Submission to the Productivity Commission Inquiry on

Economic, Social and Environmental Returns on Public Support for Science and Innovation in Australia

GOVERNMENT OF WESTERN AUSTRALIA

Department of Agriculture and Food

Index

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Executive Summary

This submission addresses aspects of two issues in the Productivity Commission's terms of reference (see Appendix one). These issues are firstly, the economic impact of public support for science and innovation in Australia and its impact on Australia's recent productivity performance. Second is the identification of impediments to the effective functioning of Australia's innovation system.

This submission focuses on the provision of agricultural R&D and its economic impact on the agricultural sector. The viewpoint of this submission is that of a regional provider of agricultural R&D (i.e., Department of Agriculture and Food, Western Australia – DAFWA) with its rich experience in serving the agricultural sector of Western Australia.

Economic impacts of agricultural R&D and farm productivity
Several international and national studies are reported showing that public funding of agricultural research represents a profitable use of tax-payer funds. For Western Australia, 60 typical projects funded within DAFWA over the past decade have generated benefit cost ratios mostly in the range of 2-10:1, with the weighted average being 7.5:1. The total net present value of the 60 projects was $548 million.

The often acknowledged intent of public investment in agricultural science and innovation is to underpin productivity and environmental improvement in the sector, and certainly high productivity rates have been measured for WA's principal broadacre sector. However, proving empirically the causal link between R&D and productivity gain is difficult. There are many causes of productivity gain and often there are long lead times for successful research and innovation. Hence, it is difficult to make an unambiguous, irrefutable empirical case of attribution for the role of publicly funded science and innovation in delivering productivity gain for agriculture. Nonetheless, there are strong arguments for the likelihood of the link between expenditure on R&D and agricultural productivity being strongly positive. International evidence points to a decline or stagnation in real funding for public R&D being associated with a slowdown in agricultural productivity growth.

It is possible that almost half the value of agricultural output in Australia in 2003 can be attributed to new technology generated by domestic R&D since 1953. At a real rate of interest of 4%, the compound value of the stream of benefits from domestic research from 1953 to 2003 is $878 billion (in 2004 $s). It is likely that Australian producers, processors and consumers have retained about 80 percent of all benefits generated by this national agricultural R&D.

In contributing to national agricultural output, broadacre farmers in Western Australia have experienced among the highest levels of productivity growth, particularly in grain production with average productivity growth per farm of 4.78 per cent per annum from 1978/9 to 1999/2000. Relative to most other States, WA broadacre farm productivity displays both a relatively high multifactor productivity growth rate and lesser variation in that rate.

An often over-looked feature of productivity gain is its role in income maintenance. Productivity growth has delivered growth in agriculture's real gross value of production (GVP) over the last half century in Western Australia, yet in the absence of that productivity gain it is highly likely that there would have been a large decline in agriculture's real GVP.

Impediments to agricultural R&D and Innovation

Several impediments to the effective functioning of Australia's innovation system for agriculture have been identified including:

(i) an inhibitory culture

In general, Australian society under-values and relatively poorly rewards scientific endeavour and creativity. To alter attitudes and to build a culture that encourages and rewards scientific endeavour and creativity is likely to require a multi-pronged, enduring approach.

(ii) a limited national science capacity

A significant proportion of science-based employees in public sector agricultural agencies such as DAFWA are experienced staff likely to retire over the next decade. In DAFWA over 30 percent of operational staff are aged over 50. Hence, there is a fairly small window of opportunity to transfer their skill, knowledge and experience to a new generation of researchers. However, attracting enough of that new generation into public sector agricultural agencies and retaining them is proving problematic.

The reward structures and security of R&D funding are inadequate, in spite of the investment in agricultural R&D being a relatively high return area and in spite of the economic advantages to Australia of its agricultural sector remaining a low-cost source of food and fibre for local industry, a source of export earnings, and source of safe, affordable food for local and overseas consumers.

In the future, it is highly likely that ‘quantum’ leaps in agricultural productivity will arise from adapting new or emerging technologies from other industries including the bio-medical, energy, electronics, packaging, logistics and engineering industries. Hence, investing in developing and maintaining linkages across disciplines and across state and national boundaries is likely to generate significant future returns besides the main focus of maintaining funding in key agricultural sub-disciplines. However, there is limited capacity to develop those networks, to attract researchers into agriculture and ensure knowledge transfer occurs.

(iii) high transactions costs

High transaction costs impede the effective and efficient use of resources for delivering science and innovation services. These costs are in part due to there being several funders of agricultural R&D and several providers who both compete and collaborate.

The high transactions costs arise from the constant building and maintaining of a range of partnerships that stretch from the local through to national and international arenas. Forming a critical mass of researchers, skills and institutional mixes to successfully bid for agricultural R&D can involve considerable expense of time and resources, quite apart from the on-going reporting and assessment tasks increasingly associated with undertaking research.

(iv) wasteful competition

Although some funding programs (e.g. Cooperative Research Centre funding) facilitate cooperation between research institutions to deliver focused research outcomes, many other programs promote organizational or regional competition for funds. This competitive approach can improve efficiencies and may stimulate innovative research approaches. However, the experience of many R&D staff is that competition for funds and competition over products from research can be counterproductive, especially where research providers feel under duress due to funding uncertainties, rationalisation pressures and asset fixity (be that physical or human capital). Negative impacts can arise from:

- reduced collaboration
- failure to share essential or useful information and material
- unnecessary duplication of R&D activity
- lack of integrated R&D effort within and across industries and institutions
- over-investment in institutional promotion and
- institutional rivalry and counter-productive commercialization imperatives

Where competition is wasteful, the agricultural sector and the community is actually disserved by this less effective and efficient R&D process.

(v) misaligned incentives
One of the difficulties in building innovation pipelines from research to commercialisation tends to be the misalignment of incentives facing participants along the pipeline. The various incentives include minimizing organisational cost, generating peer respect, maximising leverage from organisational funds, maximising receipt of external funds, protecting intellectual property, ensuring institutional acclaim, maximising industry outcomes, generating royalty streams and maximizing positive publicity. Misalignment in incentives along the innovation pipeline reduces the effectiveness and efficiency of the process taken as a whole.

(vi) investment uncertainties
Various uncertainties surround agricultural R&D funding leading to difficulties in the provision of R&D services. Firstly, public funding for agricultural R&D in Australia is either stagnating or declining in real terms, making it difficult both to attract researchers into agencies that draw on those funds and to provide career pathways for these researchers. Secondly, public funders (e.g. rural R&D corporations, state treasuries) of agricultural R&D increasingly offer short-term, prescriptive, often highly applied project funding. These changeable short-term prospects and projects provide limited employment security and restricted career progression opportunities for researchers.

Of these six impediments the more important that need to be addressed through national policy change are:

(i) investment uncertainties. It will not be possible to replenish or maintain a sound national agricultural research capacity in agricultural R&D if funding security and career pathways in agricultural science remain uncertain. There is a need for objective determination of national R&D priorities linked to areas with prospective high return and strategic importance. If a larger proportion of R&D funds are allocated longer term to these priority areas then those funds and areas of research can become an attractive and challenging career focus, and mentoring task for the current and prospective generations of researchers. In short, R&D funders and providers need to allocate a larger share of funds to longer projects in key areas to lessen investment uncertainties and provide an environment more conducive to mentoring and career development.

(ii) wasteful competition and high transaction costs. There is a need to rationalise the number or activity focus of agricultural R&D providers. Encouraging the establishment and maintenance of key critical R&D capacities is likely to be needed to reduce wasteful competition and high transaction costs. A number of options need to be explored such as amalgamation of institutions or parts of institutions, re-structure and support of some organisations to become centres of excellence in key research areas with critical mass advantages, rationalisation of the number of agricultural R&D funders, and specialized funding for co-ordination and network formation and maintenance. Some opportunities to improve national collaboration in planning and delivery of a national approach to agricultural R&D, its regional delivery and local extension have already been identified by the Primary Industries Ministerial Council.

Introduction

This submission to the Productivity Commission seeks to address the first two sections in its terms of reference:

1. Report on:

    - the economic impact of public support for science and innovation in Australia and, in particular, its impact on Australia's recent productivity performance;
    - whether there are adequate arrangements to benchmark outcomes from publicly supported science and innovation and to report on those outcomes as measured by the benchmarks.

2. Identify impediments to the effective functioning of Australia's innovation system including knowledge transfer, technology acquisition and transfer, skills development, commercialisation, collaboration between research organisations and industry, and the creation and use of intellectual property, and identify any scope for improvements;

As this submission comes from the Department of Agriculture and Food, Western Australia (DAFWA) it is understandable that the principal focus of this submission is the science and innovation affecting the agricultural and food sectors.

Economic Impact of Public Support for Agricultural Science and Innovation: A WA Perspective

There is extensive international evidence that public funding of agricultural research represents a sound, defensible use of tax-payer funds regarding the profitability of the investment. In a meta-analysis of 292 studies Alston *et al*. (2000) found:

- No evidence that returns from research investments were declining;
- Returns from research appeared higher in developed countries;
- Estimated rates of return from research were lower for enterprises with longer production cycles;

In Australia it is commonplace for publicly funded agricultural research projects and programs to be subject to *ex ante* and *ex post* economic assessment. For example, economists in State agricultural agencies have been evaluating research investments for over 20 years. These evaluations have been used to publicly account for the use of funds, to support external funding proposals, to assist in priority-setting priorities and resource allocation, to help transform research projects and to act as a training opportunity for inexperienced staff. Many of these economic analyses of projects are reported in the public domain. For example, a review of a sample of 60 evaluations conducted during the 1990s within NSW DPI revealed that benefit cost ratios were in the range of 3-30:1 with the majority in the range of 10-20:1. Similarly, 60 major projects funded within DAFWA over the past decade and assessed over the period 2000/1 to 2005/6 have generated benefit cost ratios mostly in the range of 2-10:1, with the weighted average being 7.5:1 (see Figure 1). The total net present value of the 60 projects was $548 million.

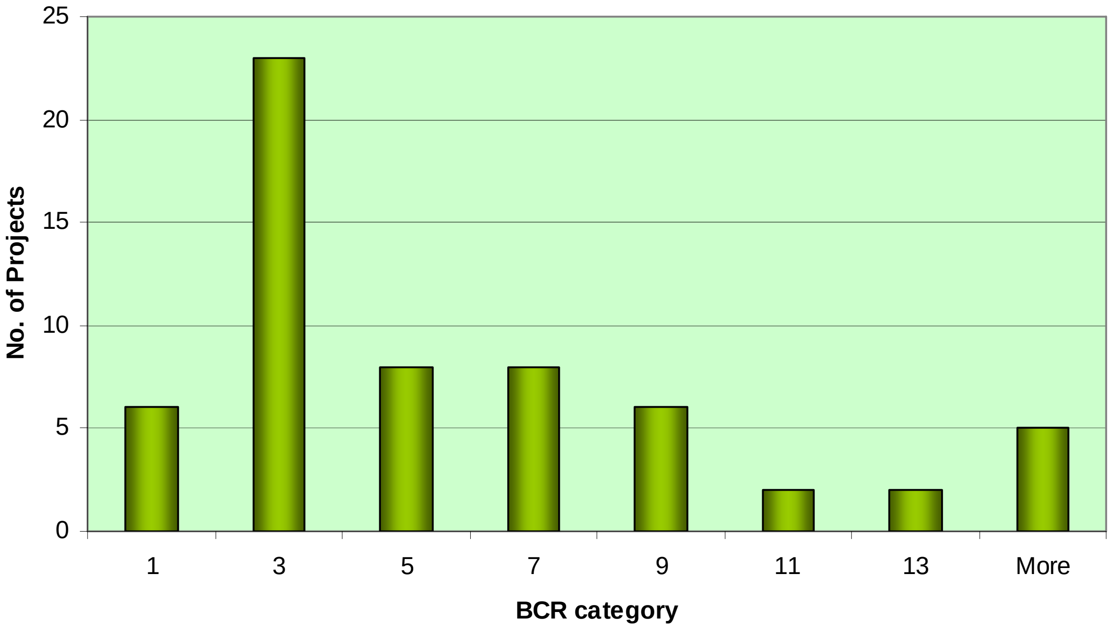

Figure 1: Histogram of DAFWA project benefit cost ratios (BCR): 2000/1 to 2005/6

The historical intent of much public support for agricultural science and innovation has been to deliver benefits primarily to the farm sector, principally through productivity improvement. Broadacre farmers in Western Australia, for example, have experienced particularly high levels of productivity growth in grain production compared with producers from many other regions, with average productivity growth per grain farm of 3.5 per cent per annum, over 21 years up to 1998-1999 (Ha and Chapman, 2000). By contrast sheep specialist, beef specialist and sheep-beef specialist farms recorded productivity annual productivity growth of only 0.6, 2.1 and 1.4 per cent over the same period.

Productivity improvement enables farm businesses to combat their long run decline in terms of trade and achieve higher levels of profitability. Part of that profitability, and an often over-looked feature of productivity gain, is its role in income maintenance. Agricultural production involves dynamic natural systems subject not only to conditions of growth but also decay. By illustration, a high-yielding crop variety eventually will be subject to evolving disease and pest threats. The yield and quality advantages of a crop, due in part to its disease and pest resistance traits, eventually will succumb to an evolved threat. In the absence of research and innovation that protects the crop's advantages, the economic merit of the crop will be eroded.

As shown in Figure 2, although productivity growth has delivered real growth in agriculture's gross value of production (GVP) over the last half century in Western Australia, in the absence of that productivity gain it is highly likely that there would have been a large decline in agriculture's real GVP. Hence, one of the under-stated roles of productivity gain is to underpin or at least maintain the real GVP of agriculture. Hence, the important policy and research management issue and question is not just ascertaining what is the comparative return of research investments or the relative rates of productivity gain but also what will occur in the absence of those investments. This finding has particular relevance to agricultural R&D where evolving natural systems alter, and often lessen, the stream of benefits from innovation.

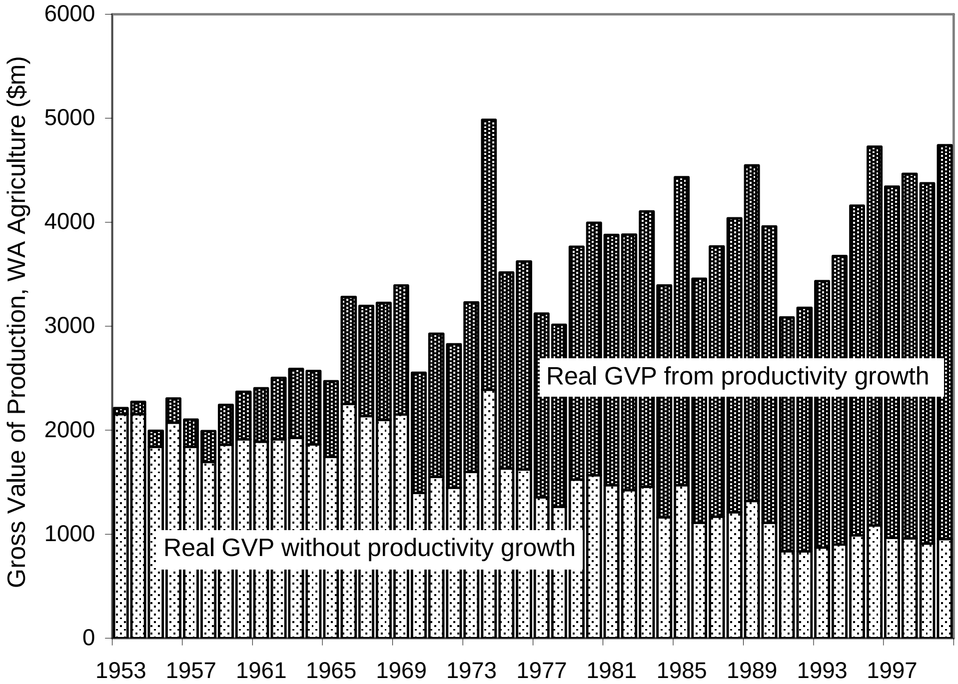

Figure 2: Real gross value of agricultural production (GVP) in Western Australia, showing the portion due to accumulated productivity improvement.
Source: Kingwell and Pannell (2005)

Besides the potential erosion of benefits within Australia there is also the potential capture of benefits by non-residents of Australia. Mullen (2002) points out that the benefits of new technology in Australian agriculture are shared with producers, processors and consumers who are non-residents of Australia. He estimates, on the basis of previous research into the distribution of the benefits from research that perhaps Australian producers, processors and consumers retain 80 percent of all benefits. The inference is that investment in agricultural R&D in Australia leads to the capture of most of those benefits by the Australian economy.

In linking productivity gain in the Australian farm sector to expenditure on Australian R&D, it needs to be noted that farm productivity will also be affected by R&D spill-ins from other countries' investments in R&D. Figure 3 disaggregates the value of all productivity gains in Australian agriculture since 1953 into those attributable to domestic R&D and those attributable to other sources of productivity including foreign knowledge and domestic sources such as public infrastructure and farmers' education. This disaggregation is based on the assumption that in recent decades, domestic R&D has advanced productivity at the rate of 1.2 percent per year. A further assumption is that prior to 1969 productivity grew at 80 percent of its current rate (0.96%). Almost half the value of output in 2003 can be attributed to new technology generated by domestic research since 1953. At a real rate of interest of 4%, the compound value of the stream of benefits from domestic research from 1953 to 2003 is $878b (all in 2004 $s).

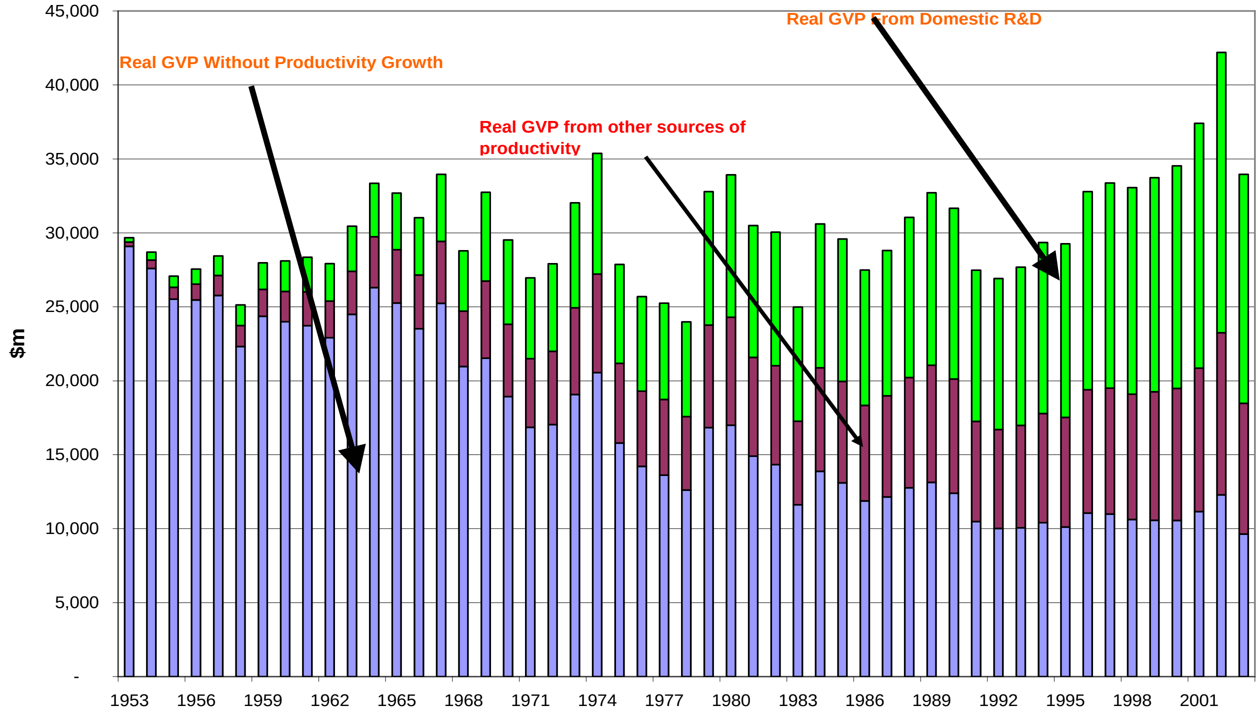

Figure 3: Real gross value of agricultural production (GVP) in Australia, sources of productivity improvement.
Source: Mullen (forthcoming)

The Productivity Commission acknowledges the desirability of productivity gain and the important economic role it plays (Productivity Commission 2005). The Commission found that multifactor productivity growth in Australia's agricultural sector averaged almost 3 per cent a year over the period 1974-75 to 2003-04 (or 2.3 per cent in trend terms). This was considerably stronger than that achieved in Australia's combined market sector (1 per cent in trend terms).

Islam (2004) estimated multifactor productivity growth in broadacre agriculture in each state of Australia. His findings are reported in Table 1.

Table 1: Estimates of multifactor productivity growth in broadacre agriculture in Australian States: 1978/9 to 1999/2000

State	**Multifactor Productivity**	
	Growth (% p.a.)	Standard deviation
WA	*4.78*	*12.67*
Vic	4.51	19.51
Tas	2.39	9.98
SA	5.99	22.07
NSW	4.25	17.89
Qld	3.46	14.73
Australia	**3.73**	**12.42**

Source: Islam (2004)

Islam's results for Australia are consistent with those reported by the Productivity Commission (2005). Interestingly, WA displays both a relatively high multifactor productivity growth rate yet lesser variation in that rate relative to most other States.

The Commission found that agriculture has been a strong contributor to the Australian economy's overall multifactor productivity growth. From 1974-75 to 2003-04, agriculture accounted for around 16.4 per cent of market sector multifactor productivity growth, or more than double its value-added share of the market sector. Over the period agriculture was the second highest contributor of the twelve market sector industry divisions after manufacturing (31 per cent of multifactor productivity growth). Further, the Commission estimated the 'dividend' from multifactor productivity growth to be worth just over $170 billion over the period.

Although the often acknowledged intent of public investment in agricultural science and innovation has been to underpin productivity and environmental improvement in the sector, proving this empirically has proved difficult. There are many causes of productivity gain and often there are long lead times for successful research and innovation. Hence, it is difficult to make an unambiguous, irrefutable case of attribution for the role of publicly funded science and innovation in delivering productivity gain for agriculture.

Similar views are expressed by Mullen and Crean (forthcoming) who state:

> *While more is known about the returns from public investment in agricultural research, in practice it has not proved possible to estimate a relationship between investment in research and productivity growth that is significant and stable in an econometric sense. It is most probable that such a relationship exists but because of the complex way in which current investments in research and extension – public, private, basic, applied, domestic and foreign – influence the stock of knowledge in use by farmers over long investment periods while other dimensions of the economic and social environment are changing, not least within the research sector itself, it is likely that with present data availability and modelling capabilities it will not be possible to precisely estimate a simple relationship*.

Although the necessary disaggregated time series data may not be available to empirically measure the significance of the relationship between publicly funded research and agricultural productivity, nonetheless most practitioners consider there is an underlying causal link between research activity and productivity improvement. For example, Thirtle *et al*. (2004) report results of a study of multifactor productivity growth in UK agriculture, from 1953-2000. They show that prior to 1984 multifactor productivity grew at 1.68% per annum and after that date at only 0.26% per annum. They suggest that the large decline could be explained mainly by cuts in funding to research and development (R&D) and the demise of public extension. Other factors, possibly related to the decline in R&D funding, were the reduction in patent applications and a slower growth in farm size.

Ball (2005) reports a slowing in agricultural productivity in the USA and suggests that a key source of its previously higher productivity growth was public investments in research. With those investments being flat in real terms since the 1980s, he raises questions about the prospects for continued agricultural productivity growth in the USA.

Klotz-Ingram and Day-Rubenstein (2004) argue that growth in agricultural productivity in the USA over the last century can be attributed largely to investments in agricultural research and technology development. They consider there are two forces that guide technological development that underpins US agriculture. The first is “demand-pull,” where the needs of the marketplace and the public create the demand for a product or technology. They suggest that government policies in the USA, such as environmental regulation, have boosted demand-pull forces to encourage the development of environmentally benign technologies. The second force is “supply-push.” where scientists and inventors find new and valuable technologies.

Klotz-Ingram and Day-Rubenstein argue that USA government policies with their emphasis on intellectual property protection have fostered the supply-push of new technologies and encouraged increased private funding of agricultural research. By contrast, public funding of agricultural research has flattened in real terms and productivity enhancing innovation is no longer the principal focus of publicly funded research, perhaps thereby contributing to the slowdown in productivity gain.

Studies reported by the Productivity Commission (2005) and other emerging studies suggest that much public and privately funded agricultural research does cause productivity gain but with lags as long as 30 years. Also, whilst their separate influences cannot be precisely estimated, other factors likely to be influential in the relationship between local research and productivity include foreign investment in research, extension, farmer education and public infrastructure.

Benchmarking and reporting outcomes from publicly supported science and innovation

DAFWA employ a range of processes to encourage and benchmark its staff and organisation’s performance in science and innovation. DAFWA regularly undertakes an independent stakeholder review of its activities. This provides a mix of objective and subjective feedback from clients as to the performance of DAFWA as a whole, as well as for its key components.

Its leading areas of research are continually subject to benchmarking through an on-going need to bid against other national R&D providers for external R&D funds. The requirement to generate and maintain national renown is also felt at a personal level by a majority of researchers. Their promotional prospects are formally tied to their demonstrated abilities to undertake research, publish in peer-reviewed journals, win research grants and generate industry outcomes based on their proven roles and likely attribution of impact. DAFWA maintains an internal program of awards for excellence and provides training to ensure the effective and efficient senior management of staff.

Through its reporting requirements to funders such as Rural R&D Corporations and the State Department of Treasury and Finance, DAFWA’s delivery of its contracted services is assessed. Benefit cost analyses of major areas of R&D activity are regularly assessed and reported to the Auditor General and DAFWA must annually report to the State Treasury. For example, DAFWA receives several millions of dollars of industry funds, complemented with State Treasury consolidated revenue, to undertake crop variety improvement. Crop variety improvement seeks to raise the quality of grain to the benefit of end-consumers and to maintain or increase grain yield principally to the benefit of producers. These tasks involve considerable expenditure on applied R&D, including laboratory testing, glasshouse and field testing. The performance of DAFWA varieties is benchmarked against the scores of other varieties available to WA farmers from other providers. Table 2 lists the performance of DAFWA as a crop variety provider in 2004 and 2005.

Table 2: Benchmarked performance of DAFWA as a crop variety provider

Variety	2004 Percentage of Western Australian crop area sown to crop varieties developed by DAFWA	Estimated hectares planted	2005 Estimated percentage of Western Australian crop area sown to crop varieties developed by DAFWA	Target hectares planted
Wheat	84.2	4,403,269	80.7	3,931,167
Barley	93.6	1,090,318	95.4	874,423
Oats	95.8	149,821	97.1	75,859
Lupins	99.9	544,026	96.0	399,195
Field Peas	7.4	68,002	8.4	58,155
Chickpeas	87.0	1,931	84.0	2,056
Total	**86.7**	**6,257,367**	**83.7**	**5,340,855**

Source: DTF (2006)

Impediments to the effective functioning of Australia's innovation system

This section draws on collated views and insights generated by interviews with senior managers in DAFWA. This public sector organisation receives annual funding of around $170 million and employs about 1400 staff located across 70 centres. Its mission statement is:

> *The Department of Agriculture and Food will accelerate the success of agriculture, food and fibre industries through information, science and innovation, responsible management of the resource base, policy and regulation across all elements of the supply chain .(p259, DTF, 2006)*

DAFWA's role is to beneficially influence the performance of the agricultural and food sectors. Its role depends on its ability *inter alia* to generate and provide knowledge and innovation that supports and encourages sound business decision-making in these sectors. Accordingly, knowledge creation and knowledge sharing are core competencies in DAFWA and often that knowledge is generated through scientific endeavour and scientific appraisal.

In such an organisation with its on-going focus and history in the business of science and innovation the views of its senior managers are forged on the anvil of experience and therefore are worth noting.

Impediment One: An Inhibitory Culture

A common view among the senior management of DAFWA was that one impediment to greater innovation was the apparent absence in Australian society of an underlying culture that greatly valued science and the creativity of innovative science. To rapidly and successfully develop leading edge innovation systems, it was felt that Australia needed to build and maintain a society that valued more, science and creativity. However, it was acknowledged that cultural constraints are difficult to alter or remove, and that therefore a multi-pronged approach would be needed to build a culture of creativity that encouraged and rewarded scientific endeavour.

The impact of culture and its impact on science effort have also been noted by Coates (2003) for the USA. He commented that public ignorance of science is affecting scientific endeavour with the population being left open to extremist, erroneous or fantastic claims, leading sometimes to unsound policy solutions, faulty recommendations and ultimately bad laws and regulations. Further, within the USA many businesses are not supporting their domestic science providers but rather are out-sourcing their science projects to developing country providers or are employing cheaper foreign-born scientists within their businesses (Coates 2003). The signals this behaviour sends to society about the perceived importance of science and local innovation only reinforces an inhibitory culture toward local scientific endeavour and creativity.

For Australia, several DAFWA managers felt that knowledge generation, innovation and improvement should not be seen as the sole province of traditional and emerging knowledge institutions. Rather it should be seen as an aspect of personal responsibility with individuals becoming committed to embed knowledge building, innovation and action into their everyday lives.

Key areas for government action and policy were suggested:

- Education and life long learning systems to deliver an educated and skilled population capable of creating and using knowledge to its full potential,
- Facilitating the establishment of networks of firms and research centres of excellence that could tap into the growing stock of global knowledge to create new products and responses to local and overseas market needs,
- A dynamic, reliable information infrastructure to facilitate effective communication,
- An economic and institutional framework that promoted new knowledge generation and the flourishing of entrepreneurship.

Impediment Two: a Limited National Science Capacity

Through cycles of recruitment, several managers reported difficulty in attracting and retaining Australian-trained scientists into the public sector. In particular there appears to be a shortage of skills in chemistry and some areas of technology. Moreover, many potential employees of public sector agricultural agencies find the salaries, conditions and locations on offer to be unattractive. Indicative of the current relative attractiveness of a research career in agricultural science are figures on higher degrees enrolments by field of education (Table 3). Agriculture and engineering have experienced nationally large declines in higher degree enrolments, potentially jeopardizing the future flow of R&D innovation to those sectors mostly dependent on those skills.

Currently, a significant proportion of science-based employees in public sector agricultural agencies such as DAFWA are experienced staff likely to retire over the next decade. In DAFWA over 30 percent of operational staff are aged over 50. Hence, there is a fairly small window of opportunity to transfer their skill, knowledge and experience to a new generation of researchers. But, as already noted, attracting enough of that new generation into public sector agricultural agencies and retaining them is proving problematic.

Some managers felt that, to maximise its opportunities, Australia would need to understand the global distribution of innovative people, and factors that influenced their mobility and attraction. As a nation we needed to demonstrate that Australia was developing a culture, infrastructure and incentive structure that supported science and innovation workers. The status of services in health, education, policing, housing and arts would assist in positioning Australia as a lifestyle destination for science workers and R&D businesses.

Table 3: Higher degree research enrolments by broad Field of Education, 1993 and 2001

Broad Field of Education	1993 Commencing enrolments	2001 Commencing enrolments	Change in enrolments (%)
Agriculture, Environmental and Related Studies	591	426	–27.9
Engineering and Related Technologies	1 506	1 135	–24.6
Natural and Physical Sciences	1 961	1 732	–11.7
Society and Culture	2 529	2 411	–4.7
Architecture and Building	183	185	1.1
Education	1 079	1 094	1.4
Health	1 094	1 369	25.1
Information Technology	250	329	31.6
Creative Arts	487	740	52.0
Management and Commerce	554	875	57.9
Total	**10 234**	**10 292**	**0.6**

***Note*:** Combined courses are coded to two Fields of Education, therefore the sum of all of the Fields of Education in a column may be greater than the column total.
***Source*:** Adapted from the Higher Education Statistics Collection.

If attracting young persons into science within Australia proves too difficult or if attracting overseas scientists into Australia also proves unsuccessful then Australia will need to seek international science partners. Australia, by international comparison, is a modest player in research and scientific innovation. It does not have the capability to be a world leader in all areas of science so it needs to identify or develop its strategic areas of comparative advantage carefully.

Australia's few areas of high return international research and innovation leadership need to be identified and supported as resources for leverage or engines of potential economic growth. Other emerging areas of potential high return also require support, perhaps through formation of innovation hubs that provide a critical mass of R&D endeavour and infrastructure. In many fields of research, international partnering or international out-sourcing may be the preferred strategy. In many settings, Australian businesses may be best served by developing national and international linkages that enable them to be fast followers where some other country or sectoral hub leads in specific technology development.

In many ways, Australia's investment in science and innovation is like any other form of investment. It needs to be diversified, underpinned by sound risk management principles, yet it should target likely areas of high return that build on Australia's existing or emerging comparative advantages.

Broadacre agriculture, for example, continues to be one sector and area of science and innovation in which Australia continues to demonstrate international excellence. Management and innovation in that sector is grounded on science and innovation excellence. The sector has a long history of technological innovation and responsiveness to local and international market opportunities. Relative to the equivalent sectors in many other countries (see Table 4) the Australian broadacre agricultural sector receives little support from government via price support, protection or subsidy arrangements. Yet the sector, mostly through productivity improvement, has remained internationally competitive and is a low-cost, safe source of food and fibre for local industry and local and overseas consumers.

Table 4: Ranges of Producer Subsidy Equivalents (as %) in OECD countries by crop, 2001-03

	Producer Subsidy Equivalent (%)						
Crop Type	**<10**	**10<20**	**20<30**	**30<40**	**40<50**	**50<70**	**70<90**
Wheat	Australia, Czech Rep., New Zealand, Slovak Rep.	Canada, Hungary, Turkey	Poland	Mexico, USA	EU	Switzer-land	Japan, Norway
Maize	Hungary, New Zealand, Slovak Rep.	Canada, Poland	Turkey, USA	EU, Mexico	Switzer-land		
Other grains	Australia, Czech Rep., Hungary, New Zealand, Poland, Slovak Rep., Turkey	Canada		Mexico, USA		EU, Switzer-land	Japan, Korea, Norway
Rice	Australia			EU, Mexico		USA	Japan, Korea
Oilseeds	Australia, Czech Rep., Hungary, Slovak Rep.	Canada, Poland	Turkey, USA	EU	Japan	Mexico	Korea, Switzer-land
All commodities	Australia, New Zealand	Canada, Poland, Turkey	Czech Rep., Hungary, Mexico, Slovak Rep., USA	EU		Iceland, Japan, Korea	Norway, Switzer-land

Source: OECD PSE/CSE database, 2004.

Within Western Australian agriculture, almost all 'quantum leap' advances in productivity and profitability have involved the application of new technologies. Some examples are trace element soil treatment, new plant species (e.g. subterannean clovers, medics, lupins), animal breed improvement, bulk-handling equipment, labour-saving large machinery, non-till crop establishment and computer-based marketing. It is highly likely that further 'quantum' leaps will arise from adapting new or emerging technologies from other industries including the bio-medical, energy, electronics, aerospace, military, packaging, logistics and engineering industries. Hence, investing in developing and maintaining linkages across disciplines and across state and national boundaries is likely to generate significant future returns besides the main focus of maintaining funding in key agricultural sub-disciplines.

For agriculture the following three-pronged approach is needed:

- continued investment in productivity and sustainability improvement in the major commodity areas;
- assisting industries to target emerging markets where premiums can be obtained;

- development of higher value products and improved technology across the supply chain, with a strong focus on benefit retention in Australia.

Impediment Three: High Transactions Costs

One aspect of the delivery of science and innovation services that DAFWA managers consider at times impedes the effective and efficient use of resources is the imposition of high transaction costs. In many spheres of agricultural science endeavour there are a plethora of funders and providers. Funds are available from local, state, national and international sources (e.g. rural R&D corporations, Australian Research Council, ACIAR, NAP and NHT funds via regional catchment councils, agricultural produce commission payments, commercial firms, intellectual property payments, state and federal government appropriations to universities and agricultural agencies and for co-operative activities such as centres of excellence and co-operative research centres). The R&D providers include universities, state agricultural agencies, regional catchment councils, private consultancy firms, agri-business firms and some grower groups.

The nature of the funding sources and providers leads to the unleashing of a mix of collaborative and competitive forces. Underpinning all the activity, however, tend to be high transaction costs. These costs involve building and maintaining a range of partnerships stretching from the local through to the national and international arenas. Often a critical mass of researchers, skills and institutional mix is required for an R&D application to be successful. Whilst there are merits in collaboration, and also noting that competition can deliver benefits, most managers quoted the large time and expenses associated with building and maintaining relationships across institutions and disciplines.

There are various aspects to the transactions costs. Some are the high costs of applying for funds whereby the paperwork and approval process both within the institution and for the funder can be extensive, even where relatively small amounts of R&D funds are being sought. Some funders have stringent reporting and review requirements. Hence, adhering to accountability processes can involve large costs of time. Researchers can be involved in institutional politics, administrative and clerical work that does not represent the best use of time and skill. Also, some funders are highly prescriptive regarding reporting requirements, research outcomes and the badging and communication of findings. These requirements appear to contribute little to the efficiency or effectiveness of the development or delivery of research outputs, tend to involve additional cost and at times are more about funder exposure and their publicity than facilitating industry outcomes. Further, adhering to the strict detail in research contracts often is necessary otherwise future funding may be jeopardized, yet desirable flexibility and dynamism in the research process can be impeded by this constraining legalistic framework. Lastly, even though little revenue or commercial advantage may be gained by intellectual property right formation and management, considerable resources can be engaged in discussion and resolution of such intellectual property issues.

Impediment Four: Wasteful Competition

Some funding programs (e.g. Cooperative Research Centre funding) facilitate cooperation between research institutions to deliver focused research outcomes. However some other programs promote organizational competition for funds. This competitive approach can improve efficiencies and may stimulate innovative research approaches. However, several DAFWA managers relayed their experiences suggesting that competition for funds and competition over products from research can be counterproductive, especially where research providers feel under duress due to funding uncertainties, rationalisation pressures and asset fixity (be that physical or human capital). This can result in the following negative impacts:

- reduced collaboration
- failure to share essential or useful information and material
- unnecessary duplication of R&D activity
- lack of integrated R&D effort within and across industries and institutions
- over-investment in institutional promotion
- institutional rivalry that disserves the agricultural sector and major funders

The negative impacts of competition also occur where funding initiatives, designed to stimulate collaboration between public sector providers, are underpinned by a commercialization imperative. Competition forced on rival providers can lead to waste, duplication and lost opportunities. For example the Cooperative Research Centre for Value Added Wheat and the Cooperative Research Centre for Molecular Plant Breeding should be collaborating far more than has been evident. However their incentives are to maximize their separate value rather than the sum of their returns.

Another wasteful feature of competition is the desire by institutions or science disciplines to maintain their turf. The resulting insularity of behaviour weakens or lessens the beneficial outcomes of collaborations across institutions and disciplines. Yet it has already been acknowledged that in the agricultural and food sectors it is highly likely that further ‘quantum’ leaps in innovation will arise from adapting new or emerging technologies from other industries including the bio-medical, energy, electronics, aerospace, military, packaging, logistics and engineering industries. Hence, investing in developing and maintaining linkages across disciplines and institutions is likely to generate significant future returns.

In Western Australia a collaborative research model is being implemented (Agriculture Research Western Australia (ARWA). ARWA incorporates the Department of Agriculture and Food, Murdoch University, Curtin University and the University of Western Australia. It has a potential to lessen unproductive institutional rivalry by encouraging a combined effort by contributors irrespective of their institution to focus on major industry and environmental projects. It represents a bottom up approach to building a portfolio of functional projects to address rural industry needs.

Various policy options to lessen waste and dissipation of resources in unproductive rivalry are available including:

- altering funding formulae to reward cross-institutional co-operation. For example, a greater funding weight being given to joint author publications where authors are based in different institutions.
- further supporting the Primary Industries Ministerial Council initiative aimed at improving national collaboration in planning and delivery of a national approach to R&D, its regional delivery and local extension.
- funding to establish centres of excellence that support key researchers in different institutions working within a virtual or co-located centre.
- greater sharing in the development of national R&D priority-setting.
- funding (or caveats on funds) to ensure joint appointments across institutions and/or disciplines.
- buy-outs and transfer payments. For example, to develop a critical mass of research capacity in some disciplines may require that some research sections or departments in some institutions are transferred to another institution. To encourage such shifts in resources

may require paying the institution losing their research personnel some compensation (or invoking a financial penalty if the transfer is opposed). Encouraging flexibility and mobility of resources within and across regions will remove some of the wasteful aspects of institutional rivalry.

Impediment Five: Misaligned Incentives

Several of the DAFWA managers pointed out that one of the difficulties in building innovation pipelines from research to commercialisation is the misalignment of incentives along the pipeline. A range of incentives exist such as minimizing organisational cost, generating peer-reviewed publications, maximising leverage from organisational funds, maximising receipt of external funds, protecting intellectual property, increasing opportunities for post-graduate students, ensuring institutional acclaim, maximising industry outcomes, increasing industry profits, generating royalty streams, etc. Misalignment in the mix of players and incentives along the innovation pipeline does reduce the effectiveness and efficiency of the process taken as a whole, even occasionally generating perverse behaviour.

Improving the effectiveness and efficiency of the innovation pipeline by better understanding and where possible altering the incentive drivers is a topic both for further research and policy innovation.

Impediment Six: Investment Uncertainties

Various uncertainties surround agricultural R&D funding leading to difficulties in the provision of R&D services. Firstly, public funding for agricultural R&D in Australia is either stagnating or declining in real terms and its research intensity is declining (Mullen and Crean 2006), making it difficult to attract researchers into agencies that draw on those funds and to provide career pathways for them. Secondly, the public agencies (e.g. rural R&D corporations, state treasuries) that provide public funds for agricultural R&D increasingly are prescriptive about the sorts of R&D outputs and outcomes they seek, often involving increasingly short-term highly applied R&D projects. These changeable short-term projects do not provide long-term employment security or career progression opportunities for researchers. Further, the rural R&D corporations are occasionally subject to re-structure and managerial change that cause delays and uncertainty in provision of funding. Further, abrupt change in funding priorities of some rural R&D corporations, state and federal treasuries is possible and this fuels uncertainty about provision of R&D funds for many R&D providers.

It is interesting to note that New Zealand (Johnson *et al*. 2006) is now moving away from short-term contestible funding based on a public choice model toward a longer term commitment of resources to individual providers who then plan their own priorities. The deficiencies of the variable short-term funding model were illustrated by the comments of one scientist:

> "... *the key issue in uncertainty. Once you put in a funding application you don't know for nine months whether or not you are going to be successful. That makes it difficult to plan ahead*." (Johnson *et al*., 2006, p 47)

Another impediment to the conduct of agricultural R&D is uncertainty or inconsistency in the application of an investment framework for publicly funded agricultural R&D. Mullen and Crean (2006 and forthcoming) point out the considerable ambivalence regarding the role of public research institutions in undertaking applied R&D. Arguments are raised about productivity enhancing R&D predominately being a private good that taxpayers should not support. However, other commentators point out that often applied agricultural research delivers a mix of public and private goods derived from the non-rival and non-excludable characteristics of at least some of the information generated by the research process. Much public agricultural R&D at present seeks to develop technologies that are both profitable for farmers and which deliver improved environmental outcomes off-farm. Applying consistently an investment framework that identifies where best to use public funds in agricultural R&D is made difficult due to estimation of on farm benefits often being a simpler task compared to estimating off-farm benefits. These sorts of difficulties, when overlain with political imperatives and bandwagon effects in public R&D funding, result in uncertain and inconsistent investment rulings regarding use of public funds for R&D. The outcome is sub-optimal allocations of R&D funds as typified by some of the R&D expenditures in response to natural resource management problems.

Reviews of natural resource management funding (e.g. SKM 2006) plus criticism and suggested improvements (Ridley and Pannell 2005, Wallace 2003, Pannell 2006) indicate that a better, more effective use of public funds is possible. Some managers in DAFWA pointed out how Commonwealth policy developments, reflected in programs such as the National Action Plan on Salinity and Water Quality, have targeted investment in priority areas of natural resource management, but have also circumvented previous Federal-State government funding arrangements that included support for strategic research. These new frameworks operate predominantly at local levels yet have eroded support for technical advice on research priorities and approaches. The requirement for Sates to co-fund the National Action Plan on Salinity and Water Quality with funds previously allocated to extension and technical capacity has only intensified this erosion of capacity. Hence, reduced investment in science and technical capacity is likely and this will lead to a reduced regional and therefore in aggregate, national, ability to identify and deliver technical solutions.

Another emerging difficulty, similar to the difficulty of correctly specifying agricultural R&D projects along the public good-private good continuum, is the observation that the distinction between basic and applied research is blurring (Coates 2003). The historical view is that publicly funded scientists should conduct more fundamental and strategic research which is the foundation for all other research efforts and outcomes. Moreover the private sector should conduct more applied research, undertake more developmental efforts, and bring products to market. However, such a simple categorisation of effort is in practice difficult due to impacts of emerging technologies, intellectual property protections and knowledge-embedding options that can alter the non-rivalry, non-price excludable characteristics of research. The implication is that the convenient separation of research effort into basic and applied categories is no longer as simple. Although the argument is sound that public funding should be directed mostly to basic and strategic research, applying this principle in practice may be increasingly problematic. This blurring of the basic and applied research categorisation is yet another source of uncertainty that makes the allocation of public R&D funds more difficult.

To facilitate R&D activity across the private-public good spectrum and the basic to applied continuum the Commonwealth needs to support a coordinated approach to building innovation pipelines from research to commercialisation. Such coordination is necessary to ensure that private investment and private providers of R&D are not crowded out by public providers, that under-investment in R&D does not occur, that applied R&D remains focused on end-user requirements, that transactions costs are lowered and that economic gains are realised.

Key Recommendations

Of these six impediments the more important that need to be addressed through national policy change are:

(i) investment uncertainties. It will not be possible to replenish or maintain a sound national agricultural research capacity in agricultural R&D if funding security and career pathways in agricultural science remain uncertain. There is a need for objective determination of national R&D priorities linked to areas with prospective high return and strategic importance. If a larger proportion of R&D funds are allocated longer term to these priority areas then those funds and areas of research can become an attractive and challenging career focus, and mentoring task for the current and prospective generations of researchers. In short, R&D funders and providers need to allocate a larger share of funds to longer projects in key areas to lessen investment uncertainties and provide an environment more conducive to mentoring and career development.

(ii) wasteful competition and high transaction costs. There is a need to rationalise the number or activity focus of agricultural R&D providers. Encouraging the establishment and maintenance of key critical R&D capacities is likely to be needed to reduce wasteful competition and high transaction costs. A number of options need to be explored such as amalgamation of institutions or parts of institutions, re-structure and support of some organisations to become centres of excellence in key research areas with critical mass advantages, rationalisation of the number of agricultural R&D funders, and specialized funding for co-ordination and network formation and maintenance. Some opportunities to improve national collaboration in planning and delivery of a national approach to agricultural R&D, its regional delivery and local extension have already been identified by the Primary Industries Ministerial Council.

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Appendix One

Terms of Reference

ECONOMIC, SOCIAL AND ENVIRONMENTAL RETURNS ON PUBLIC SUPPORT FOR SCIENCE AND INNOVATION IN AUSTRALIA

The Productivity Commission is requested to undertake a research study on public support for science and innovation in Australia.

Background

The Australian Government has identified science and innovation as one of its strategic priorities, recognising its contribution to Australia's economic and social prosperity. The Government has provided significant support for science and innovation, which it has augmented since 2001 through Backing Australia's Ability (BAA) , and funding now exceeds $5 billion per annum. In light of this investment, the Government considers that a study of public support for science and innovation is warranted. This study will complement the ongoing and planned reviews of BAA programmes.

Scope of the study

The Commission is requested to:

1. Report on:

    - the economic impact of public support for science and innovation in Australia and, in particular, its impact on Australia's recent productivity performance;
    - whether there are adequate arrangements to benchmark outcomes from publicly supported science and innovation and to report on those outcomes as measured by the benchmarks.

    The analysis should cover all key elements of the innovation system, including research and development, taking into account interaction with private support for science and innovation, and paying regard to Australia's industrial structure.

2. Identify impediments to the effective functioning of Australia's innovation system including knowledge transfer, technology acquisition and transfer, skills development, commercialisation, collaboration between research organisations and industry, and the creation and use of intellectual property, and identify any scope for improvements;

3. Evaluate the decision-making principles and programme design elements that:

- influence the effectiveness and efficiency of Australia's innovation system; and
- guide the allocation of funding between and within the different components of Australia's innovation system;

    and identify any scope for improvements and, to the extent possible, comment on any implications from changing the level and balance of current support;

Report on the broader social and environmental impacts of public support for science and innovation in Australia.