Past Studies of the Benefits from ACIAR Research: A Review - Dr John Mullen

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Contents

Introduction 3

The CIE Studies 4

The Lindner Studies 6

Conceivable benefits 8

Plausible benefits 8

Convincing benefits 8

Benefits to Australia 9

Summarising the CIE and Lindner studies 10

Brennan’s Evaluations of Australian Benefits from ICRISAT, ICARDA and CIMMYT 11

The Benefits to Australia from ICRISAT 13

The Benefits to Australia from ICARDA 14

The Benefits to Australia from CIMMYT 14

Comparing the Benefits to Australia from ACIAR’s multi- and bilateral R&D Programs 15

The Benefits to Australia from ACIAR’s Support of CABI 15

The Importance on Continuing Productivity Growth in Australian Agriculture 16

Trends in TFP in broadacre agriculture 17

TFP and terms of trade 18

Correcting TFP measures for climate variability 18

The Relationship between Research and Development and Productivity in Agriculture 19

Conclusions 22

References 25

Introduction

Since its inception ACIAR has been concerned about measuring the impact of the research it has funded. Latterly this impact assessment work has been reported in ACIAR's Impact Assessment series, IAS, which began in 1998 and is now 86 reports in length. While the objectives of some of these reports have been to develop methodological guidelines for various dimensions of impact assessment or to assist in internal ACIAR management, for a large proportion of them, the main objective was to quantify the economic impact in developing countries and in Australia of the research undertaken with financial support from ACIAR. The IAS series has largely focussed on ACIAR's bi-lateral funding. The impact in Australia of key CGIAR centres supported by ACIAR through its multilateral program has been quantified in a series of analyses by Dr John Brennan and colleagues. The other significant program area, capacity building, has not been subject to systematic evaluation but delivers significant benefits to Australia as well as developing countries, partly because much of the capacity building is undertaken in Australia.

There are five important general comments to be made about the IAS reports. First they only cover a small proportion of the bilateral research projects funded by ACIAR (less than 10% of the bilateral programme budget). Second they focus on quantifying economic or industry impacts and hence environmental and social impacts usually go unmeasured (although identified qualitatively). Of particular pertinence here is that the gains in scientific capacity and knowledge in which Australian scientists and research institutions share, are difficult to measure and hence usually go unquantified. Also pertinent is that ACIAR activities contribute to poverty alleviation, a goal of Australia's foreign aid program, which is likely to have additional value to society over and above economic impacts. Third ACIAR has a separate program for building research capacity (about 5% of total budget) and the benefits to Australia from this component of ACIAR activities also go unmeasured. Fourth, generally the research areas chosen for impact assessment are those expected to have been successful and so the average return from research subject to impact assessment is likely to have been higher than that to the rest of the portfolio[1]. The fact that the returns to the sample of projects subject to impact assessment have well exceeded investment by ACIAR lessens concerns about this non-random choice of successful projects for impact assessment.

Fifth, while our focus is on estimating benefits to Australia, this can only be done approximately because of the different methodologies applied. Where the new technology applies to industries where most of production is exported and Australia is a price taker then most of the benefits will be retained by Australian producers. Where the technology is introduced in largely domestic industries then the benefits will be retained in Australia and shared between producers and consumers.

ACIAR has funded two lines of analysis to aggregate through time the economic benefits measured in the IAS reports and to relate them to its investment. The first of these comprise a series of reports prepared by the Central for International Economics, CIE (IAS 39, IAS 63 and an unpublished update of IAS63). Second, aware that impact assessment reports varied in their plausibility, ACIAR commissioned Raitzer and Linder (IAS 35) and Lindner, McLeod and Mullen (IAS 86, 2013), hereafter referred to as the Lindner studies, to review the reports and rate them for their plausibility with one end result being the identification of a subset of reports, the estimate of benefits from which were convincing, establishing a lower bound estimate of the returns to ACIAR's bilateral research activities.

[1] Some projects subject to impact assessment have subsequently been found to have low returns and no doubt there have been some projects not assessed which have earned high returns.

The concept of 'Australian benefits' has to be carefully defined but has been left somewhat ambiguous in the previous studies. The key issue concerns the attribution of benefits from the activities of ACIAR and its partners. The typical practice in an impact assessment is first to estimate total benefits from the development and adoption of the new technology or policy change. This may well be done for several countries where the impact has been felt including Australia. Then there are at least two levels of attribution that might be of interest. First, perhaps only a share of these total benefits can be attributed to ACIAR and its partners. Second, of the flow of benefits attributable to ACIAR and partners, some might be interested in the flow of benefits to ACIAR activities alone, as was the interest of the Lindner studies. Benefits to ACIAR alone are usually estimated by attributing to ACIAR the same share of benefits as its share in total project costs (from all partners) on the grounds that ACIAR's funding is no more efficient (earns the same rate of return) as funding from the partners. Many impact assessment analyses report, or allow the derivation of, all three benefit streams. The convention in the CIE and Lindner studies has been to report the benefits attributable to ACIAR and partners as total benefits and the benefits attributable to ACIAR and ignore the total benefits from the introduction of the technology or policy change that institutions other than ACIAR and its partners contribute towards.

The IAS studies report streams of benefits and costs through time. To aggregate benefits and costs over time, the CIE and Lindner analyses have used a CPI index to convert these streams to a common year (the year the analysis was conducted) and then applied a discount rate of 5% to compound forward past benefits and costs and discount back future benefits and costs to the common year. This procedure allows benefits and costs to be aggregated in a consistent manner.

All dollar values from these studies used below have been converted to 2012 using the CPI index and expressed in 2012 present value terms using a 5% interest rate.

The CIE Studies

The first of the CIE studies (IAS 39, Pearce et al. (2006) primarily addressed the benefits to Australia from ACIAR funded research. This study used a very similar pool of IAS reports to the earlier Raitzer and Lindner (2005) report but included 7 analyses that pre-dated the IAS series. Of the studies reviewed, 28 considered benefits to Australia at least qualitatively and 16 (covering 29 projects) provided quantitative estimates of benefits to Australia.

Total benefits to Australia and partner countries (from the 35 impact assessments) were $11.8b and net benefits after ACIAR and partner country investments were deducted came to $11.2b[2]. Pearce et al. found that 62% of projects quantified benefits to both Australia and the partner countries while 85% identified both quantitative and qualitative benefits to Australia. They estimated that from the set of 16 studies, total benefits to Australia were $1,115m or 9.4% of all benefits from the set of 35. They noted that at the time of their report, 2006, cumulative investment by ACIAR since its inception was about $2.2b.

Pearce et al. analysed a further five case studies (research areas) and were able to quantify impacts in three of these. They estimated an additional $264m in benefits to Australia from these three case studies.

The quantified Australian benefits came from productivity gains (both on- and off-farm), trade gains and protection from exotic pests and diseases either on incursion or before Australian borders are reached.

[2] The CPI factor to return to 2004$s is division by 1.25 and the compounding factor was 1.48.

Following IAS39, the CIE developed a database for storing the results from impact assessments (CIE, 2009, IAS60) and providing summary information in a consistent manner across reports – the ACIAR Database for Impact Assessments (ADIA). The first review of impact assessments using ADIA was IAS63 by Harding et al. (2009)[3].

At the time of the Harding et al. (2009) report there had been 59 reports in the IAS series but of these only 37 had quantitative estimates of benefits recorded in the database. Total benefits (attributable to ACIAR and partners) were $16,834m from a total investment of $312m[4]. Benefits and costs attributable to ACIAR (on the basis of a cost share of about 54%) were $9,077m and $171m, respectively. In both cases the benefit cost ratio was 54:1. Total benefits flowing to Australia were estimated to be $1,569m, about 9.3% of total benefits and considerably exceeding the total investment in the 37 projects.

An unpublished update of the Harding et al. analysis using the ADIA database was provided to ACIAR by CIE in December 2011. At the time of this update the IAS series was 75 reports in length with 48 of these reporting quantitative estimates of benefits (not including earlier reports subsequently updated). Total investment by ACIAR and partners over the 48 IASs was $439m and by ACIAR alone, $219m[5]. Total benefits (attributable to ACIAR and partners) were $37,002m and benefits to ACIAR (based on a 50% cost share) were $18,459m, giving a benefit cost ratio of 84.2:1. Total quantified benefits to Australia amounted to $2,549m or about 7% of total benefits. At the time of this unpublished update, ACIAR had invested $3.1b since its inception giving a minimum benefit cost ratio of 6.03:1.

[3] IAS60 reported on the appropriateness, effectiveness and efficiency of ACIAR's program as well as presenting the data used on the benefits from ACIAR's bilateral research as reported in the IAS series. The Harding et al. analysis did not include the 7 pre IAS studies used by Pearce et al.

[4] The CPI factor to return to 2008$s is division by 1.10 and the compounding factor was 1.22.

[5] The CPI factor to return to 2010$s is division by 1.05 and the compounding factor was 1.10.

The Lindner Studies

The IAS studies have been conducted by many people under varying conditions with respect to data availability, methodology applied and the complexity of technology impacts. Hence it is not surprising that despite ACIAR providing guidelines for impact assessment, there is considerable variation in the quality of the studies across the whole series. Aware that impact assessment reports varied in their plausibility, ACIAR commissioned first, Raitzer and Linder (R&L, 2005) and then Lindner, McLeod and Mullen (LM&M, 2013) to review the reports and rate them for their plausibility with one end result being the identification of a subset of reports, the estimate of benefits from which were convincing, establishing a lower bound estimate of the returns to ACIAR's bilateral research activities. Presumably one reason ACIAR commissioned these two studies was to gain a more independent perspective since CIE undertook many of the IAS analyses. These two studies are referred to from here as the Lindner studies given the common author.

At the time of the R&L (2005) study, 34 reports had been published in the IAS series but only 29 of these made quantitative estimates of economic impact and these 29, covering 53 individual research projects, formed the study pool for R&L. They rated each study according to two overarching criteria – transparency and analytical rigour. They assigned the reports to one of three nested classes – 'potential' which encompassed all 29 reports , 'plausible' (a subset of 'potential') requiring some degree of adoption and reasonable levels of transparency and rigour and 'substantially demonstrated' (a subset of 'plausible') where there was a high degree of certainty attached to the benefit stream.

R&L focussed on those benefits and costs that could be attributed to ACIAR (the third level of attribution) and hence estimates of benefits and costs are not easily comparable with the other studies.

Up to the time of the R&L study, ACIAR had invested $2,062m in its bilateral program (7.8% of which was accounted for by the 29 IASs)[6]. Total potential benefits from the 29 (attributable to ACIAR alone) were estimated to be $6,310m giving an overall benefit cost ratio of 3.1:1 against ACIAR total investment since inception (which fell to 1.3 if only realised total benefits were considered). They estimated that 13.9% of total benefits attributable to ACIAR accrued to Australia ($877m). This ratio is higher than the estimate by Pearce et al. but R&L's attribution process and differences in the study pool make comparisons difficult.

Only 12 of the 29 met R&L's criteria to join the 'Plausible' group but the total benefits from this group at $2,989m still exceeded total investment by ACIAR since inception. Australia's share remained at 14% ($419m).

The most conservative group, the 'substantially demonstrated benefits' group comprised just 7 studies and delivered benefits attributable to ACIAR of $2,709m and a benefit cost ratio of 1.31 against ACIAR total investment since inception. Australia's share of benefits from this group rose to 17.2% ($466m[7]). Nearly 90% of the benefits in this group came from three projects:

- Eucalyptus improvement in China;
- Banana skip biocontrol in PNG;
- Pig genetic improvement in Vietnam and Australia.

Other research areas in the 'substantially demonstrated' group included:

[6] The CPI factor to return to 2004$s is division by 1.25 and the compounding factor is 1.48.
[7] I can't explain why benefits to Australia increase in this scenario. Total benefits are smaller as expected but the share to Australia is large enough to offset this.

- Acacia hybrids in Vietnam;
- Increased efficiency of straw utilisation by buffalo and cattle;
- Pigeonpea improvement;
- Control of footrot in small ruminants in Nepal.

Other research areas in the 'Plausible' group included:

- Australian tree species in China;
- Controlling *Phalaris minor* in the Indian rice-wheat belt;
- Genetics of and breeding for rust resistance in wheat in India and Pakistan;
- Water and nitrogen management in wheat-maize on the North China Plain;
- Identifying the sex pheromone of the sugarcane borer moth.

Other research areas delivering large benefits attributable to ACIAR but in the 'potential' group included;

- Conservation tillage and controlled traffic in China and Australia;
- Development of vaccines for Newcastle disease in Africa and Asia.

The analysis by LM&M (2013), commissioned in 2012 by ACIAR, was to 'update' the R&L study and so has focussed on the IASs from IAS36 to IAS80. While LM&M made some modifications in the criteria used, the intent again was to assess IAS reports where an estimate of economic impact had been made, against criteria encompassing transparency, rigour and extent of adoption and allocate them to three nested classes – 'conceivable', 'plausible' and 'convincing'.

Since R&L, a further 46 impact assessment studies had been completed by late 2012. However, 15 of these impact series reports were dedicated to a continuing review of management practices, frameworks and methodology and were excluded from the LM&M prospective study pool. A further 4 IASs were removed to avoid double counting benefits of bilateral research projects that were assessed in more than one IAS.

The scope of the LM&M study was much broader than that of R&L largely because ACIAR broadened the scope of individual IAS analyses. The main reason for this was a deliberate attempt to mitigate the perception of 'cherry picking' only successful projects to assess, and thereby to provide a more balanced picture of the overall economic impacts of its bilateral research program. One way in which this was achieved was to commission some thematic studies which assessed the economic impacts of a cluster of cognate R&D projects. For instance, the disparate impacts of a total of 17 projects was estimated in the assessment of ACIAR's overall investment in fruit fly research, while the scope of an assessment of benefits to Indonesia and Australia from investment in plantation forestry research encompassed 12 projects.

Partly as a consequence, some studies identified more than one distinct type of research output, with a separate impact pathway from uptake of outputs to outcomes to impacts. For instance, in the fruit fly impact assessment study, independent research outputs were identified that had distinctly different impacts on biosecurity in Pacific Island Countries (PICS), biosecurity in Australia, and field control of fruit fly in several countries that mitigated damage and thereby either reduced production costs or enabled access to new markets. Other outputs also enabled access to new markets, either from innovations in post-harvest disinfestation techniques, or by establishing host free status to the satisfaction of importing countries.

Equally disparate were the challenges of quantifying estimates of economic impacts for each impact pathway, so it is quite possible that some such estimates of benefit streams are more credible than others.

For those impact assessment studies where diverse research outputs with dissimilar impact pathways were identified, the associated quantitative estimates of benefit streams were rated separately. In the ultimate study pool of 27 IAS reports covering 103 bilateral R&D projects, 38 independent quantitative estimates of streams of benefits were specified. Each was rated as either conceivable, plausible, or convincing.

The 2012 present value, PV, of cumulative expenditure by ACIAR alone on these study pool projects was $151m, and the corresponding combined investment by ACIAR and partner organisations was estimated to have been $448m. By 2012, the PV of cumulative investment by ACIAR on all bilateral R&D since inception was $2,517m.

Conceivable benefits

All 38 quantitative estimates of benefit streams that formed the study pool were rated as conceivable benefits. In aggregate, the 2012 PV of all conceivable benefits was estimated to be $30,170m, of which $6,733m were realised in the sense that some level of adoption at been achieved when the impact assessment study was carried out. Overall, the ratio of total conceivable benefits to combined investment in study pool projects was 67:1 somewhat smaller than the estimate in the updated Harding et al. report. The benefit-cost ratio for realised benefits alone was 15:1.

Of the estimated level of total conceivable benefits from study pool projects, $13,195m could be attributed to funding from ACIAR (note that LMM estimated ACIAR's cost share to be 31% whereas Harding et al. (updated) used an average of 50%). This exceeds the ACIAR's cumulative investment in all bilateral R&D since inception of $2,517m[8], so the corresponding benefit-cost ratio is 5.2:1. Realised conceivable benefits attributable to ACIAR of $2,729 also just exceed the cumulative investment by ACIAR in all bilateral R&D.

The benefits to Australia amounted to $1,232 or 4.1% of total conceivable benefits which is over half the total investment by ACIAR in bilateral R&D.

Plausible benefits

Of the 38 conceivable benefit streams only 28 benefit streams were rated by LM&M as being at least plausible.

The PV of benefits rated to be plausible was estimated to be $24,987m (2012 PV), which is approximately one third less than the PV of conceivable benefits. Nevertheless, total plausible benefits exceeded the combined cost of all study pool projects by a ratio of 56:1, while this subset of plausible benefits attributable to ACIAR of $10,771m was 4.3 times larger than all investment by ACIAR in bilateral R&D projects since 1982.

The benefits to Australia that were classed as plausible also amounted to $1,232m or 4.9% of total plausible benefits.

Convincing benefits

Of the 28 conceivable benefit streams rated as being plausible, 15 were then rated as being convincing (Table 1). In aggregate, the 2012 PV of all convincing benefits was estimated to be $22,995m of which $5,303m were realised. Overall, the ratio of total convincing benefits to combined investment in study pool projects was 51:1, and the benefit-cost ratio for realised benefits alone was 12:1. Of these total and realised benefit flows, $10,098m and $2,358m respectively could be attributed to funding from ACIAR. The ratio of

[8] Harding et al. (Updated) estimated that ACIAR's investment in the bilateral program had been $3.1m (PV2012$s). LM&M used data back to 1982 when ACIAR began. I can't explain this difference.

ACIAR convincing benefits to ACIAR study pool costs and investment by ACIAR since 1982 were 103:1 and 4.3:1.

The flow of benefits to Australia classed as convincing amounted to $1,101 or 5.1% of total convincing benefits.

Table 1: Benefits and Costs from ML&L's Convincing set of IAS's

Report	Benefit Stream	Benefits ($m)		Costs ($m)		B/C ratio
		Total	ACIAR	Total	ACIAR	
36	Mudcrab hatchery technology in Vietnam	24	8	7.0	2.3	3.4
43	Irrigation water management in Vietnam	74	50	4.3	2.9	17.4
46	Bee mite pest control in Australia	161	108	8.2	5.5	19.7
47	Improved tree species in Vietnam	203	111	2.6	1.4	19.7
52	Pig breeding in Vietnam	4,206	1,648	45.2	17.7	118.1
52	Pig feeding in Vietnam	1,135	445			
56	Fruit fly biosecurity benefits to Australia	67	30	70.8	32	1.6
56	Fruit fly post-harvest benefits in Pacific and Australia	47	21			
57	Endoparasite control in goats in Philippines	48	4	8.5	0.7	5.6
59	Grain drying in the Philippines	0	0	6.0	3.9	0
62	IPM in stored grain in Philippines	2,508	1,812	14.1	10.2	177.4
71	Indonesian Forestry - sandalwood in Australia	936	373	44.1	17.6	323.9
71	Indonesian forestry - Australian trees in Indonesia	13,354	5,320			
75	Rice yields in Laos	128	105	0.9	0.7	144.6
80	Oil palm in PNG	105	64	4.7	2.9	22.4
	Total	**22,995**	**10,098**	**216**	**98**	**103.0**

Benefits to Australia

There were 4 streams delivering benefits to Australia comprising:

- Biosecurity gains from understanding mite pests of honey bees (IAS46) ($161m);
- Incorporation of ICRISAT germplasm in Australian sorghum breeding program (IAS48) ($131m);
- Access to Japanese mango market through post harvest treatment of fruit fly (IAS56) ($4m);
- Development of the sandalwood industry in Ord River (IAS 71) (($936m).

Only one of these benefit streams, sorghum germplasm, was not classed as being convincing but rather, plausible. The total flow of benefits to Australia classed as convincing, $1,101m, while almost half ACIAR's investment in bilateral R&D since 1982, easily exceeded the investment by ACIAR of $151m in the set of IAS under review here.

As has been found in previous studies, a small number of highly successful projects 'carried' the rest. Three benefit streams – the use of Australian germplasm in Indonesian forestry, pig breeding in Vietnam and IPM in stored grain in the Philippines – accounted for 73% of all conceivable benefits, 89% of plausible benefits and 93% of convincing benefits. Two other smaller benefit streams associated with these – sandalwood in the Ord and pig feeding in Vietnam – were also convincing, so that nearly all convincing benefits derived from these three research clusters. Unfortunately there is no science allowing identification of these 'gushers' ex ante.

The findings here that the returns to ACIAR's investment in bilateral research are high are consistent with Raitzer and Lindner, the forerunner to this analysis, and with the CIE analyses of the benefits to Australia from the bilateral program. They are also consistent with a large body benefit cost analyses at a project level (reviewed by the Productivity Commission (2011)) and econometric studies at an aggregate level (Alston et al. (2010) for the US and Sheng et al. (2011) for Australia).

Summarising the CIE and Lindner studies

It is very difficult to assess the level of consistency between the CIE studies and the Lindner studies. The Lindner studies focussed on benefits and costs attributable to ACIAR and unfortunately the stream of total benefits and costs associated with the study pool would be difficult to derive without extensive reworking of the R&L data. If this were done benefits and costs could be aggregated over the R&L and LM&M studies and compared with CIE estimates for both total benefits and benefits to Australia.

The two sets of studies are consistent in their assessment that the returns to ACIAR's bilateral research program have been high. Investment in the projects assessed in the IAS series is easily covered (by a multiple of 80 according to the updated Harding et al. analysis and by almost 70 according to the ML&L analysis). Moreover the benefits both in total and those attributable to ACIAR exceed the total investment in the bilateral research program since 1982 even when benefits are restricted to those that are 'substantially demonstrated' in R&L's terms or 'convincing' in LM&M's terms[9].

The flow of benefits attributable to ACIAR from the seven benefit streams classed by R&L as 'substantially demonstrated' amounted to $2,709m (compounded forwarded and expressed in 2012 $s). In this study 15 benefit streams were classed as 'convincing' and delivered $10,098m in benefits attributable to ACIAR. These two benefit streams can't be simply aggregated because the benefits of pig breeding and feeding research in Vietnam are included in both streams. In IAS17, the estimated benefit of this project was $475m (2012 $), and the net value of substantially demonstrated benefits in R&L after deducting this sum was $2,234m. When this net amount attributable to ACIAR is added to the estimate in this study of $10,098m of 'convincing' benefits, the aggregate value of highly credible benefits is $12,332m, which exceeds ACIAR's total investment in bilateral R&D of $2,517m by a factor of 4.9:1. In our view this represents a lower bound estimate of the returns to ACIAR's investment in bilateral R&D since 1982.

R&L's estimates of benefits to Australia from their potential and substantially demonstrated classes were $877m and $466m respectively. The Australian benefits estimated by LM&M for the equivalent classes were $1,295 and $1,164m respectively. Duplication between these studies the benefit estimates is a problem although it may not be significant. The benefits to Australia across both studies which are classed as conceivable and convincing might be in the order of $2,000m and $1,500m respectively, about 20% less than the estimate in the updated Harding et al. report.

It seems to me that the best estimates of the flow of benefits to Australia from ACIAR's bilateral R&D program come from the updated Harding et al. report of December 2011. As already noted their estimate of the total flow of benefits to Australia was $2,550m (from the first 75 IAS reports), which was 7% of total benefits. This estimate is higher than the level of benefits suggested by the Lindner studies but not disturbingly so. Total investment by ACIAR in the IASs covered was $439m and total investment in bilateral R&D since 1982 was $3,100m which is considerably more than the estimate of $2,367m used in the LM&M

[9] The benefit cost ratio is less than one for a few scenarios where only realised benefits are considered.

study. Considering these differences it seems probable that the benefits to Australia from the set of IASs to date come close to matching ACIAR's total investment since 1982.

Brennan's Evaluations of Australian Benefits from ICRISAT, ICARDA and CIMMYT

In addition to its funding of bilateral research projects, ACIAR also has a multilateral funding programme. In 2011the Government established the Australian International Food Security Centre with an initial focus on establishing food security in Sub-Saharan Africa. Prior to that, the main focus of the multilateral programme was support of the International Agricultural Research Centres (IARCs) such as ICARDA, CIMMYT and ICRISAT (about 15 in total). In recent years ACIAR has been spending about $10m per year on this program split between core funding and support for specific projects.

John Brennan and colleagues (1999, 2002, 2004) assessed the benefits flowing to Australia from its support of ICARDA (International Centre for Agricultural Research in Dry Areas), CIMMYT, (International Maize and Wheat Improvement Centre) and ICRISAT, (International Crops Research Institute for the Semi-Arid Tropics). Their findings are summarised in Table 2 where the annual benefit flows, largely derived from the use in Australia of germplasm from the three IARCS, has been expressed in PV 2012 $s. The annual flow of benefits might be in the order of $97m per year with most going to Australian farmers.

It is very tempting to draw an inference that for an annual investment in the IARCs of around $10m, Australia can expect an annual flow of benefits in the order of $100m or a benefit cost ratio of 10:1. While this may prove to be a good ballpark estimate of the returns Australia might expect from this level of investment in the IARCs, this ballpark estimate should not be applied without at the same time acknowledging significant qualifications, both positive and negative, that need to be made.

Table 2: The annual benefits to Australia from ACIAR's funding of the IARCs ($m2012)

		Producers ($m)	Consumers ($m)	Australia ($m)
CIMMYT	Wheat	59.8	0.2	60.0
ICARDA	Barley	4.2	1.4	5.5
	Durum	-2.8	0.7	-2.1
	Chickpeas	2.5	0.2	14.1
	Faba Beans	13.9	0.2	14.1
	Lentils	11.3	0.0	11.3
	Total	**29.1**	**2.5**	**31.7**
ICRISAT	Sorghum	-1.8	5.6	3.8
	Chickpeas	-2.7	3.9	1.3
	Total	**-4.5**	**9.5**	**5.0**
Total		**84.4**	**12.2**	**96.7**

Source: Table extracted from Brennan reports and rebased to $m2012. The CIMMYT, ICARDA and ICRISAT reports were expressed in 2003, 2001 and 1996 $s and the CPI factors to convert these amounts into 2012$s were 1.28, 1.35 and 1.5 and the compounding factors to arrive at present values were 1.55, 1.71 and 2.18.

First, Brennan and colleagues focussed on a subset of benefits amenable to economic analysis, in particular the economic benefits from a flow of genetic material from these IARCs. Australia may also have received benefits from its support of these IARCs in the form of improved crop management practices which may have delivered productivity gains and better environmental outcomes and in the form of gains in scientific capacity leading to economic impacts in later times. These benefits were not valued by Brennan and colleagues. Note also that benefits to the developing countries from ACIAR's support are not valued although alleviating poverty in these countries is valued by Australia.

Second, these studies were undertaken in 1999, 2002 and 2004 and in many cases the benefit streams were prospective in that, while IARC germplasm was being used in Australian breeding programs, few varieties in the field contained IARC germplasm with the notable exception of wheat varieties from CIMMYT. Moreover while they expressed benefits as an annual stream, these annual flows were initially derived from particular technologies with defined time horizons. In preparing this paper we informally contacted key people involved in Australia's crop breeding programs for their views about the continuing contribution of germplasm from the IARCs. It would seem that the prospective benefits identified by Brennan and colleagues did materialise and new material has been introduced which is likely to be used with Australian germplasm and germplasm from breeding programs in other countries in developing varieties for use by Australian farmers.

However some breeders warned that the IARCs sometimes overstate their contribution to the Australian industry (consistent with some of Brennan's findings that other countries have gained greater benefits than Australia).

Hence it seems timely to update the reports to assess the extent to which these prospective gains have been realised and to assess where future benefit streams have already or are likely to arise.

Third, none of these studies claim to be cost benefit analyses because there was no process of directly linking ACIAR's investments, some of which take the form of core funding, to a set of outcomes directly attributable to these investments, as in, for example, the impact assessment reports where the investment in a set of specific projects is related to the benefits of a technology flowing from those projects. Rather Brennan and colleagues have sought to identify a gross flow of benefits to Australia from IARC activities. Some ways in which these flows of benefits may have been understated were identified above. However a more rigorous cost benefit analysis would require identifying what share of this benefit flow that can be attributed to ACIAR's investment, what share of benefits would have flowed to Australia in the absence of ACIAR's investments and the domestic investment in research and extension necessary to adapt IARC technologies to forms ready for adoption on Australian farms.

An important contribution by Brennan and colleagues was an improved understanding of how Australian farmers are affected by new technologies developed by the IARCs through their impact on world prices as well as yields.

The issue to be aware of is that for some of these crops, Australian farmers actually lost because the yield gains (cost savings) that they were able to achieve were less than the fall in world prices driven by higher yields achieved by their competitors. So, referring to Table 2, Australian grower were made worse off by the efforts of ICARDA and ICRISAT in developing varieties for durum, sorghum and chickpeas which delivered larger yield gains in developing countries than in Australia. However, the gains to Australian consumers (often in the livestock sector) in the form of lower prices were generally large enough to offset the losses to producers, delivering substantial net gains to Australia.

Brennan and colleagues made the important observation that these losses would have been much larger had the technology not been available at all to Australian farmers. In the later CIMMYT analysis, Brennan et al. went a step further and estimated benefits to Australia under two scenarios – the scenario used in the earlier reports of the gross flow of benefits to Australia from the use of CIMMYT varieties and also the scenario of the impact on Australia of CIMMYT activities were there no flow of germplasm to Australia. In this second scenario Australia does not take advantage of yield gains but does suffer the lower world wheat price.

Under the first scenario Australian growers lose almost $52m because yield gains are smaller in Australia than in other countries using CIMMYT varieties and are offset by a decline in the world price for wheat occasioned by these yield gains. However had CIMMYT varieties not been introduced to Australia the losses to producers would have been about $112m. Hence the net gain to Australian producers from using CIMMYT varieties is $59.8m (Table 2). Consumers gain about $24m under both scenarios so their net gain is small.

The CIMMYT analysis suggests that by not considering the scenario where there was no flow of germplasm from ICARDA and ICRISAT, Brennan and colleagues are likely to have significantly understated the net benefits from ACIAR's support of these two IARCs, as they warned.

In assessing net benefits to Australia, the other dimension of the counterfactual is the extent to which IARC germplasm would have made its way to Australia if ACIAR had not supported the IARCs. The scenario examined by Brennan and colleagues of zero flow of germplasm is somewhat extreme. Nevertheless, it would seem that without the ongoing formalised pathway between the IARCs and Australian research institutions which ACIAR support has required, the flow of germplasm to Australia would likely have been irregular and haphazard. The opportunity for Australian scientists to work collaboratively with IARC scientists is particularly important for the small crops where issues of critical mass in research resources are likely. Hence a large share of the net gains to Australia identified in the IARC analyses can properly be attributed to ACIAR.

The Benefits to Australia from ICRISAT

ICRISAT, founded in 1972, conducts research into its mandate crops – sorghum, millets, chickpeas, pigeon pea and groundnuts. In 1994-95 Australia contributed $26m to the CGIAR system with about $1.7m to ICRISAT. Brennan and Bantilan found that benefits to Australia in the immediate future were only likely to derive from the sorghum and chickpea research programs and they attempted to quantify these expected benefits. They pointed out that they did not attempt to capture the benefits at the more basic end of the R&D spectrum in terms of the value of ICRISAT's role as a source of germplasm for these mandate crops.

At the time of their report Brennan and Bantilan found that the pigeon pea industry was very small in Australia and that while there were somewhat larger millet and groundnut industries there was little evidence of links with ICRISAT. While at that time there was little evidence of ICRISAT material in sorghum and chickpea varieties then being grown, ICRISAT material was being used in breeding programs and hence was likely to deliver benefits in the future to Australian growers. ICRISAT material was expected to deliver improved midge resistance in sorghum with average yield gains of about 2.5%. In the WA chickpea industry ICRISAT material was expected to give yield gains of about 10% through varieties with increased cold tolerance. In eastern states ICRISAT material was expected to deliver just over 2% in yield gains.

However ICRISAT varieties have been adopted across the SAT region and hence led to falling world prices. Because Australian farmers haven't experienced the same yield gains as others in the SAT, the cost savings to Australian farmers from the higher yields are likely to have been more than offset by lower world prices. As noted above the negative results for Australian producers (Table 2) are likely to be reversed when consideration is given to larger losses were no ICRISAT germplasm used in Australia.

The Benefits to Australia from ICARDA

ICARDA was established in 1977 at Aleppo, Syria and its research covers the countries of Central and West Asia and North Africa which have environments similar to parts of eastern and western Australia. Brennan et al. (2002) reviewed flow of benefits from ICARDA to Australia. Like ICRISAT, while ICARDA has a wide range of research interests including the management of farming systems and the management of natural resources such as water, it is responsible for developing improved varieties of lentil, barley, faba bean, durum and chickpeas. Brennan et al. focussed on the benefits from a flow of ICARDA germplasm to Australia.

ICARDA barley germplasm is expected to deliver greater drought tolerance and hence be of benefit in the drier areas of South Australia and Victoria with alkaline soils. ICARDA germplasm was being used in the Australian durum breeding program and was expected to be incorporated in new varieties released over the following 10 – 12 years. For chickpeas, the ICARDA germplasm was expected to deliver ascochyta blight resistance into kabuli chickpeas then being used in Australia. The benefit to faba beans was expected to come through better resistance to chocolate spot and a consequent reduction in the use of fungicides. All lentil varieties used in crop rotations in the Wimmera and Mallee regions of Victoria and South Australia are based on ICARDA varieties.

At the time of their report, most of the benefits to Australia from ICARDA identified by Brennan et al. were prospective in nature (as for ICRISAT). They did not disclose ACIAR's investment at that time either in ICARDA or in the IARCs in total.

The Benefits to Australia from CIMMYT

CIMMYT, located in Mexico, aims to improve the productivity and sustainability of maize and wheat systems for poor farmers in developing countries. Semi-dwarf wheat varieties, which have made a major contribution to reducing poverty, were largely developed by CIMMYT. Brennan and Fox (1995) estimated that by 1994 over 90% of area sown to wheat in Australia was sown to semi-dwarf varieties, worth almost $240m per year for the period 1974 to 1993.

Unlike the situation for ICARDA and ICRISAT, at the time of the analysis of the benefits to Australia from CIMMYT by Brennan and Quade (2004), benefits were being realised (as opposed to being prospective) because the first semi-dwarf varieties based on CIMMYT material was released in 1973. 'By the end of 2003, 193 varieties had been released in Australia incorporating CIMMYT genetic material, either as direct CIMMYT introductions (3%), Australian varieties using a CIMMYT line as a parent (20%), or Australian varieties with some CIMMYT ancestry in at least one of the parents (77%)' (Brennan and Quade, p.vii). The important contribution of Australian breeding programs to adapting the CIMMYT material is also clear from these figures. Capturing spillover benefits from IARCs like CIMMYT requires not only investment in the IARCs but also strong domestic research institutions.

Brennan and Quade estimated that by 2001 yield gains attributable to CIMMYT averaged 4.6% across Australia. However they also noted that world wheat yields from CIMMYT germplasm increased on average by 12.2%. World wheat prices were estimated to be 7.4% lower which meant that before considering what would happen had Australia not used CIMMYT material, Australians growers would have been worse off. Had Australia not acquired the CIMMYT material, the costs to Australian growers would have been even larger (Table 2) because they would have experienced the price falls without the benefits of the yield gains. Hence there have been substantial net gains to Australia, of almost $60m per year, from the use of CIMMYT material.

Brennan and Quade (2004) noted that ACIAR's funding of CIMMYT activities averaged about $2.0m per year. It seemed as though other Australian institutions including the GRDC made contributions almost as large (Appendix B in Brennan and Quade).

Comparing the Benefits to Australia from ACIAR's multi- and bilateral R&D Programs

As indicated by the discussion to date, there is no easy way to add up the benefits to Australia from the bilateral and multilateral research programs funded by ACIAR. The types of analysis are quite different. Brennan and colleagues set out to estimate benefits to Australia from IARC research activities particularly with respect to advanced crop germplasm. They did not attempt to attribute a share of the flow of benefits to Australia to ACIAR funding as done in a traditional benefit cost analysis nor did they consider the costs in Australia of incorporating IARC germplasm into Australian varieties. Their studies are now quite dated but presuming that more recent IARC research has maintained this flow of benefits estimated by Brennan and colleagues, it seems highly likely that the returns to this investment are high. One reason to expect this is that the adoption path for technologies based on new varieties is relatively easy compared to many other forms of technology, those that are highly information or management intensive for example. A key finding of these studies was that sometimes Australian producers have not been able to achieve similar yield gains to other countries and hence suffered losses from falls in world prices. However these losses would have been much greater had Australian producers not been in a position to utilise the IARC germplasm.

The CIE and Lindner studies of ACIAR's bilateral program focussed much more narrowly on the IAS series which accounted for less than 10% of the bilateral program. Nevertheless these analyses demonstrated that the total benefits from the sample of projects assessed far exceeded both the cost of the set of projects and also ACIAR's total investment in bilateral research since 1982. Unfortunately the databases used in the CIE and Lindner studies were different and hence estimates of costs and benefits were slightly different. Despite these differences it was clear that there was strong flow of benefits to Australia from the bilateral program which clearly covered the costs of the set of projects assessed and almost exceeded ACIAR's total investment in the bilateral program since 1982.

It needs to be remembered that no attempt was made in either the multilateral or bilateral studies to comprehensively quantify all possible benefits. In particular, benefits from new knowledge and capacity building typically were not estimated, and social, human health, and environmental benefits were also not quantified.

The Benefits to Australia from ACIAR's Support of CABI

CABI, formerly the Commonwealth Agricultural Bureaux provides a range of services to agricultural institutions around the world. Quite a few agricultural research institutions in Australia subscribe to CABI publishing services. Pearce and Monck (ACIAR IAS 42, 2006) estimated a value for two widely used CABI products – CABI Abstracts, a comprehensive bibliographic abstracting and indexing database covering the applied life sciences, and CABI Compendia, an encyclopaedic-type reference presenting forestry, crop protection, animal health and aquaculture information using multimedia tools.

Information services like the CABI products are inherently difficult to value. Pearce and Monck based their valuation on estimates from surveyed scientists about time saved reviewing literature from using CABI products rather than alternative information services. At least conceptually these gains in efficiency in research processes lead to an increase in the rate of return to agricultural research.

Pearce and Monck estimated the value to Australia of these CABI products ranged between $2.2m and $3.5m per year (in 2012 PV terms).

While these gross benefits to Australia from CABI are significant, at this stage we have little basis on which to make a judgement about the role ACIAR has played in gaining access to these benefits. My understanding is that research institutions pay a subscription to access CABI products and so these subscriptions must be deducted to arrive at a measure of net benefits.

Presumably ACIAR makes a contribution to core funding. Core funding may allow CABI to reduce subscription rates and hence encourage marginal users to sign up as well as giving a cost saving to inframarginal users. At present we have no data on which to base an estimate of these cost savings. It is worth noting that the benefits of ACIAR's core funding flowing to all users of CABI products, not just Australian users.

The Importance on Continuing Productivity Growth in Australian Agriculture

Much of the material here is taken from a paper by Mullen (2012) for the Australian Farm Institute.

Productivity growth has contributed strongly to growth in output in Australian agriculture, as is highlighted in Figure 1. It shows that in the absence of productivity growth over the past 60 years, the current gross value of production for the Australian agricultural sector would only be approximately A$12 billion per annum, rather than more than A$40 billion. It also highlights that more than 70% of the value of agricultural production in 2010 could be attributed to past productivity growth, based on estimates that the average rate of productivity growth in Australian agriculture has been 2% per annum since 1953.

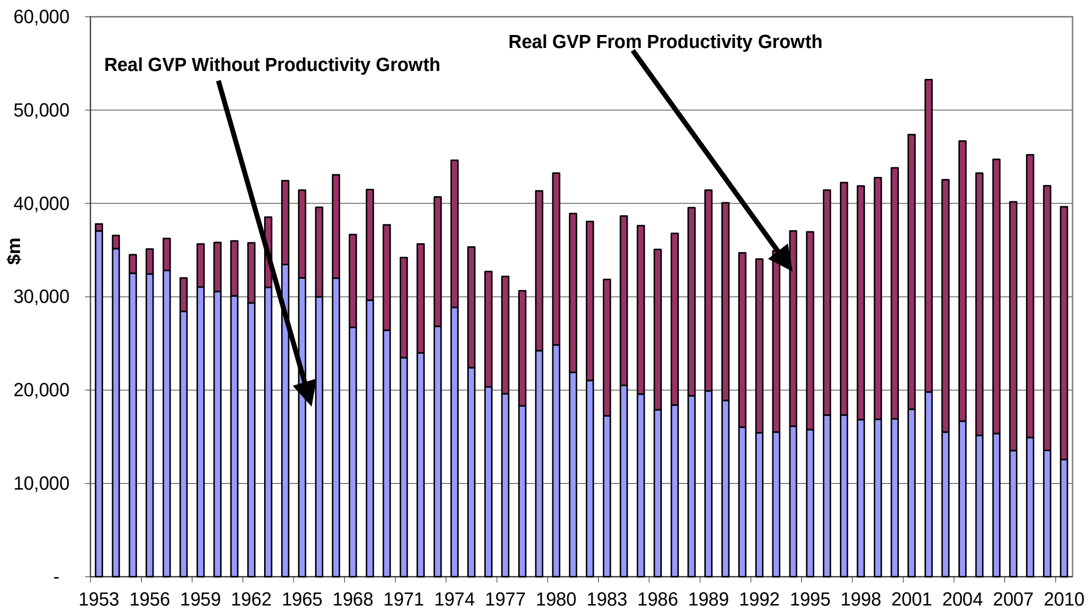

Figure 1: The value of productivity growth (2%) to Australian agriculture, 1953–2010 (A$2010).
Source: Derived by the author from ABARES data in *Australian Commodity Statistics.*

Whilst this past performance by the sector is impressive, there is growing concern that the rising value of the Australian dollar and the strength of the mining sector threaten the future competitiveness of Australian agriculture. In addition there is evidence that productivity growth has slowed, not just as a result of poor seasons but also because of declining levels of public investment in agricultural research and development (R&D). There are also concerns that growth in agricultural productivity may be eroded by accelerating climate change, which some expect will impact on Australian agriculture to a greater degree than on other agricultural exporters.

Trends in TFP in broadacre agriculture

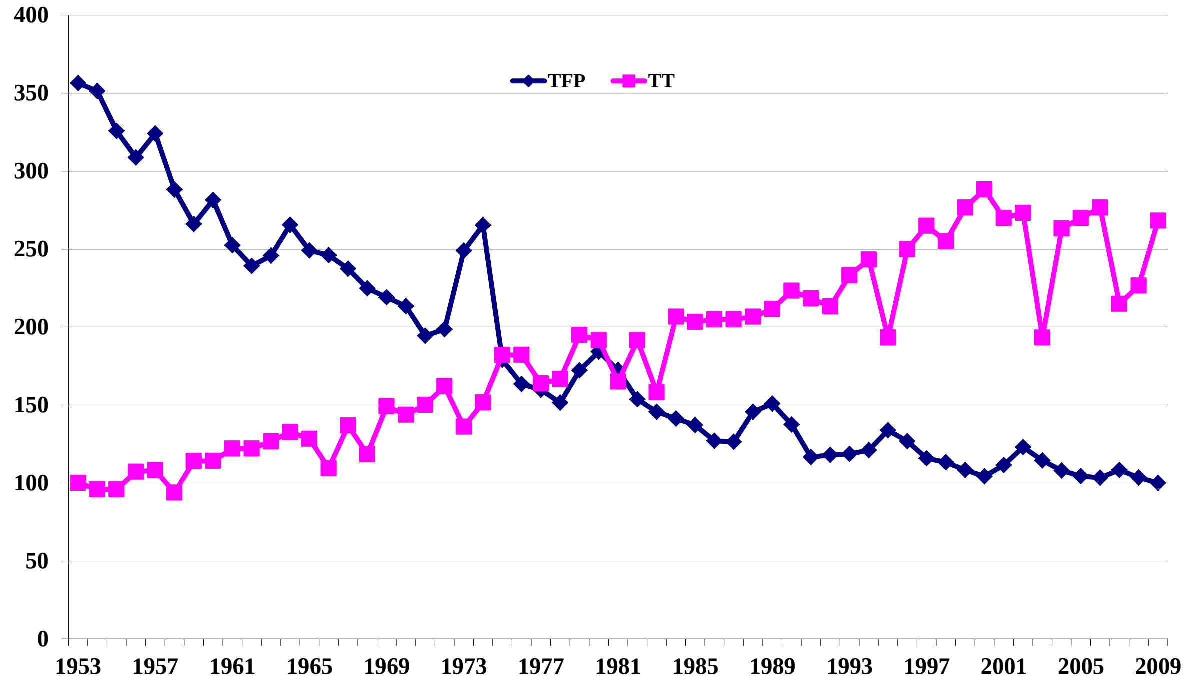

Figure 2:TFP and TT in broadacre agriculture, 1953–2009 - Source: Derived by the author from ABARES data.

ABARES has conducted farm surveys over many years for broadacre agriculture, encompassing the extensive grazing and cropping industries (but not horticulture, intensive livestock or irrigated agriculture), and for dairying. Data from these surveys are used to follow trends in productivity using gross output measures. Most broadacre farms in Australia jointly produce several crop and livestock commodities and hence TFP must be measured at a whole farm level.[10]

TFP for Australian broadacre agriculture increased almost threefold, from an index of 100 in year 1953 to 288 in 2000 (Figure2). It then declined to 193 in 2003 and 215 in 2007 reflecting particularly poor seasons in a run of poor years before increasing to 268 in 2009. The series is highly variable, falling in 21 of the 57 years, reflecting seasonal conditions. Such variability makes it difficult to discern trends in the underlying, more stable rate of technical change. The average annual rate of TFP growth over the entire period was 1.9% per year, about 0.5% per year lower than the long-term rate previously reported (in Mullen 2007, for example).

[10] ABARES monitors the productivity of segments within broadacre agriculture – such as specialist sheep producers or specialist crop producers – but does so using stratified samples from their overall farm survey still at a whole farm level.

TFP grew at the rate of 2.2% per annum from 1953 to 1994 but since 1994 there has been no significant growth in TFP and since 2000 when drought condition became particularly severe, the rate of growth of TFP was -1.2% per annum (Sheng et al. 2010). In examining possible reasons for these changes, it was found that while poor climatic conditions over the 2000s decade were an important contributor, the slowdown in public investment in R&D since the 1970s (discussed further below) had also made a significant contribution.

TFP and terms of trade

Changes in TFP can be compared with changes in the terms of trade faced by farmers as a partial indicator of whether Australian agriculture is becoming more or less competitive. The conventional wisdom is that the terms of trade facing Australian agriculture have been declining inexorably. However, while the terms of trade declined for about 40 years from 1953 (Figure 3), since the early 1990s the rate of decline has been much slower. While the TFP index grew from 100 in 1953 to 268 in 2009, the terms of trade index declined from about 355 to 100, at a rate of 2.2% per year over the period 1953 to 2009. This decline was faster than the rate of productivity growth in broadacre agriculture. The rate of decline in terms of trade was 2.6% per annum from 1953 to 1990, but over the period from 1990 to 2009, it slowed to 1.1% per annum. Rates of productivity growth for the corresponding periods were 2.5 % and 0.1%.

Without the benefit of a decomposition of TFP back to 1953 (as outlined by O'Donnell, 2010 and Hughes et al., 2011) it seems likely that because growth in TFP has largely been offset by the decline in the terms of trade, there has been little change in the profitability of the sector as a whole (from the equation above). This may explain in part why the real value of agricultural production has hovered around the A$40 billion mark consistently for only the last decade. It may also be that the profitability of broadacre agriculture has declined, but is being offset in gross agricultural output data by stronger productivity growth rates in the non-broadacre sectors.

Correcting TFP measures for climate variability

Properly accounting for climate variability is critical to correctly assessing the relative importance of technical change and technical efficiency in Australian farm productivity data. Hughes et al. (2011) pointed out that unless climate variability (estimated using soil moisture data) was properly accounted for, the extent of technical inefficiency was likely to be overstated. Once adjusted for climate, TFP growth series appears to be less variable. It seems likely that were the series in Figure 3 adjusted for climate, it would have fluctuated more narrowly around the 250 level since about 1993 showing little growth since then.

Upon decomposing their adjusted TFP series, Hughes et al. (2011, p. 35) found that for the period 1978 to 2008, climate adjusted TFP and TC for broadacre cropping agriculture in Australia both grew at an annual rate of 1.53% with a decrease in technical efficiency of 0.31% exactly offset by a gain in scale and mix efficiency. However since 2000 climate adjusted TFP has only grown at a rate of 0.24%. Technical change has grown a little more strongly at the rate of 0.4% per year. This slowdown is consistent with Sheng et al. findings.

It is quite concerning, because it suggests that if climate variability has been fully accounted for, it is unlikely that productivity growth will return to a rate anywhere close to 2% (as experienced from 1978 to 2000), especially given the continuing decline in public investment in agricultural R&D. The slowdown is more pronounced in western and northern regions as compared to the southern region (GRDC regions).

Moreover they found that since 2000 gains from technical change were offset to a considerable degree by a decline in technical efficiency. Together trends in these two measures mean that: 'while farms overall are improving, the average farms have not been able to improve at the same rate as the best farms' (Hughes et al. 2011, p. 34). Despite this declining trend, the level of technical efficiency across regions and farming types averaged 0.8 suggesting that Australian broadacre cropping farmers have been reasonably close to the production frontier.

The relative contribution of technical change and technical efficiency to productivity growth has potentially important policy implications with respect to the proportion of funds devoted to R&D (with the aim of shifting the production frontier) compared to extension (aiming to move more farmers towards the frontier). Hughes et al. (2011) found that while technical change made the largest contribution to TFP growth since 1978 (1.53%), the level of technical efficiency has been drifting down at the rate of -0.31% per year and this rate of fall becomes significant relative to the much smaller rate of technical change since 2000 (0.4%).

Having assessed past trends in broadacre TFP and its components, the focus turns to key issues that are likely to affect TFP in the future and the competitiveness of agriculture within the Australian economy and relative to the agricultural sectors in other economies. The set of issues reviewed here include the implications climate change might have for productivity growth, the importance of investment in R&D for productivity growth and external factors – such as trends in the terms of trade, the growth of the mining sector and the exchange rate – which are likely to influence the prosperity of agriculture in the period to 2030.

The Relationship between Research and Development and Productivity in Agriculture

The Productivity Commission (PC) (2011) now accepts that investment in agricultural R&D in Australia has made a significant contribution to agricultural productivity growth. The original econometric analysis for broadacre agriculture by Mullen and Cox (1995) estimated that from 1953 to 1988 the *rate of returns* from public investment in R&D had been in the order of 15–40%. The most recent updating of that analysis by Sheng et al. (2011), using a longer dataset, accounting for foreign 'spill-ins' of technology and a research strategy adapted from Alston et al. (2010), estimated a rate of return of nearly 30% from their preferred model. The analysis also confirmed that there are long lags of the order of 35 years from the commencement of research and when its impact becomes small

These aggregate econometric studies are also consistent with the many reputable benefit cost analyses at a project level conducted in Australia by state departments of agriculture and by private consultants for the Research and Development Corporations (RDCs). Much of this material is referenced in the recent report from the Productivity Commission (2011) and Mullen (2011). Prevailing high rates of return to research provide strong support for the longstanding hypothesis that there remains some degree of underinvestment in agricultural research in Australia.

Despite this strong evidence of the contribution of public R&D to agricultural productivity growth, public support for R&D has been declining since the 1970s. The way in which the data on R&D investment have been assembled from ABS sources and from a previous dataset developed by Mullen et al. (1996) is described in Mullen (2007). Expenditure was attributed to research providers, rather than funders. As a result, expenditure by state departments of agriculture or universities, for example, includes funds obtained from rural RDCs. Attention was focused on the expenditures for *socio-economic outcomes*[11] related to farm production but investment in R&D for the fisheries, forestry, environment and processing of farm products

[11] As defined by the ABS classification of R&D activities

socio economic objectives was not included. The GDP deflator was used to express investment in R&D in 2010 dollars.

Total public expenditure on agricultural R&D in Australia grew from A$146 million in 1952–53 to almost A$1000 million in 2000–01 before declining markedly to A$716 million in 2008–09 (in 2010 dollars) (Figure 3). Expenditure growth was strong to the mid-1970s but has essentially been static since that time although there was a spike in investment in 2001. Likewise, agricultural research intensity, which measures the investment in agricultural R&D as a percentage of GDP, grew strongly in the 1950s and 1960s, but has been drifting down from about 4.0–5.0% of agricultural GDP in the period between 1978 and 1986 to about 3.5% in recent years (as compared to 2.4% per annum in developed countries). Private sector investment in R&D has been rising but Keogh et al. (2011) finds that private sector R&D investment is complementary to public sector R&D investment in Australia, rather than a substitute.

As already noted Sheng et al. (2010) found that this slowdown in R&D investment (along with poor seasonal conditions) contributed to the slowdown in broadacre TFP growth. This slowdown is a response to recent decades of stagnant public sector R&D investment, and the long time-lags associated with returns to such investment noted above.

Despite this finding and the consistent findings of high returns to agricultural research investment in Australia, public investment in agriculture remains under threat with the recent PC (2011) report recommending a halving of the RDC levy because it doubts that the matching grant has called forth much additional research from industry.[12] It expects that were the government to reduce the Gross Value of Agricultural Production (GVAP) cap for a matching grant to 0.25%, the RDCs would increase their levies to offset this reduction. In other words The PC holds the view that public sector is ‘crowding out’ industry investment.

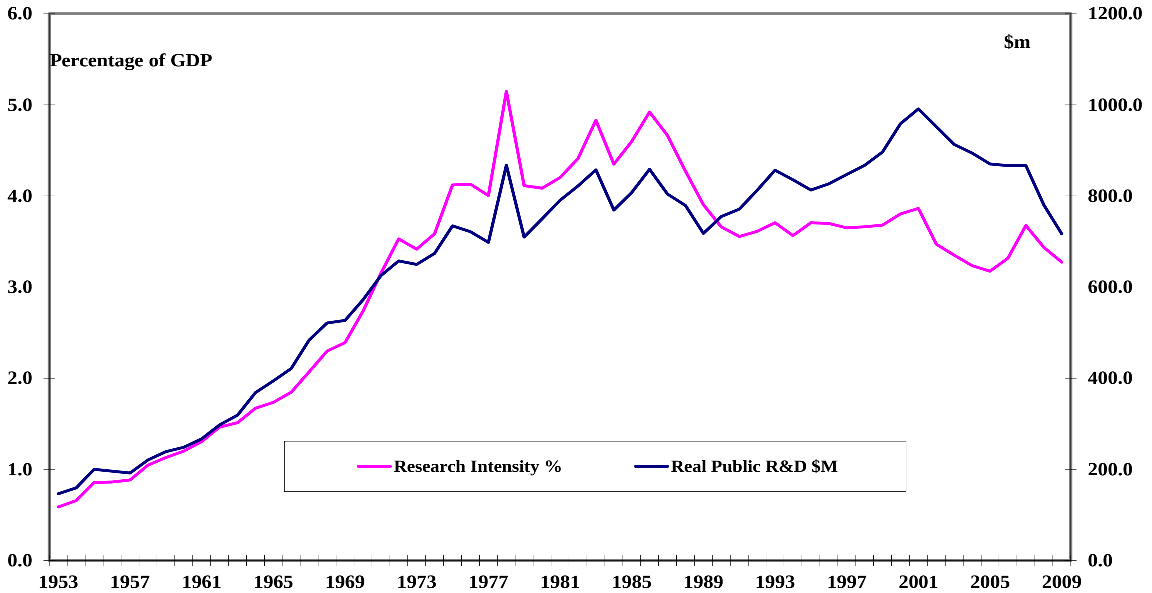

Figure 3:Real public investment and research intensity in Australian agricultural R&D.
Source: Derived by the author from various public sources including ABS R&D data.

[12] The PC argument is also based partly on a contested assessment, not pursued here, that public support for agricultural research is much higher than for research in other sectors.

Mullen (2011) reviewed the ‘crowding out’ hypothesis and suggested that such a scenario would most likely be typified by low rates of return to research and pressure to reduce levy rates. Observed high rates of return are only consistent with crowding out in the unlikely scenarios of either sharply diminishing returns to future research and/or constraints on the supply of research services. The PC provides little empirical evidence to support their recommendations.

Moreover there seem to be good reasons why RDCs will face resistance to increases in R&D levies. It should not be surprising that farmers understate their true willingness to pay for research under the common uniform levy of the RDC model (see Alston and Fulton, 2012). Remaining incentives to ‘free ride’ are complemented by heterogeneity in the resource endowment of farms and in the applicability of particular technologies. In addition the long lags in the development of new technologies may be a disincentive to increasing levies. This disincentive arises not only because farmers may not receive any benefits in their working life but more likely because they do not appreciate the contribution to their present farming system of past research efforts nor foresee how present research efforts may change farming systems decades hence. Some of these arguments are noted in the PC report. The PC also argued for a stronger culture of impact assessment within research institutions so that stakeholders could be persuaded of the benefits from their investments and research funds be allocated to higher returning activities.

Sheng et al. (2011, Table 7, p. 34) examined the consequence for productivity growth under various scenarios about the future funding of R&D. Their scenarios were based on real public investment in agricultural R&D in 2007[13] and the elasticity of TFP with respect to research knowledge stocks. One scenario involved increasing research investment permanently by 10% (A$170m) from 2008 and assuming that the growth rate for TFP started at its long-term average of 1.96%. Given the long lags, it is not surprising that the growth rate in agricultural TFP only increased to 2.02% for the period to 2020. Only when lag effects to 2050 were accounted for did the long-term growth rate average 2.09%, which remains a small response.

Since 2007 public investment has fallen by about A$150 million in real terms which is close to a decrease of 10%. Were this to be a permanent decrease then it might be expected the rate of growth in TFP to be less than 1.9% per annum.

Sheng et al. also examined scenarios where R&D was maintained at 3.1% of the Gross Value of Agricultural Production (GVAP) (the level of research intensity[14] attained in 1978). Under this scenario (based on ABARES projection of GVAP to 2015), TFP growth might be expected to increase to an average rate of about 2.4% per year once the long lag effects began to be of influence (after 2020). However, such an R&D intensity would have implied an important increase of the level of R&D investment (from A$866 million to A$1.245 million in 2007 and from A$717 million to A$1299 million in 2009). Hence it would seem that to achieve a growth in TFP approaching 2.5% per annum, domestic investment in research has to be increased to over 3.0% of GVAP, quite a reversal to the trend over the last three decades.

The other issue to be resolved is how this level of investment is to be shared between the public purse and the industry through the RDCs.

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[13] Note the heading in their Table 7 is somewhat misleading.

[14] Note research intensity here is defined in terms of the gross value of agricultural production rather than in terms of agricultural gross domestic product. The GDP measure in 1978 was 5.1%, also a maximum.

Data on public and private expenditure on extension services are scarce. Mullen et al. (1996) derived a series by applying budget shares derived from management information systems used by the state departments back in the 1990s to total expenditure by the departments. These budget shares have never been updated and so the confidence bounds around the updated series on extension used by Sheng et al. (2011) are larger. Nevertheless it is highly likely that public expenditure on extension has fallen at least as much as expenditure on R&D. The nature of public extension services has also changed markedly to the extent that advice tailored to particular farms is now rarely available. There has been a marked increase in the private extension services through consultants and agribusiness firms but the level of expenditure associated with this is unknown.

Hughes et al. (2011) noted a decline in technical efficiency (although the level of technical efficiency remained high) and the estimates by Sheng et al. (2011) suggested that the returns from investment in extension were higher than those from R&D. Hence some may argue that a larger proportion of public funds be diverted to extension at the expense of R&D. I don't share these views. Arguments about market failure in the provision of extension are harder to make than in the provision of R&D. Perhaps RDCs should continue to closely monitor how private extension services interact with public (and private) research services and encourage farmers to see extension services as another farm input to be acquired where expected benefits exceed costs.

Conclusions

The intention in Mullen (2012) was to assess what rate of productivity growth will be required in the period to 2030 for Australian agriculture to remain competitive both within the Australian economy and relative to the agricultural sectors of other countries.

The competitive position of Australian agriculture is influenced by a range of factors including its own growth in productivity and the terms of trade it faces. External factors such as productivity growth and the terms of trade in other sectors of the Australian economy and in other economies are at least as important. The uncertainty about future trends in these various factors influencing agriculture's competitiveness makes it impossible to judge with any degree of confidence the rate of productivity growth that agriculture should be aiming for.

Mullen and Crean (2007) have previously observed that productivity growth at a rate of 2.0% since the 1950s until about 2000 was strong relative to other sectors of the Australian economy and the agricultural sectors of OECD countries, and this has been confirmed above at least for the Australian sectors. Much of this growth in TFP has come from technical change which, driven by R&D, shifts the production frontier outwards. It has been highly variable because of climate variability

Few other Australian sectors and few other agricultural sectors have maintained a rate of growth in this 2.0–2.5% range over long periods. Hence, a conservative approach might be to accept that this range is as much as could be realistically expected and to consider threats to Australian agriculture continuing to perform at this level. A growth rate of 2.0% (2.5%) would mean that output would double between 2012 and 2047 (2040).

It is most concerning that growth in agricultural productivity has certainly slowed since 2000 but perhaps from as far back as 1994 (Sheng et al. 2010). Since 2000 productivity growth has actually been negative.

Simultaneously productivity growth in the Australian economy also slipped to very low levels and was negative between 2006 and 2011.

Hughes et al. (2011) developed a measure of broadacre cropping TFP adjusted for climate variability. By this measure, growth in TFP between 2000 and 2008 was 0.24% per year with the rate of technical change faring a little better at 0.4% per year. It is tempting to think that now that a more normal run of seasons has returned, TFP growth will again resume this long term 2.0% rate. However evidence (Sheng et al. 2010 and Hughes et al., 2011) that the decline in growth is not due to climate alone is strong.

It seems most probable that a significant proportion of this slowdown in growth can be attributed to the stagnation in public investment in agricultural R&D since the late 1970s and the more marked decline in recent years. This decline in investment has occurred despite strong evidence that the returns to research have been high and that the lag between investment and impact on productivity is high. Moreover high rates of return seem more consistent with a hypothesis that there is market failure in the provision of research services to agriculture than with the alternative view that public investment is 'crowding out' investment by industry.

This suggestion that the rate of growth of TFP could stay at less than 1.0% rather than recover to a long-term rate of 2.0% is obviously quite concerning for the future competitiveness of agriculture both domestically and internationally. It would seem that to maintain TFP growth in the 2.0–2.5% per year range, investment in agricultural R&D has to be returned to a level of 3.0% of agriculture's GVAP (or 5% of GDP), a major challenge for government and industry. It seems likely that this rate of growth is required to maintain agriculture's competitiveness with other sectors in the Australian economy and with the agricultural sectors of other countries.

Other sources of productivity growth such as technical efficiency seem unimportant relative to research driven technical change. Most empirical work suggests that Australian farmers are operating close to the production frontier although Hughes et al. (2011) suggest a drift away from the frontier in recent years. While climate change offsets productivity growth, its impact would be reduced if TFP growth were to resume a 2% per year trajectory.

Perhaps a recovery in productivity growth in the rest of the economy will also boost agricultural productivity. Measures of technical change (and TFP) in agriculture also pick up sources of productivity growth in the economy at large such as gains in infrastructure, telecommunications, microeconomic reform and education. These links have not been explored empirically.

Whether growth in productivity in the 2.0–2.5% range is sufficient to maintain agriculture's competitiveness depends on trends in productivity and prices in other sectors of the Australian economy and in other countries.

The mining sector is of particular interest because the surge in demand for resources has seen the sector expand rapidly and the exchange rate has appreciated markedly. While productivity growth in agriculture has to date been much stronger than that in the minerals sector, the relative terms of trade between the sectors has almost certainly favoured the minerals and energy sectors.

Looking to the future, productivity in the mining sector may well grow strongly once this current period of rapid investment slows down. However the World Bank forecasts that prices of agricultural, mineral and energy commodities are all most likely to decline out to 2025 from their present high levels and perhaps agricultural commodity prices may decline a little less than the prices of other commodities.

The relative profitability of the agricultural sector vis a vis the minerals sector, its competitiveness in other words, depends on relative changes in the terms of trade and in the rate of productivity growth. If there is little change in the relative terms of trade in coming decades then the key driver of productivity growth in agriculture is likely to be R&D induced technical change. While not ignoring other sources of productivity growth, a return to past rates of investment in research, whether funded from public or industry sources seems crucial to maintaining the high rate of productivity in agriculture relative to other sectors of the economy.

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