working in agriculture decreased from 65% to 12%. In Australia in 1970 the agricultural sector accounted for 8% of the nation's employment; by 2013 the proportion had fallen to 2%. In 1970 agricultural exports were 41% of the nation's exports, yet by 2012 that share had fallen to 12%. The agricultural sector now forms only around 2% of Australia's gross value of production. In relative terms, but also in absolute terms in some situations, the employment opportunities for agricultural scientists have diminished.

The structural changes arising from labour productivity and economies of size, and worsened by current budgetary pressures on governments, impact on the nature and quantity of human services required by or being available to the agricultural sector. Inevitably local student numbers in agricultural science are affected which in turn lessens the demand for agricultural academics. Ensuring funding to support these

academics and their agricultural research colleagues is problematic. Special pleading, through relying on political persuasion, is not likely to be successful. On-going structural change in agricultural communities and agricultural industries is only further eroding their once powerful political and economic voice. Furthermore, as pointed out by Kingwell (2011), increasingly many farmers are time-poor. These farmers are sufficiently busy trying to ensure the profitability of their farm businesses, without also dealing with the issue of ensuring healthy employment prospects for those involved in the R,D&E and agricultural education sectors that support agricultural innovation.

Data provided by the Australian Council of Deans of Agriculture reveal that over the period 2001 to 2012 undergraduate annual enrolments in agriculture and related disciplines in Australian universities have declined by 2,500. That is, there are 2,500 fewer undergraduate students in agriculture and related disciplines in Australian universities, now compared to a decade ago. This decline in undergraduate student numbers potentially translates into a decline in university funding for agricultural schools or departments and a rationale for shedding some of their staff, unless there is offsetting income from other sources such as post-graduate numbers or competitive research funds.

As with state and federal agricultural agencies, many Australian universities are also under funding duress that force those universities to seek income and reduce costs, where possible. So university managers switch resources into low-cost courses that attract large student numbers (i.e. not agriculture), and focus on attracting full-fee paying overseas students. Since 1990 total student numbers in the higher education systems have grown by 183% from 485,000 to 1,373,000 in 2014. Fee-paying overseas student numbers have increased from 10,944 in 1990 to 294,000 in 2014. International university rankings, largely based on publication eminence, play an important role in attracting these students. Hence many universities appoint or reward staff who will lift the university's international ranking and thereby attract more fee-paying overseas students. These staff are those able to regularly publish in high-impact overseas journals.

When academics, including agricultural academics, focus on publishing papers in international journals and are encouraged in more theoretical endeavours, the risk arises that their research and teaching can become disconnected from local farming and agribusiness issues. The end result is a looser or distant connection between some academics and practical agriculture and a greater likelihood that fewer staff will become well-known within the agricultural sector. The counter-vailing view, however, is that by retaining an international scientific presence and prestige, Australian scientists are more likely to be internationally connected and thereby potentially privy to emerging scientific innovations that, if relayed back to relevant Australian R&D organisations, could eventually be beneficially applied to an Australian context.

The loose connection between academic endeavour and practical farming and agribusiness is also unfortunately encouraged by some Australian universities' policies relating to 'outside work'. The SERC (2015) report states that in some universities, consultancy work by their staff is encouraged, whilst in some others it is banned. By contrast, academics in the USA are encouraged to work in their consultancy businesses, and thereby often develop and retain strong connections to industry. The same cannot be widely said for agriculture in Australia and its university academics, and this has implications for the nature and pace of future agricultural innovation in Australia. It encourages many agricultural academics to concentrate on publishing in high impact overseas journals rather than creating beneficial impacts for local agricultural industries.

This issue has been frequently canvassed by a range of academics and industry leaders in recent years. For example, in an opinion piece, Australian Nobel laureate Professor Brian Schmidt (2014) commented:

> *At the moment a culture of innovation is absent in large parts of the academic research sector of Australia. There is little contact with industry, role models for moving ideas out of the academic environment are rare, and therefore few industry players are interested in partnering with universities. Nor are academics rewarded*

> *for moving between industry and academia. Indeed the system strongly discourages such mobility through tenure, hard-to-transfer superannuation, and research quality measures.*

Corroborating the views of Professor Schmidt are findings from the Senate Economics References Committee's report on Australia's innovation system (SERC, 2015) and the National Innovation and Science Agenda announced by the Prime Minister in December 2015 (Commonwealth of Australia, 2015). These reports both indicate that Australia's rate of collaboration between education institutions and innovation-active businesses is the lowest in the OECD.

As pointed out by others, such as Keogh (2014), this lack of connectedness to industry endangers Australian agriculture. Unlike the USA where academics employed in the land grant universities have a requirement to be engaged with industry, academics employed in Australian university agricultural faculties are prone to being isolated from the sector, driven by incentives that place little value on industry engagement, other than that required to win industry research grants. Australian university promotional systems reward publications, and largely ignore the economic, social or environmental impact of that research.

The ranking measures quoted by universities to show their international merit (e.g., Times Higher Education World University Ranking) often heavily draw on research publications and citations. Interaction with and impact on industry rarely feature in these metrics and so there is an inbuilt disincentive for university staff to seek engagement with industry, unless it leads to publishable research in high-impact journals. University administrators keen to lift the international rankings of their universities are more likely to employ and reward those academics whose publishable outputs help lift the university's ranking. With such incentives the consequence for many Australian agricultural faculties is a strong tendency to be less directly engaged with farmers and the agriculture sector, which then causes many farmers to not be inclined to champion the cause of university research when it comes to funding debates. It also results in aspiring university researchers being less focused on applied research, and so the isolation from agricultural industries becomes self-fulfilling and easy to perpetuate.

Ag Forum blog comments of Professor Snow Barlow (University of Melbourne) are worth noting, as they highlight the particular difficulties faced by agricultural scientists working in Australia's leading universities. He writes:

> *The national excellence in research ranking system, the ERA, concentrates heavily on publication in high impact international journals preferably with international partners and collaborators. High performance under these metrics is not compatible with more applied field based research published in regional journals. These ERA based policy settings are currently being played out strongly in the research intensive Go8 Universities where Agricultural and Food Faculties are being incorporated into larger Faculties of Science. These discipline based faculties are correctly focused on ERA excellence through publishing in high impact international journals. Agricultural researchers despite being very productive in these combined faculties must conform if they wish to succeed*. (See Barlow (2014)).

In a similar vein are Ag Forum blog comments by Professor David Pannell (University of Western Australia) who responded to comments by Mick Keogh (2014) by saying:

> *There certainly are people doing good applied agricultural research in universities, but there could be more, and you are right that there are incentives in place that tend to encourage researchers to lean towards more theoretical research, rather than applied research. The move, in recent years, towards encouraging and rewarding research "quality" in universities has been particularly counter-productive in this regard, as*

applied research tends to be judged as lower quality by the people who get to make these judgments.

Even where an agricultural academic wants to stay connected to agriculture by engaging in publishable blue sky research with a possible relevance for agriculture, gaining funding support is difficult. For example, the Australian Research Council (ARC), a main funder of blue-sky R&D, inadequately supports agricultural blue-sky R&D in universities, further limiting university staff's role in the agricultural innovation process. The share of ARC funds being allocated to agricultural and veterinary sciences projects (see Figure 1) has been declining. In 2015 those successful applications made up about 2 per cent of the value of all successfully-funded applications; and the current success rate of applications in agricultural and veterinary sciences projects is under 10 per cent. In fact, as shown in Figure 2, the current situation is particularly dire for agricultural applications to the ARC, with successful agricultural projects being a declining share of ARC funding since the late 2000s. Over the years 2011 to 2014 successful agricultural projects formed on average less than 0.9 per cent of the funds allocated by the ARC.

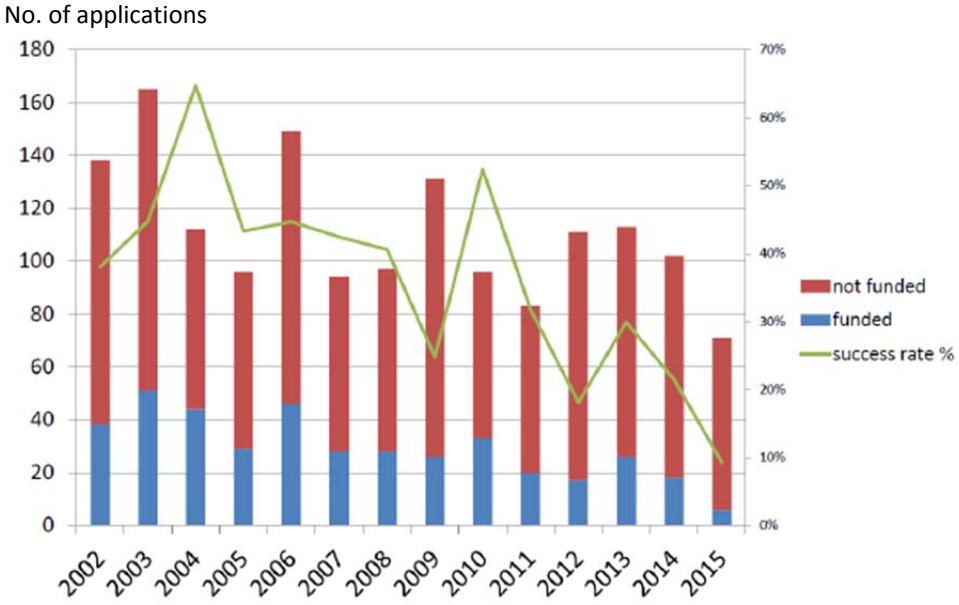

Figure 1. ARC funding of agricultural and veterinary science proposals 2002 to 2015
Source: ARC and the Australian Council of Agricultural Deans

It appears that often applications with an agricultural flavour are viewed as either conceptually inferior or there is a view that such research should be the realm of industry rather than ARC funding. Failure to receive ARC funding weakens the resolve of researchers to submit further proposals, so the share of applications in the field of agriculture diminishes. The diminishing share of ARC funds devoted to agricultural basic research is not offset by funding from rural R&D corporations. Those corporations primarily have a highly applied focus to their research fund allocations and so it follows that Australia may now be under-investing in blue sky agricultural research. Yet such research is often a foundation for agricultural innovation.

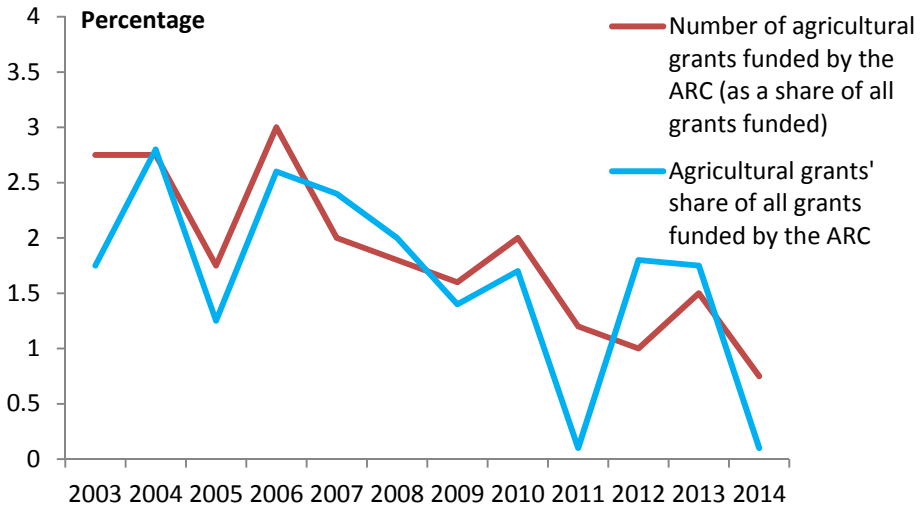

Figure 2. ARC funding of agricultural proposals 2003 to 2014
Source: ARC and the Australian Council of Agricultural Deans

Employment prospects in agricultural innovation are not only affected by public policy regarding the tertiary sector. Private sector investment in agricultural R,D&E also affects employment prospects. Studies of agricultural investment in Australia (Productivity Commission, 2011) point to very low levels of business investment in R&D in Australia; although as pointed out by Keogh (2014b), business investment in agricultural R&D is in fact much higher than the often-quoted commission estimates. Nevertheless, as pointed out in Senate Economics References Committee's report on Australia's innovation future (SERC, 2015) businesses in Australia are not hugely incentivised to invest in R&D and the innovation process. Obtaining finance to support such endeavours is difficult. Often Australian businesses find it easier to use the venture capital market in the USA.

Moreover, the policy and regulatory environment in which such Australian businesses operate is subject to unanticipated change which then forms part of the (dis)incentive structure of the business. The SERC (2015) report notes: *The high turnover of measures creates uncertainty in business, which in turn, impacts on investment decision options and reinforces investment short-termism* (p.15). Also as outlined in the Prime Minister's *National Innovation and Science Agenda*, announced in December 2015 (Commonwealth of Australia, 2015), Australian businesses face a number of additional disincentives due to certain fiduciary and business laws in Australia that are not mirrored in countries like the USA.

The Senate Economics References Committee's report on Australia's innovation system (SERC, 2015) and the National Innovation and Science Agenda announced by the Prime Minister in December 2015 (Commonwealth of Australia, 2015) also indicate that in Australia there is limited support for growing new businesses beyond their start-up stage. In addition, there is a potentially serious future shortfall of staff skilled in the disciplines of science, technology, engineering and mathematics areas.

So, what to do?

Policies Matter

One obvious reaction is to first recognise that innovation and the resultant creation of economic, social and environmental wealth stems from more than the simple provision of new 'widgets'. As stated at the beginning of this paper, the innovation process can be purely technical — making a new or better widget. But innovation can also involve creation of organisations or policies that provide incentives, synergies and complementarities that ensure economic, social and environmental improvements are generated. The

comments of King (2012) at this point are worth noting as they outline a role for economists in helping provide useful policy and organisation innovation for the agricultural sector:

> *Economists also design economic artifacts (e.g., markets, contracts, organizational structures, public policies) that reshape economic systems in order to better meet human needs. This work, which I will call economic design, is complementary with but differs fundamentally from economic analysis. While economic analysis is motivated by a question or a puzzle and focuses on explaining what is and predicting what will be, economic design is motivated by a problem or opportunity and focuses on what can be and ought to be or on what will yield a satisfactory outcome.* (p. 276)

This work by economists and others, helping design policies and organisational structures, that in this case promote greater economic, social and environmental wealth in Australian agriculture is a needed and laudable endeavour. However, as King (2012) outlines, often the initial economic design initiatives created or recommended are rarely strictly optimal solutions to their motivating problem, and require improvement or update after their initial implementation.

Given some of the current impediments to agricultural innovation already identified, clearly one area of needed policy change is the incentive structures commonly in place in Australia's tertiary sector. Already the Prime Minister has signalled as part of the National Innovation and Science Agenda that *We will change funding incentives so that more university funding is allocated to research that is done in partnership with industry.* More specifically the Agenda stipulates that in order to force greater interaction and collaboration between the university and business sectors the government will:

- *introduce new arrangements to encourage collaboration between researchers and industry by streamlining and refocussing a greater proportion of research block grant funding toward collaboration. We will also provide an additional $127 million over the forward estimates to research block grant funding.*
- *introduce, for the first time, clear and transparent measures of non-academic impact and industry engagement when assessing university research performance. This will be piloted through the Australian Research Council in 2017 and fully implemented by 2018.*
- *connect more small and medium businesses with researchers by expanding and relaunching the successful Research Connections programme as Innovation Connections, opening up Australian Research Council Linkage Projects to continuous applications to fast track decisions on collaborative research grants, and opening a new application round for the Cooperative Research Centre programme in February 2016.*

The long-standing Cooperative Research Centres programme has been reformed to enhance its focus on industry and growth sectors; and this has relevance for agricultural industries and regions whose economic development prospects could be triggered by relevant innovation.

Additional organisational reform may be needed in the tertiary sector. My personal view is that the agricultural sector in Western Australia, for example, has not been well-served by the piece-meal, often institution-specific, alterations in agricultural education and research. The supposedly collegiate Agricultural Research (WA) model of better integrating agricultural R&D in Western Australia in the 2000s, failed badly. Institutional and personal rivalries and lack of incentives for collaboration appear to have scuttled its viability.

Given current budgetary pressures on government finances, the future for agricultural education, research and research training is unlikely to be underpinned by increased support from the public purse. Hence, the future funding of agricultural education, research and research training that will deliver local innovation is more likely to comprise public-private partnerships. Some large private corporations or industry groups are

likely to be increasingly persuaded by self-interest that there is some merit in contributing to such public-private partnerships.

One plausible option is to establish a small network of Agricultural Foundations that via public-private funding provide a critical mass of researchers, students and research and entrepreneur trainers to stimulate the creation of innovations relevant for key agricultural industries. In the absence of such a small network (or some similar more workable equivalent) it is likely that institutional rivalries and uncoordinated rationalisations within the tertiary sector will more rapidly erode the local focus of agricultural science education, agricultural research and agricultural research training capability in Australia.

Another option is to more clearly segment R,D&E funding into basic, applied and commercialisation activity. Having separate funds and perhaps separate structures for these activities, with appropriate linkages across jurisdictions, may provide greater focus for these tasks. Different skills, work cultures and incentives apply to these different activities, so tailoring funds, people and institutions with their particular cultural histories to these separate, yet related tasks, may be a better use of public and private funds.

Implementing such change, and thereby affecting organisations such as universities and CSIRO, with their rich traditions and particular work cultures, is likely to be difficult. Hall (2012) points out that often huge institutional inertia holds back partnerships and network development, even where market incentives would be expected to stimulate collaboration. An international comparison of governance of universities (OECD, 2003), for example, showed that Australian universities were among the top-ranked universities regarding their degree of autonomy. More than half of university research in Australia is funded from internal sources, including student fees, financial and property investments, philanthropy, business income and a range of fees and charges (SERC, 2015). In many other countries, governments have much greater influence over their activity. Hence, instituting change in the Australian tertiary sector will be a cultural, financial and political challenge. The ability of Australian universities to strongly commit to their perceived self-interest rather than the national interest of the agricultural sector should not be understated.

Another aspect of possible desirable policy change within the tertiary sector concerns research training. An editorial in *Nature* in December 2015 (Nature, 2015) draws on a National Science Foundation (NSF) survey of doctorate recipients in the USA. The chances of academic employment were slim. Most doctorate holders in the NSF survey were working outside academia across a variety of sectors, including industry, federal government and non-profit organizations. Yet many young researchers felt their graduate training did not adequately prepare them for these different careers, nor did they feel adequately informed of their future prospects or the realities of their training. These findings are likely to be similarly applicable to Australia, perhaps even more so. Hence, as an action of economic design, it is worth examining what changes in post-graduate training, career advice and reporting of employment statistics are needed to facilitate innovation, particularly local agricultural innovation, in Australia. In effect, the review question is: Are current Australian agricultural PhD programs truly fit-for-purpose, considering the likely employment opportunities and needs in coming years facing local and overseas students?

Another issue for organisational reform concerns Australia's rural R&D corporations. Although these organisations are a commendable example of organisational and policy innovation that has well-served Australian agriculture (Gray, 2012) nonetheless refinements to their operations may be needed to facilitate innovation. Their legislatively narrow commodity focus can limit investment in wider farming system and business improvement. Many Australian farms produce more than one commodity and manage natural resources, labour and capital across the whole-farm business. Prioritising R&D needs within a whole-farm context can be difficult when a sole commodity lens is used for R&D allocation. The corporations feel compelled to generate benefits for all their stakeholders (i.e. levy payers), leading to research products and information that is often highly generalizable. Catering for the needs of sub-groups of stakeholders, or pursuing regionally specific opportunities are not easily incorporated within a commodity framework.

Also it tends to mean that the innovation focus of these corporations is dominated by pre-farm gate concerns, in spite of the benefits that could be generated beyond the farm-gate. By illustration, costs beyond the farm-gate are a main component (up to 30%) of the final wheat price in end-user markets (see Stretch et al 2012; White et al 2015). Many of the services beyond the farm-gate are provided by only a few firms and there are limited competitive forces to drive and support innovation in some parts of some supply chains. Comparing the degree of farm-level innovation in grain production, for example, against post-farm gate innovation suggests that the bulk of innovation activity has occurred at the farm-level. In Australia, not only has there been little capital investment in rail infrastructure but there has been little investment in innovation in the rail freight of grain; yet the transport and post-farm gate handling of grain represent major costs in the export of grain from Australia. There is a need to examine how to encourage investment in post-farm gate innovation when limited competitive pressures apply within parts of some supply chains. Also, it would appear that better interaction between the rural R&D corporations and the Australian Research Council is required in order for more appropriate levels of co-ordinated investment in blue sky agricultural research occurs.

Another issue that has already received some policy attention in the National Innovation and Science Agenda concerns how to better incentivise investment in innovation activity. In December 2015, the federal government announced provision of new tax breaks for early stage investors in innovative startups. Investors will receive a 20% non-refundable tax offset based on the amount of their investment, as well as a capital gains tax exemption. A 10% non-refundable tax offset will now apply to capital invested in new Early Stage Venture Capital Limited Partnerships (ESVCLPs), and the cap on committed capital has now increased from $100 million to $200 million for new ESVCLPs.

Rules that limit depreciation deductions for some intangible assets (like patents) to a statutory life have been removed so these assets can be depreciated over their economic life as occurs for other assets. Insolvency laws are to be reformed to reduce the default bankruptcy period from three years to one year. Also introduced will be a legal ‘safe harbour’, protecting directors from personal liability for insolvent trading, if those directors appoint a professional restructuring adviser to develop a plan to turnaround the startup if it is in financial difficulty. In addition, a new $200 million CSIRO Innovation Fund is to be established for co-investments in new spin-off companies and existing startups that will develop technology from CSIRO and other publicly-funded research agencies and universities.

However, it needs noting that one major source of potential investment funds, Australian super funds, currently direct almost none of their funds to support innovation in early stage, potentially high-growth companies. Australian super funds now exceed $2 trillion and are the fourth largest in the world, yet they do not target innovative start-ups. By way of contrast, investors in the USA committed around $84 billion into local start-up firms in 2015, while Australian investors (not super funds) were forecast to put in only $250 million for their local start-ups in 2015. Whether or not there are legal or informational impediments that prevent, even a tiny share of Australian super funds to be used for investment in start-up businesses requires investigation.

Concluding Remarks

Innovative economies are known to be more productive, more resilient and adaptable to change, and better able to support higher living standards (OECD, 2015). Yet Australia is listed last by the OECD in relation to collaboration between innovation-active firms and education institutions that both can be sources of innovation ideas and products. While Australia performs well in research, producing a wide range of intellectual property from basic to applied discoveries, few become worthwhile innovations.

Regarding agricultural innovation in Australia, this paper reiterates findings that the profitability and productivity of Australian agriculture has been well-served by agricultural innovation that via R,D&E has generated a wealth of useful technologies (i.e. ‘widgets’ matter). Of equal import, this paper highlights that structural change in the Australian economy has greatly reduced the relative economic and political

significance of the agricultural sector. Greater economic expansion in other parts of the economy, fewer farms, labour-saving technologies, budget restrictions facing federal and state governments, incentive systems in tertiary education and Australian agribusiness in combination now limit employment and career prospects for many engaged in agricultural innovation. The implication is that local innovation is being potentially restricted. Because of the creative role played by researchers and others in the R,D&E process leading to worthwhile innovation, it is vital that these people in the tertiary and agribusiness sectors are appropriately incentivised (i.e. people matter).

Lastly, this paper argues that the most crucial challenge to delivering agricultural innovation that benefits Australian agriculture and the wider economy is effective policy and organisational design (i.e. policies matter). Although the federal government has signalled some desirable policy and organisational changes that are intended to deliver greater economic, social and environmental wealth for Australians, including those in its agricultural sector, even more change is required; especially regarding tertiary sector incentive structures and more public-private partnerships that could link to or better serve agricultural innovation.

A few other issues that deserve further scrutiny in order to inform the design of policy and organisations to enhance agricultural innovation are also noted.

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