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Price and yield effects of spill-overs in international agricultural research: evidence from ICRISAT and Australia

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Abstract

International agricultural research aimed at improving productivity in developing countries also has spill-over effects on developed countries. Research that affects the supply of commodities is also likely to affect the world price of tradeable commodities. In this paper, the effects of spill-overs to Australia from successful cost-reducing research into sorghum and chickpeas at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) aimed at developing countries are assessed. Genetic materials developed and distributed through ICRISAT are used in Australia to increase productivity. The price-reducing effects of successful research are incorporated into the analysis of spill-over impacts on productivity. The net effects on welfare for producers and consumers of sorghum and chickpeas in Australia and the Rest of the World (ROW) are identified. The consequences of the impacts are discussed and the implications for further funding of international agricultural research are also discussed.

JEL classification: O19

Keywords: Price effect; Research spill-over; International agricultural research; ICRISAT; Australia

1. Introduction

International agricultural research under the auspices of the Consultative Group on International Agricultural Research (CGIAR) is aimed at improving productivity in developing countries. Several studies have identified spill-over benefits from that research to developed countries (Brennan and Fox, 1995; Pardey et al., 1996; Thomas, 1996). Those studies have identified the cost-reducing impacts of higher-yielding germplasm developed through CGIAR centres. However, it has long been acknowledged that the net benefits of agricultural research in a tradeable commodity for its target region are influenced by the spill-over of the effects of that research to other producing regions with which the target region competes for a share of the world market. Edwards and Freebairn (1984) showed that the greater the extent to which the research innovations are adopted in other competing regions, the lower the net benefits for the target region. Davis et al. (1987) further developed the incorporation of spill-over effects into the analytical framework for the evaluation of research.

A genetic improvement in yield means an increase in productivity, in the sense that there is higher out-

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put for each level of input. In economic terms, the yield-increasing effects of a new variety result in a shift of the supply curve (Lindner and Jarrett, 1978; Norton and Davis, 1981; Edwards and Freebairn, 1984; Alston et al., 1995). In this paper, following those studies, the increase in productivity is defined as a parallel vertical shift in the supply curve through a lowering of the production costs per tonne. If it is assumed that new varieties do not interact with changes in other inputs (see Brennan, 1989; Brennan and Fox, 1995), the economic benefits can be estimated directly from these cost reductions.

Alston and Pardey (2001) have highlighted the importance of attribution issues in evaluating returns to research. In particular, they discussed the attribution of benefits among research groups, and provided an illustrative study of US benefits from the CGIAR system In this paper, we address that same form of spill-over benefits, but from one specific CGIAR centre, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India, to Australia.

The shifts in world supply attributed to research emanating from international agricultural research are likely to have had an impact on the world price for the relevant crops (Alston and Pardey, 2001). It is likely, therefore, that the increased supply resulting from the increased productivity obtained through the International Agricultural Research Centres has affected the prices received for traded production of the relevant crops. Since the markets for such crops are generally less than perfectly elastic, the increased supply in target countries will have reduced the price for all producers. Thus, the gains indicated by this analysis are likely to be lower than if the assumption of perfect elasticity (as in Brennan and Fox, 1995; Pardey et al., 1996; Thomas, 1996) had been maintained. As a result, at the same time as producers in some countries were receiving benefits from cost-reducing yield improvements, these price effects are likely to have reduced the welfare for producers of those crops and produced benefits for consumers.

Thus, the approach used in this study is to account for the price effects that occur through significants shifts in world supply. Because the crops analysed are often only produced or traded in moderate quantities, they are likely to face less elastic demand, and any significant increase in production is likely to have an impact on the price of traded supplies.

In the analysis in this paper, the spill-over effects of research at ICRISAT on the production of sorghum and chickpeas in Australia are identified. An attempt is made to quantify the extent of those spill-over effects from the ICRISAT program largely through their effect on Australian yields. An economic, framework for evaluating the spill-over impacts of ICRISAT research on Australia is developed. A detailed evaluation of the economic impacts of sorghum and chickpea research on Australia is carried out in Section 3. In the final section, the implications of the results and some conclusions are drawn.

2. Research at ICRISAT

The International Crops Research Institute for the Semi-Arid Tropics has been developing germplasm and other technologies for the crops in its research mandate (sorghum, millet, chickpea, pigeonpea and groundnuts) since 1972. Although ICRISAT aims to improve the production of these crops for developing countries, its germplasm and other technologies have been made freely available to developed countries. Australia has been regularly testing material from ICRISAT, and ICRISAT germplasm has been incorporated into a number of varieties released in Australia.

Despite the strong linkages for most crops, there was very little evidence of any direct impact of ICRISAT research on Australian production to date. A large amount of ICRISAT material in the different crops either has been used in the past or is being used at present in Australian breeding programs (Ryan, 1996). In addition, there had been some direct acquisitions and releases in Australia of Indian varieties, often made available via the ICRISAT germplasm exchange distribution system. However, there appeared to be no varieties or hybrids in any of the crops that were being grown commercially in 1996 based on ICRISAT germplasm. Nevertheless, some of the crops had ICRISAT material in the advanced lines with particular desirable characteristics in the breeding programs.

While there were relatively strong links with ICRISAT for several of the mandate crops, only in sorghum and chickpea were there both strong links and a substantial Australian industry to provide the necessary conditions for a significant benefit flowing back to Australia (Brennan and Bantilan, 1999). In addition, a significant part of resource management research at ICRISAT, such as physiological modelling, has relevance to Australia. However, it was not possible in this report to put an economic value on those areas of collaborative research. As a result, the empirical analysis was restricted to the impact on sorghum and chickpea production. For the other crops, the size of any benefits identified would have been insignificant at this time. It is, of course, possible that in the future there will be some important identifiable impacts for the other mandate crops or from resource management research.

ICRISAT makes contributions in a wide range of areas, and will have made some critical contributions that are not captured in this study (Bantilan et al., 1997). In particular, ICRISAT has the unique role of collecting, evaluating and distributing germplasm to breeding programs worldwide. While the analysis in this study does not identify the value of those activities, ICRISAT plays a critical role as a source of diversity in Australian breeding programs.

3. Economic analysis of impacts of ICRISAT research

3.1. Spill-over framework used

The framework used in this analysis is based on Edwards and Freebairn (1984). The world markets for each crop are disaggregated into two regions, namely Australia and the Rest of the World (ROW). Australia is further sub-divided into States.

The following assumptions are made for the analysis of the impact of spill-overs in Australia:

(a) Elasticities of demand and supply are the same throughout Australia.
(b) All countries other than Australia are grouped into the Rest of the World.
(c) The total production costs per tonne equals the equilibrium price (GRDC, 1992).
(d) All supply and demand curves are linear.
(e) All shifts in supply are defined as vertical shifts (i.e. cost reductions).
(f) The grains produced in Australia and the Rest of the World are direct substitutes sold on the same free international market.

The framework used is illustrated in Fig. 1. ICRISAT research leads directly to a shift in supply curve (from S_0 to S_1) for the Rest of the World (the 'target' region). Through technological spill-overs, there is also a shift in the supply curves (from S_0 to S_1) for regions within Australia. Those shifts result in a shift in Australia's aggregate supply curve. The aggregate world supply curve shift with the changes in Australia and the Rest of the World, leading to a fall in price (from P_0 to P_1) across all regions. At the new equilibrium, production is greater and price lower than if there had been no ICRISAT-induced supply shifts. The resultant welfare gains are measured as changes in producer and consumer surpluses for each region.

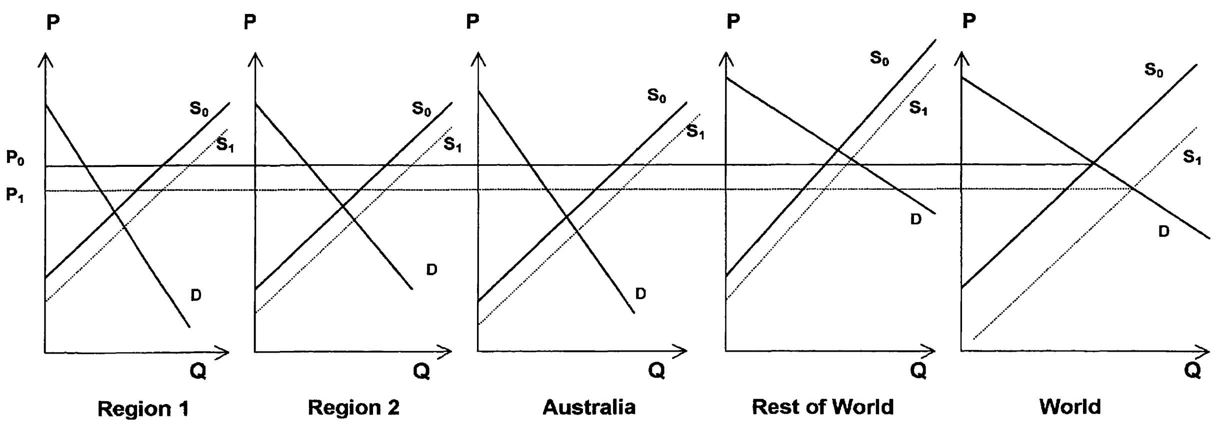

Fig. 1. Framework for analysing international agricultural research spill-overs.

Following Townsend and Thirtle (2000) and Marshall and Brennan (2001), the definition of the without-research scenario "the counterfactual" is critically important. Townsend and Thirtle (2000) distinguish between maintenance research and production-enhancing research and suggest that ignoring the losses that would have occurred without the research leads to an understatement of the impact of some research. In this study, the future impact of ICRISAT research is measured on the basis of the anticipated difference between the outcome with ICRISAT research and the outcome without ICRISAT research. As a result, the issue of maintenance research is not likely to be a significant one in this analysis.

3.2. Empirical analysis of sorghum impact

The genetic materials identified in the impact of ICRISAT research in Australia are expected to have their research impact over the 5 years starting in 1998 to 1999, with their commercial impact on farms extending well past that time. In this analysis, an attempt is made to quantify the impacts of the known research materials and their effect on hybrids and varieties released over the next 5 years. Beyond that time, there are likely to be further research impacts that are too difficult to estimate from data available to this study. As a result, the impacts measured are those expected to occur through hybrids/varieties released in the 5 years from 1998–99.

For sorghum, the most significant contribution from ICRISAT to Australian agriculture has been the introduction of improved midge resistance combined with desirable white grain and tan plant colour through lines such as ICSV 745 and PM 13654. There are several advanced breeding lines that have the resistance and combination of characteristics incorporated from ICRISAT-derived materials in them As a result, industry experts expect that hybrids with this resistance will be available to the growers in the near future, and that the resistance of such materials will have a significant economic impact on the sorghum industry.

On the basis that such resistance is likely to increase yields by 5% in the 50% of the crop affected by midge each year, the expected gains to Australia in terms of yield are estimated at 2.5%, that translates to a cost reduction of 4.02 Australian dollars/tonne (A$/t) (Brennan and Bantilan, 1999).

Estimates of the global impact of ICRISAT's sorghum research are that yields will be increased by 14.7% as a result of current research (Brennan and Bantilan, 1999). However, some of those gains are likely to be achieved well into the future, and it is estimated that the yields will increase by 10.2% over the next 5 years. Thus, the yield gains in the Rest of the World will be 10.2% over that period, compared to 2.5% for Australia in the same period (Brennan and Bantilan, 1999).

In assessing the impact of ICRISAT spill-overs to Australia in sorghum research, the following data were used in the analysis:

(a) World sorghum price is 165 A$/t.
(b) Supply elasticity 0.3, demand elasticity −3.4 for Australia (Singh and Brennan, 1998).
(c) Supply elasticity 0.2, demand elasticity −0.3 for the Rest of the World.[1]
(d) World sorghum production is 58.36 Mt.
(e) ICRISAT research will have increased sorghum yields by 10.2% in the Rest of the World by 2002, equivalent to a cost reduction of 15.27 A$/t.
(f) Australian sorghum area 551,000 ha, yields 2.12 t/ha, production 1.166 Mt.
(g) ICRISAT research will have increased Australian sorghum yields by 2.5%, equivalent to a cost reduction of 4.02 A$/t, by 2002.

The direct research impacts are a cost reduction in the Rest of the World of 15.27 A$/t, and spill-over benefits of a cost reduction of 4.02 A$/t for Australia. While these cost reductions result in savings for producers, who increase production, the resultant increased quantities produced lead to a fall in price of 5.52 A$/t, or 3.35%. That leads to substantial benefits for consumers of these grains (largely the livestock sector in Australia), while producers simultaneously face both yield increases and price falls. The net position of producers depends on the balance between the yield gains and the price fall.

Using these data in the analytical framework provides the results for sorghum shown in Table 1. For the Rest of the World producers, there is a large welfare gain of 559 million A$ (mA$) per year, with the yield increase more than offsetting the lower

[1] These elasticities are likely to vary considerably between countries.

Table 1
Annual welfare gains[a] from ICRISAT's sorghum research (at full adoption)

	Australia (million A$)	Rest of the World (million A$)	World (million A$)
Sorghum producers			
Price effect	−6.4	−312.6	−319.0
Yield effect	4.7	873.4	878.2
Net effect	−1.7	560.8	559.1
Sorghum consumers	5.3[b]	318.9	324.2
Total	3.6	879.7	883.3

[a] In 1996 Australian dollars.
[b] Livestock sector.

price. For the Rest of the World consumers, there are significant gains from the lower prices (324 mA$ per year). For Australia, the impacts are relatively small compared to these overall benefits from ICRISAT. The cost reduction provides benefits of approximately 4.7 mA$. However, the price reduction has a significant impact on the magnitude and distribution of those benefits. The net effects are a reduction in welfare for producers of 1.7 mA$ per year, which results from a gain of 4.7 mA$ from the higher yields associated with ICRISAT research, but a reduction of 6.4 mA$ because the world price has fallen 3.4% from the same research. Australian sorghum consumers (that is, the livestock sector) gain 5.3 mA$ from the lower prices, so that overall there is a net gain to Australia of 3.6 mA$.

These are the annual benefits that are expected at full adoption of the higher-yielding genotypes. On the basis that it would take 5 years for the research benefits to be fully adopted, with the first year of adoption being 1998, full benefits would not be achieved until 2002. The genotypes are assumed to have a productive life of a further 20 years beyond 2002 before being replaced or outmoded.

Based on these adoption parameters, the annual flow of benefits for sorghum has been estimated over the period 1999 to 2022. When the annual benefits are discounted (at 8% per annum) over that period, there is an estimated net gain to Australia (in 1996 discounted dollars) of 27.3 mA$, at an average of 1.14 mA$ per year. Australian producers suffer a reduction in welfare averaging 0.55 mA$ per year (despite an increase in yields), while Australian consumers of feed grains gain an average of 1.69 mA$ per year from the lower prices. In the Rest of the World, both producers and consumers reap substantial benefits from ICRISAT's sorghum research, averaging 177 and 100 mA$, respectively, per year in discounted 1996 dollars.

Table 2
Sensitivity of results for sorghum to changes in parameter values[a]

Parameter	Value	Aggregate gain for Australia (million A$)
Yield increase in Rest of the World by 2002 (%)	10.20	1.14
	8.16	1.19
	12.24	1.10
Yield increase in Australia by 2002 (%)	2.5	1.14
	2.0	0.85
	3.0	1.42
Price (A$/t)	165	1.14
	132	0.91
	198	1.37
Elasticity of demand—ROW	−0.30	1.14
	−0.24	1.11
	−0.36	1.16
Elasticity of demand—Australia	−3.40	1.14
	−2.72	1.12
	−4.08	1.16
Elasticity of supply—ROW	0.20	1.14
	0.16	1.17
	0.24	1.11
Elasticity of demand—Australia	0.30	1.14
	0.24	1.14
	0.36	1.14
Years to peak adoption	5	1.14
	4	1.22
	6	1.06

[a] Selected parameter values varied by +20 and −20% from values used in estimates.

To examine the extent to which the chosen values for the parameters of the analysis for sorghum have an impact on the findings of the study, the sensitivity of the results (measured as the aggregate gains for Australia) was examined (Table 2). Each selected parameter was varied by ±20%, and the effect on the gains for Australia estimated.

The aggregate results are clearly sensitive to the value of several of the parameters that have been used in the analysis. In addition, the relative gains of Australian sorghum producers and consumers vary with the values used. It is possible to identify 'break-even' points, the values at which Australian producers have net gains rather than net losses from ICRISAT.

These are:

(a) yield gains in the Rest of the World are 7.2% or less;
(b) yield gains in Australia are 3.5% or more;
(c) elasticity of demand in the Rest of the World larger (more negative) than −0.5;
(d) elasticity of demand for Australia larger (more negative) than −16.4;
(e) elasticity of supply for the Rest of the World less than 0.1;
(f) elasticity of supply in Australia more than 44.7.

The other parameters tend to shift the total benefits in unison, without changing the relativity between producers and consumers to any great extent.

3.3. Empirical analysis of chickpea impact

A similar assessment of the impact of ICRISAT spill-overs to Australia in chickpea research was made, with the analysis based on impacts expected to occur through hybrids/varieties released in the next 5 years.

For chickpeas, the impact of ICRISAT research is likely to be different in Western Australia (WA) from the rest of Australia. As a result, the WA impact is assessed separately in this analysis. In WA, two ICRISAT varieties, Heera and Sona, were released in July, 1997. They are seen as having a significant impact on the chickpea industry in WA. They have significant levels of cold tolerance, and are expected to yield an average of 10% higher than alternative varieties that will be available over the next 5 years. At the same time, the area of chickpeas in WA is estimated to double to 100,000 ha by 2002. In the other States, there are no such clearly identifiable benefits from the use of ICRISAT's chickpea materials. However, material either developed from or incorporating ICRISAT background is prevalent throughout the breeding materials currently in use in Australia, and a weighted average of 42% of the breeding materials have ICRISAT background. On the basis of these figures, the future gains from improved chickpea varieties in the other States will have a strong impact from ICRISAT material. It is estimated that ICRISAT germplasm will contribute 2.1% of the expected 5.0% yield growth in the 5 years to 2002. That is equivalent to a cost reduction of 39.18 A$/t for WA and 8.78 A$/t for the rest of Australia (Brennan and Bantilan, 1999).

Estimates of the global impact of ICRISAT's chickpea research are that yields will be increased by 60.2% as a result of current research (Brennan and Bantilan, 1999). However, some of those gains are likely to be achieved well into the future, and it is estimated that the yields will increase by 21.4% over the next 5 years. Thus, the yield gains in the Rest of the World will be 21.4% over that period, compared to 4.96% for Australia in the same period (Brennan and Bantilan, 1999).

In assessing the impact of ICRISAT chickpea research, the following data were used in the analysis:

(a) World chickpea price 431 A$/t,
(b) Supply elasticity 0.5, demand elasticity −3.0 for Australia (based on Singh and Brennan, 1998).
(c) Supply elasticity 0.4, demand elasticity −0.6 for the Rest of the World.[2]
(d) World chickpea production 8.2 Mt.
(e) ICRISAT research will have increased chickpea yields by 21.4% in the Rest of the World (Table 4), equivalent to cost reduction of 75.96 A$/t, by 2002.
(f) Australian chickpea area 275,000 ha, yields 0.99 t/ha, production 271,000 t.
(g) ICRISAT research will have increased Australian chickpea yields by 4.96% equivalent to a cost reduction of 20.37 A$/t, by 2002.

The direct research impacts are a cost reduction in the Rest of the World of 75.96 A$/t and spill-over benefits of a cost reduction of 20.37 A$/t for Australia. The large yield increases from ICRISAT research worldwide lead to benefits of 603 mA$ per year to producers. These benefits are partially offset (to the value of 227 mA$) by the effect of a price fall of 28.89 A$/t (or 6.70%). That price fall leads to large benefits for chickpea consumers (that is, largely the livestock sector), which are estimated at 241 mA$ (Table 3). The net impact is a gain of 617 mA$ worldwide. The impact of the cost reduction for Australia is 5.2 mA$ (Brennan and Bantilan, 1999). However, the price reduction has a significant impact on the magnitude and distribution of the net benefits to Aus-

[2] As for sorghum (Footnote 1), these elasticities are likely to vary considerably between countries.

Table 3
Annual welfare gains[a] from ICRISAT's chickpea research (at full adoption)

	Australia (million A$)	Rest of the World (million A$)	World (million A$)
Chickpea producers			
Price effect	−7.8	−219.6	−227.4
Yield effect	5.2	598.7	603.9
Net effect	−2.6	379.1	376.5
Chickpea consumers	3.8[b]	236.7	240.5
Total	1.2	615.8	617.0

[a] In 1996 Australian dollars.
[b] Livestock sector.

tralia. The net effects are a reduction in welfare for producers of 2.6 mA$ per year, which results from the gain of 5.2 mA$ from the higher yields associated with ICRISAT research but a reduction of 7.8 mA$ because the world price has fallen 6.70% because of the same research. Australian chickpea consumers (again mainly the livestock sector) gain 3.8 mA$ from the lower prices, so that overall there is a net gain to the Australia chickpea industry of 1.2 mA$ per year.

These are the annual benefits that are expected at full adoption of the higher-yielding genotypes. On the basis that it would take 5 years for the research benefits to be fully adopted, with the first year of adoption being 1999, full benefits would not be achieved until 2003. The genotypes are assumed to have a productive life of a 20 years to 2002 before being replaced or outmoded.

On the basis of these adoption parameters, there is an annual flow of benefits for chickpeas over the period 1999 to 2022. When the annual benefits are discounted (at 8% per annum), the value of the net spill-over benefits over the period considered are found to be small but positive for Australia. In the 25 years from 1998, there is an estimated net gain to Australia (in 1996 discounted dollars) of 9.1 mA$, at an average of 0.38 mA$ per year.

Australian producers have a reduction in welfare of an average of 0.81 mA$ per year, despite an increase in yields, because of the price fall from the larger yield gain in the Rest of the World. Australian consumers gain an average of 1.19 mA$ per year from the lower prices. In the Rest of the World, both producers and consumers reap substantial benefits from ICRISAT's chickpea research, averaging 119 and 75 mA$, respectively, per year in discounted 1996 dollars.

Table 4
Sensitivity of results for chickpea to changes in parameter values[a]

Parameter	Value	Aggregate gain for Australia (million A$)
Yield increase in Rest of the World by 2002 (%)	21.40	0.38
	17.12	0.58
	25.68	0.20
Yield increase in WA by 2002 (%)	10.0	0.38
	8.0	0.17
	12.0	0.59
Yield increase in rest of Australia by 2002 (%)	2.08	0.38
	1.66	0.29
	2.50	0.47
Price (A$/t)	431	0.38
	345	0.30
	17	0.46
Elasticity of demand—ROW	−0.60	0.38
	−0.48	0.24
	−0.72	0.50
Elasticity of demand—Australia	−3.00	0.38
	−2.40	0.35
	−3.60	0.41
Elasticity of supply—ROW	0.40	0.38
	0.32	0.53
	0.48	0.26
Elasticity of supply—Australia	0.50	0.38
	0.40	0.38
	0.60	0.38
Years to peak adoption	5	0.38
	4	0.41
	6	0.36

[a] Selected parameter values varied by +20 and −20% from values used in estimates.

To examine the extent to which the chosen values for the parameters of the analysis for chickpeas have an impact on the findings of the study, the sensitivity of the results (measured as the aggregate gains for Australia) was examined (Table 4). Each selected parameter was varied by ±20%, and the effect on the gains for Australia estimated.

As for sorghum, the aggregate results obtained are sensitive to the value of several of the parameters that have been used in the analysis. In addition, the relative gains of Australian chickpea producers and consumers vary with the values used. It is possible to identify 'break-even' points, the values at which Australian producers have net gains in welfare rather than net reductions from ICRISAT. These are:

(a) yield gains in the Rest of the World are 13.3% or less;
(b) yield gains in Western Australia are 18.2% or more;
(c) yield gains in the rest of Australia are 13.9% or more;
(d) elasticity of demand in the Rest of the World larger (more negative) than −1.1;
(e) elasticity of demand for Australia larger (more negative) than −38.2;
(f) elasticity of supply for the Rest of the World less than 0.2;
(g) elasticity of supply in Australia more than 23.8.

The other parameters tend to shift the total benefits in unison, without changing the relativity between producers and consumers to any great extent.

3.4. Aggregate results

The aggregate benefits over the period to 2022 are summarised in Table 5. Overall, Australia benefits from the activities of ICRISAT by an average of 1.52 mA$ per year, or 36.4 mA$ over the period to 2022. There is a net transfer of welfare from the producers of each grain to the consumers (that is, mainly the livestock sector) in Australia, but the net effect is a significant gain for Australia.

Table 5
Net welfare gains[a] for Australia from ICRISAT, 1999–2022

	Sorghum (million A$)	Chickpeas (million A$)	Total (million A$)
Average annual benefits			
Producers	−0.55	−0.81	−1.36
Consumers[b]	1.69	1.19	2.88
Total	1.14	0.38	1.52
Aggregate benefits, 1999–2022	27.3	9.1	36.4

[a] Discounted to 1996 Australian dollars at 8% per annum.
[b] Livestock sector.

4. Implications and conclusions

The analysis undertaken in this study identifies the cost-reducing impacts of higher-yielding materials obtained from ICRISAT research. The economic analysis also assesses the impact on Australia of ICRISAT's research in the Rest of the World, via an impact on prices. To the extent that ICRISAT's research in the Rest of the World has increased production, there will be a downward impact on price. Given finite supply and demand elasticities, any increase in production will mean a decline in price for the traded goods sector. Work at ICRISAT has led to development of estimates of the likely impact in future of ICRISAT's research. The increases in the world's production of chickpeas and sorghum are likely to have a downward impact on prices for the predominantly export-oriented sorghum and chickpeas industries in Australia.

On that basis, the Australian industry faces lower prices as a result of ICRISAT's research, at the same time as they are experiencing yield gains from ICRISAT technology. The economic analysis of those spill-over impacts in an economic welfare framework revealed that the overall net effect for Australia was a reduction in benefits gained by producers. These losses to Australian producers occur because they are unable to make use of the productivity gains from ICRISAT research to the same extent as producers in the Rest of the World, and hence cost reductions gained by other producers are larger than gained by Australian producers.[3] Australian sorghum producers will lose more through the lower prices than the benefits they gain from the higher yields, resulting in an overall loss of 0.55 mA$ per year. For chickpeas, Australian producers will also lose more from the price fall than they will gain from higher yields, with a resultant loss of 0.81 mA$ per year. Overall, sorghum and chickpea producers will lose an average of 1.36 mA$ per year. On the other hand, Australian consumers of those grains (that is, primarily the livestock sector) will make significant gains. Sorghum consumers will gain an average of 1.69 mA$ per year,

[3] It should be noted that Australian producers enjoy productivity gains from domestic research programs unrelated to ICRISAT that have not been considered in this study. No attempt has been made to assess whether Australian producers are becoming more or less efficient than producers in the rest of the world.

while for chickpeas the gains will average 1.19 mA$ per year.

Overall, the net gain to Australia as a result of the overall research effort at ICRISAT averages 1.28 mA$ per year, or an aggregate of 30.8 mA$ (in 1996 dollars) over the period to 2022. Approximately three-quarters of those gains are achieved in the sorghum industry, and one-quarter for chickpeas.

Attributing these spill-over impacts to ICRISAT itself is, of course, fraught with difficulties of identification and measurement (Alston and Pardey, 2001). There are difficulties associated with attributing to ICRISAT the gains from using materials developed by ICRISAT using parental materials gathered from other sources. That can result in an understatement of the contribution of prior research to the spill-over benefits to Australia., and to an overstatement of the contribution of ICRISAT to those productivity improvements.

There are increasingly important issues relating to property rights in relation to the use of genetic materials such as that involved in the spill-over effects analysed in this paper. Indeed, there was a specific issue relating to the property rights involved with the two chickpea varieties in Western Australia (see Nottenburg et al., 2001 for a discussion). Those issues are not addressed in this paper, although they are significant in the broader issue of access to the germplasm being used by and emanating from the International Agricultural Research Centres. In the analysis in this paper, the access of Australian scientists to the ICRISAT materials was not constrained by any property rights issues, and ultimately the varieties released in Australia were also made freely available to farmers. To the extent that those conditions change, future benefits from similar potential research spill-overs may be considerably altered.

There are several implications of the findings of this study:

(a) International Centres such as ICRISAT are a source of materials for potential yield gains for Australian crops, even those crops grown in systems and environments significantly different from those targeted by the international centres.
(b) Australian producers will be affected by the price implications of the successful research that is undertaken by the international centres such as ICRISAT, whether or not they take advantage of the possible yield gains spilling over.
(c) Consumers, which for many grains in developed countries means livestock industries, are likely to be significant benefactors of any research advances in the grain industries.
(d) Australia's gains are likely to be greatest for those industries where there are significant links between Australian researchers and the researchers and programs being undertaken in the international research centres. As a result, personnel interchange and overseas visits by Australian researchers to those centres are likely to have significant pay-offs for Australian grain industries, since they are a principal means of developing those links. The subsequent reduced time lags for the exchange of research information are also likely to result in increasing the impacts.
(e) Australian researchers need to maintain their vigilance over international agricultural research developments. Only where Australian researchers can keep abreast of developments in other parts of the world can the benefits for Australian producers be maintained. Producers continually face the long-term decline in real prices that results from the ongoing success of the agricultural scientists around the world, in both national and international research, to increase yield levels for so many significant crops. The long-term decline in real prices will occur whether or not Australia contributes to the international agricultural research system, and Australia's best opportunity to glean spill-over benefits from the system lies in being part of the system through financial support.

Those declines in prices can lead to significant benefits for Australian consumers of grains, whether in consuming grain products directly or in consuming livestock products that use the lower-priced feed grains, as well as for consumers in the Rest of the World. In previous studies, those benefits to consumers in developed countries such as Australia have not been recognised, although they have been found in this study to be significant. The findings of this study mean that the importance of the price effects needs to be recognised in evaluating the economic benefits spilling-over from international agricultural research.

In conclusion, this study has produced significant findings at two levels. The first level has been the identification of anticipated spill-over benefits in terms of cost reduction for producers in two of the ICRISAT mandate crops, namely sorghum and chickpea. Those cost reductions are expected to result from yield increases attributable to germplasm developed at ICRISAT or enhanced by being coordinated by ICRISAT and incorporated into genotypes that will be grown in Australia.

The second level at which significant findings have emerged for the first time is in the incorporation of the price effects of international agricultural research for these crops. In these two industries, the price effects resulting from successful ICRISAT research were found to be significant. The lower prices for sorghum and chickpea led to significant income reductions for Australian producers, and these were only partly offset by the increased yields. The gains for the Australian consumers of these grains (that is, the Australian livestock sector) from the lower prices were less than the losses from price effects for Australian producers, because the significance of exports meant that overseas consumers received many of the consumer benefits. Thus producers have incurred losses from the price effects at the same time as they have gained from the yield effects.

Recognition of these factors can assist in leading to better-informed decision-making for research resource allocation and is likely to lead to a more efficient, and more cooperative, research system worldwide. That improved system will deliver expected improvements in the efficiency of production and in the delivery of appropriate food cheaply to the consumers most in need of it.

Overall, Australia has received benefits from ICRISAT's research, at an average of 1.52 mA$ per year. Those benefits are well in excess of Australia's financial contribution to ICRISAT.

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