The benefits and beneficiaries of “public” investment in herbicide use research and development.

Bronwyn Crowe, Bob Lindner, & Rick Llewellyn

Paper presented at the 50th Annual Conference of the Australian Agricultural and Resource Economics Society, February 8-10, 2006, Sydney, Australia.

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Abstract

Australian research and development organizations invest substantial grower and/ or taxpayer (public) funds, on the control of weeds in broad-acre cropping using herbicide. Benefits from this research are distributed between growers, consumers and the agrichemical industry depending on the patent status of the technology adopted or discarded due to the research. The size and allocation of the benefits from "public" R&D affecting on-patent and off-patent herbicide use is analysed using economic surplus techniques. The results indicate that herbicide patent status does not have important implications for "public" R&D investment decisions.

Key words: Research and Development, Evaluation, Herbicide, Patent.

Contact details for authors

School of Agricultural & Resource Economics

Faculty of Natural and Agricultural Sciences

University of Western Australia, Stirling Hwy, Crawley, WA 6009

Email: croweb@are.uwa.edu.au

Phone: 08 6488 4653

Fax:08 6488 1098

Introduction

The Australian grains industry relies on herbicides for cost-effective weed control, spending nearly 1 billion on herbicides in 2004 (APVMA, 2005). Grower and/ or taxpayer (public) funded research organisations, such as the Grains Research and Development Corporation (GRDC), invest substantial sums in herbicide use research and development (R&D) to improve the effective and efficient use of herbicides. As is the case for many other types of agricultural R&D, there is a *prima facie* case for collective funding of R&D into the use of herbicides without patent protection, off-patent or generic, because the benefits are widely distributed among many grain growers. For R&D to improve the effective and efficient use of on-patent proprietary herbicides, the level of benefits and distribution of these benefits between consumers, grain growers, and agrichemical companies across time is influenced by several special features of the market for herbicides, particularly the limited duration monopoly conferred by the patent.

The return on investment of grain grower and/or taxpayer (public) funds in research and development of herbicide use depends on several factors as well as patent status. Where herbicide use R&D increases use of off-patent herbicides, and/or reduces other farm costs, mainly grain growers, and possibly consumers, will be the beneficiaries. Consumers and grain growers will be the primary beneficiaries from adoption by grain growers of herbicide use R&D that does not increase the use of on-patent herbicides. Conversely, where such research leads to increased use of on-patent herbicides, the agrichemical company holding the patent for the herbicide, as well as grain growers and consumers, are likely to benefit from the R&D. In addition to the duration of a patent on a proprietary herbicide, the extent of the pricing power enjoyed by the agrichemical company while the patent lasts clearly will be an important determinant of the distribution of benefits.

As the producer of a proprietary herbicide will benefit from herbicide use R&D that results in increased sales of herbicide, a superficially attractive option would be to rely on the agrichemical company to fund all such herbicide use R&D. However, this approach is likely to result in market failure, involving under-investment in such R&D by agrichemical companies, because their capacity to fully appropriate the benefits is limited even where use of on-patent herbicides increases as a result of the herbicide use R&D. The finite duration of patent protection means they will generally not share any of the research benefits that arise once the herbicide patent expires. In addition, impediments to practicing first degree price discrimination, such as legal constraints, market structure and product competition, further reduces the agrichemical companies incentive to invest in the amount of herbicide use R&D optimal to growers. Importantly, when agrichemical companies charge grain growers a price premium to use patented herbicides in order to recover their investment in herbicide use R&D this inevitably will result in under-utilization of the research results and/ or herbicide. Consequently, grain growers may not realize all of the benefits potentially available from herbicide use R&D.

Publicly funded research bodies, can avoid the twin threats of under-investment in herbicide use R&D, and under-utilization of the results, by fully funding an optimal level of R&D investment, and making the results freely available. However, this would allow the agrichemical companies to free ride on some R&D initiatives by increasing patented herbicide sales, with the same price premium, and thereby appropriating some of the benefits. This paper investigates who benefits, growers, agrichemical companies or consumers, from herbicide use R&D, as well as how large the benefits are using a case study.

Evaluating returns from herbicide use research and development

The most comprehensive review and meta-analysis of attempts to measure research benefits was carried out by Alston et al. (2000) who analysed 292 studies estimating returns to research. Such benefits can be measured empirically using economic surplus methods summarized in Alston et al. (1995). The economic surplus approach has been used in a large number of previous studies that have investigated the impacts of many different types of agricultural research, including weed management research (e.g. Vere et al., 2004; Sinden et al., 2004, Jones et al., 2000). The economic surplus model has been adapted in this study to incorporate the unique features of the Australian herbicide industry, including monopoly power for suppliers of patented technologies, agronomic differences between regions and the spill over of technology between regions and globally.

Most studies have analysed innovations produced by the public sector and introduced into perfectly competitive agricultural markets where the distribution of economic surplus can be measured in the output market as the sum of changes in farmer and consumer welfare. This analytical framework needs to be extended so that it can accommodate some special features relevant to the costs, benefits and beneficiaries from herbicide use R&D. In a different context, a recent study by Falck-Zepeda et al. (2000) illustrates how the basic framework can be adapted to analyse R&D investments where a wider set of beneficiaries are involved.

The active chemical ingredients of herbicide receive patent protection for 20 years from registration within Australia. This patent protection enables the chemical producer to capture a price premium during the life of the patent in certain market situations. For pharmaceutical producers, patent protection enables the capture of a price premium that is as much as 75% of the competitive market price following patent expiry (Magazzini et al, 2004; Griliches & Cockburn, 1994). Patent protection also has enabled biotechnology companies to change 30% above the cost of ‘normal’ seed for genetically modified soybeans and corn (Moschini & Lapan, 1997). While patent protection also can enable herbicide companies within Australian to capture a price premium where the chemical is superior to other products in the market, strong competition from off-patent and other patented herbicides limits the ability of agrichemical companies to extract large price premia.

The economic surplus approach requires an estimation of the yield increase and/ or input cost saving due to the innovation to be expressed as a per unit reduction in production costs, K. This is modelled as a parallel shift in the supply function leading to an increase in production and consumption and a price fall, in Figure 1 the supply shift is from S0 to S1 and K is the distance from point a to b. The increased production with lower costs outweighs the price fall for producers, while consumers benefit from the price fall, together benefiting by the area 'abcd' in Figure 1. In a study to determine the economic costs of weeds to Australian annual winter cropping regions Jones et al (2000) estimated that current weed infestations resulted in a shift (negative) in the supply curve (K) of between 10% and 20% in most cases.

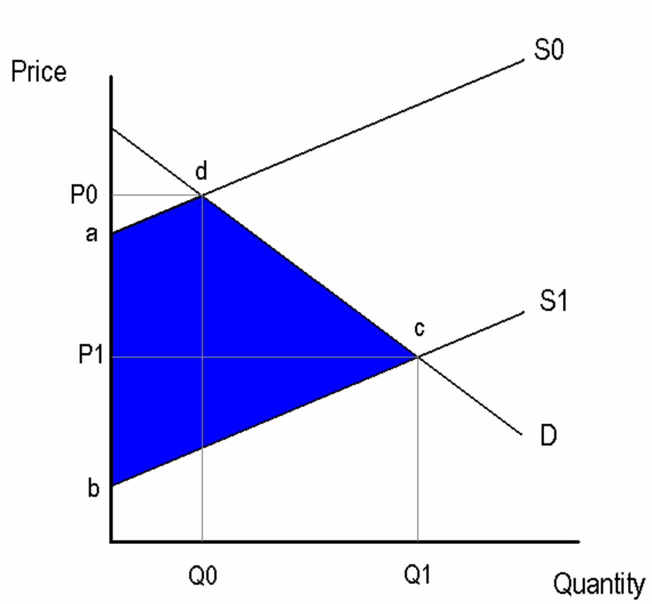

Figure 1 Economic surplus distributed to producers and consumers (abcd) from research and development (Based on Alston et al, 1995 pg 209).

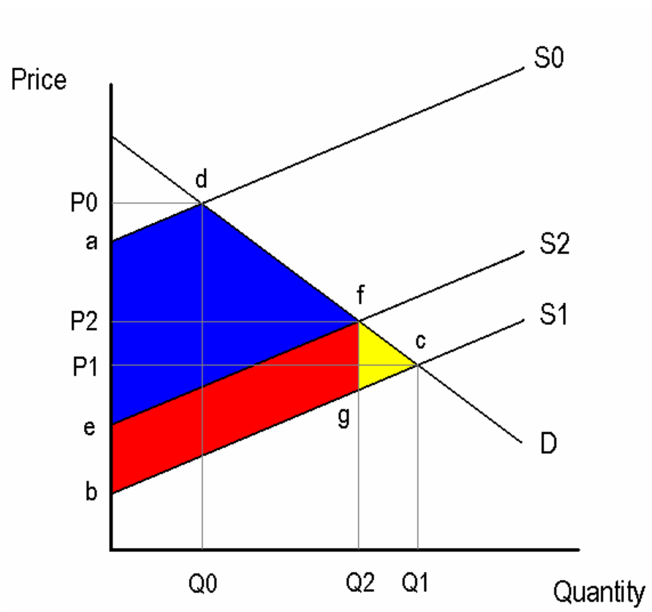

Figure 2 Economic surplus distributed to producers and consumers (aefd) and agrichemical companies (ebgf) from research and development (Based on Alston et al, 1995 pg 209).

On- patent herbicides provide suppliers with temporary monopoly power, allowing patented product providers to increase herbicide price above competitive levels, and thereby appropriate a price premium and share of the benefits, shift the area ‘ebgf’ of Figure 2. This consequently restricts the usage of the herbicide due to price rationing, so subject to the following caveat, reduces realised aggregate net benefit below potential aggregate net benefit due to under-utilisation. Grower and consumer net benefits are reduced by the agrichemical companies price premium, to area ‘aefd’ of Figure 2. It provides herbicide manufacturers with enough certainty to invest in further R&D, and with an incentive to incur the costs of obtaining registration.

Off-patent herbicides are commonly provided by competing suppliers, so typically, herbicide prices fall to competitive levels, and there are no price premium. Herbicide use is then not restricted by price rationing, so subject to the following caveat, potential aggregate net benefits are fully realised and therefore greater herbicide usage. Grower and consumer net benefits are the total area ‘abcd’ of Figure 2.

To account for the timing of the flow of benefits and costs from R&D, estimates determining the diffusion curve are required. These comprise first, the R&D lag, including the period when R&D takes place, incurring costs, before any adoption can occur. Second, the adoption lags, (the period from first availability of the innovation to when the maximum adoption level is achieved. Thirdly, the period of maximum adoption/impact, and finally the timing and rate of disadoption. The timing of the flow of benefits has a very important impact on the total benefit received by all parties (Maredia et al, 2000).

As agricultural innovations often have location-specific characteristics, it cannot be assumed that the same K value and adoption profile is appropriate across all production regions. In this study, a horizontal multi-market approach has been used with the Australian production area disaggregated into three zones (Northern, Southern and Western Regions), that benefit from the technology through different spillover levels as applicable. Separate markets for Australian consumption and Rest of World (ROW) production and consumption allow the impact of changes in Australian production on world prices and therefore all consumers to be estimated.

Case Study: Demonstrating effectiveness of a new on-patent herbicide in a minor crop

This section presents a case study of the benefits and beneficiaries of herbicide use research and development in relation to the herbicide’s patent status. This case study was based on current investments in R&D by Australian publicly funded organizations, such as the GRDC and state government departments of agriculture or primary industry.

Background

There is an increasing importance being placed on the role of minor crops in the Australian grain industry. Minor crops refer to new cultivars and/or relatively small high value markets, such as high value pulses. The increasingly diverse range of grain crops and cultivars grown by Australian farmers means weed control methods are becoming more specialised for each situation. More so than for traditional broadacre cereal crops, these smaller acreage crops often rely heavily on the accredited use of safe and effective herbicides to be profitable. There is little incentive for agrichemical companies to invest in R&D for specific use of herbicides or in minor crops due to the limited sales this would generate for the cost of the R&D required. The return on investment of this R&D for the agrichemical company is expected to be low. However, the benefit to grain growers of R&D into specific use of herbicides or in minor crops could make investment favourable to public R&D organisations. In this hypothetical case study the benefits and beneficiaries of R&D into the effectiveness of a new herbicide for the minor crop chickpeas, across various agricultural sub-regions of the Northern Region of Australia, are examined.

Data

The implications of the hypothetical new herbicide were considered for chickpeas in the Northern, Southern and Western cropping regions of the Australian cropping belt (Figure 3). Initial chickpea production and consumption for each region are given in Table 1. Global consumption was assumed to equal global production. The initial price and the cost of production were set at $515/tonne. No technology spillover to the rest of the world was assumed as changes to the registration of herbicide products in Australia would not influence other countries, or have flow on effects through herbicide price and production quantities. The analysis ran for 10 years and used a discount rate of 5%.

Figure 3 Australian agro-ecological cropping zones and regions (GRDC).

Table 1 Regional production and consumption (ABARE, 2004) and elasticity of supply and demand of chickpeas (Sinden et al, 2004).

Region	Production ('000t)	Consumption ('000t)	Elasticity of supply	Elasticity of demand
Western	20	0	0.2	-
Southern	20	0	0.2	-
Northern	50	0	0.2	-
Aust Consumers	0	1	-	0.5
ROW	7,688	7,877	0.50	2.2

The demand and supply elasticity of chickpeas in each region and the rest of the world, Table 1, were taken from Sinden et al. 2004 with comparison to a review of various sources and analyses, including Kingwell (1994), Griffith et al. (2001) and Jones et al. (2000). It is assumed that the supply and demand elasticities do not change over the 10 year analysis period.

The R&D Project

The hypothetical R&D project demonstrated the application and use of a new herbicide in a minor crop. Based on the example of Balance (isoxaflutole), a recently released on-patent pre-emergent herbicide widely used in chickpea production in the Northern Region, likely adoption and benefit from research into this new herbicide would be high within the small group of potential adopters. Bayer CropScience conducted field trials into the efficacy, residue, and toxicology of Balance to gain registration for pre-emergent use to control broadleaf weeds in chickpeas and sugarcane in all Australian states. However, it was unlikely to be commercially useful to Bayer CropScience to further investigate the effectiveness of Balance in multiple sub-regions, as the impact on potential market size is likely to be minor. This case study investigated the return to researching the effectiveness of a new herbicide for chickpeas in sub-regions of the Northern Region, assuming Balance was not available.

Determining the hypothetical new herbicide's effectiveness in different sub-regions of the Northern Region required an R&D project involving field trials in a number of geographic locations possibly across a number of seasons. The R&D project was estimated to cost $200,000 p.a. the year the new herbicide was released, 2005, $100,000 in 2006 and $50,000 in 2007 and 2008. It is assumed there are no spillover effects of this R&D project into other regions or enterprises.

The R&D project disseminated information on the benefits of adopting the new herbicide over other weed control methods across various agricultural sub-regions. Growers thereby make their adoption decision earlier than they would without the R&D project. The maximum level of adoption of the new herbicide therefore is reached more quickly than if the R&D project had not occurred. With the R&D project, the new herbicide is assumed to be adopted by 50% of chickpea production in the Northern Region in 4 years. Adoption is assumed to be linear both with and without the R&D project.

The benefit to grain growers and the agrichemical company of the hypothetical R&D project into the new herbicide is based on R&D projects conducted previously into the use of Balance, Table 2. Previous R&D into the use of Balance in chickpeas has shown a yield advantage of Balance combined with Simazine over the use of Simazine alone at 1 l/ha of 18% (McCosker & White, 2004; BCG, 2000) and 6% over Simazine at 2 l/ha (BCG, 2000). Simazine at a rate of 1-2 l/ha was the standard pre-emergent broadleaf weed control in chickpeas prior to the release of Balance. This case study assumed Balance was not available and the hypothetical new herbicide entered the market for pre-emergent broadleaf weed control in chickpea providing an 8% yield advantage to growers in the Northern region.

Balance costs $25/ha, a 3.5% increase in the cost of production of chickpeas over Simazine at 2l/ha of $13.70. This case study assumed the hypothetical new herbicide price was comparable to Balance, the cost penalty of 3.5% reduces the net benefit to growers of adopting the new herbicide to 4.5%.

The hypothetical new herbicide was assumed to be patent protected, therefore the agrichemical company is able to increase the herbicide price above a competitive level or extract a price premium. Given the range of price premium mentioned previously for biotechnology and the high demand among chickpea growers for an effective selective herbicide prior to Balance, a 20% premium was assumed. A 20% price premium means if the new herbicide was not patent protected when released the competitive price would be $20/ha, however, due to the monopoly position of the agrichemical company they are able to charge $25/ha. Were the new herbicide off-patent, i.e. not patent protected, grain growers would be charged $20/ha and therefore only experience a 2.6% increase in the production cost of chickpeas. The net benefit to grain growers of adopting the hypothetical new herbicide were it off-patent was 8.0% less 2.6%, 5.4%, Table 2.

Table 2 Comparison of yield and production cost benefits to grain growers and agrichemical company of applying the hypothetical new herbicide rather than the previous treatment in chickpeas of the Northern Region, where the new herbicide is on and off-patent (based on McCosker & White, 2004; BCG, 2000).

	On-Patent	Off-Patent
Increase in chickpea yield from adopting Balance	8.0%	8.0%
Increase in chickpea production cost from adopting Balance	3.5%	2.6%
Net benefit of adopting Balance to grain growers	4.5%	5.4%
Proportion chickpea production cost appropriated by agrichemical company	1.0%	0.0%

Without the R&D Project

Without the R&D project growers and agronomists would distribute information about the new herbicide through existing networks. However, without the independent field work and extension activities of the R&D project growers would not respond as quickly to this information. Adoption of the new herbicide is assumed to be 50% of chickpea production in the Northern Region 5 years after release without the R&D project, rather than 4 years with the R&D project.

Results

The time profile of benefits to Australian grain growers of adopting the new herbicide when patent protected, with and without the R&D project, is shown in Figure 4. The total NPV of benefits to Australian wheat growers for this period ($559k) can be compared to the assumed total NPV of R&D costs of $366k and an agrichemical company benefit of $155k, Table 3. The benefit: cost ratio of the R&D project for "public" investment was 1.5, and the internal rate of return (IRR) 28%. The benefit: cost ratio from the agrichemical company perspective was 0.4 and the IRR was -30%.

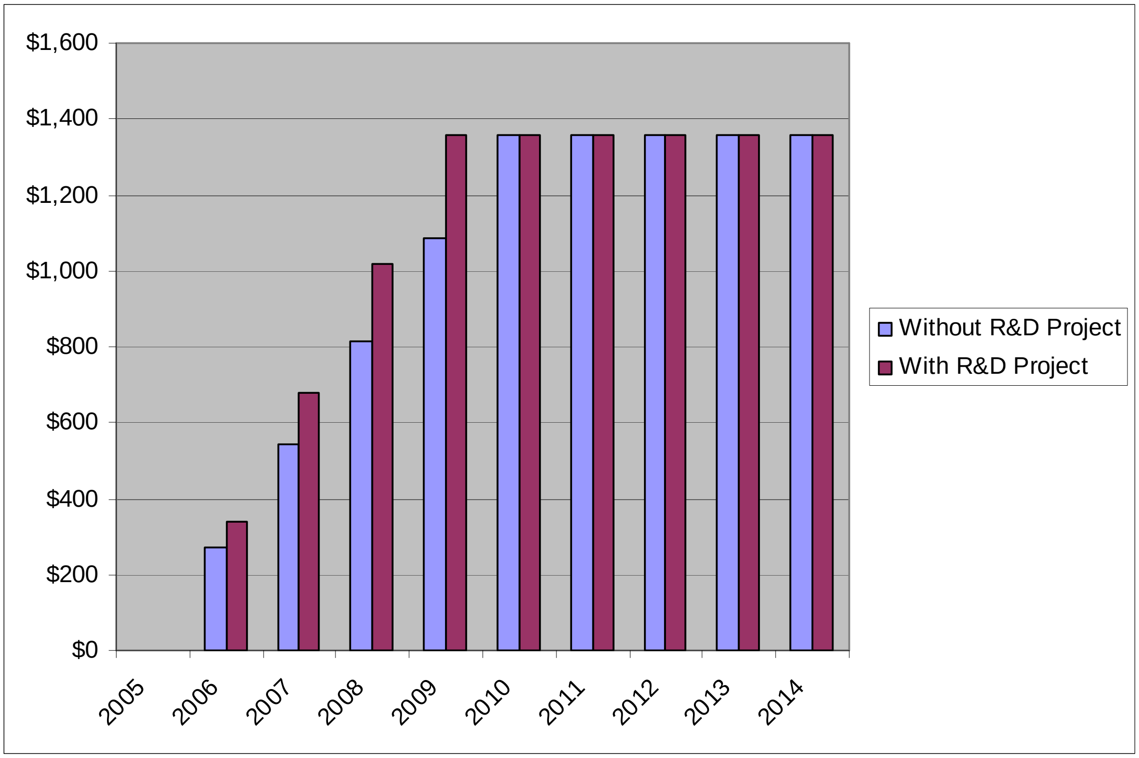

Figure 4 Time profile of benefits to Australian grain growers from adopting the hypothetical new herbicide with and without the R&D project ($k).

Table 3 Australian grain growers, consumers and agrichemical company, and ROW producer and consumer surplus from the R&D project into a new herbicide for chickpeas, and the R&D projects cost (Net Present Value $k)

Beneficiary	On-Patent	Off-Patent
Western Region	$ 0	$ 0
Southern Region	$ 0	$ 0
Northern Region	$ 559	$ 870
Agrichemical Company	$ 155	$ 0
ROW Producer	$ 0	$ 0
Total Producer Surplus	**$ 714**	**$ 870**
Australian Consumer	$ 0	$ 0
ROW Consumer	$ 0	$ 0
Total Consumer Surplus	**$ 0**	**$ 0**
Total Surplus	**$ 714**	**$ 870**
R&D Cost	**$ 366**	**$ 366**

Figure 5, shows the benefits from the R&D project to Australian grain growers and the agrichemical company holding the herbicide patent over time where the herbicide is on- and off-patent . Australian grain growers receive 78% of the benefits from the R&D project, with the agrichemical company receiving the other 22% and Australian consumers 0%. Were the herbicide off-patent Australian grain growers would receive 100% of the benefit, the agrichemical company 0% and Australian consumers 0%.

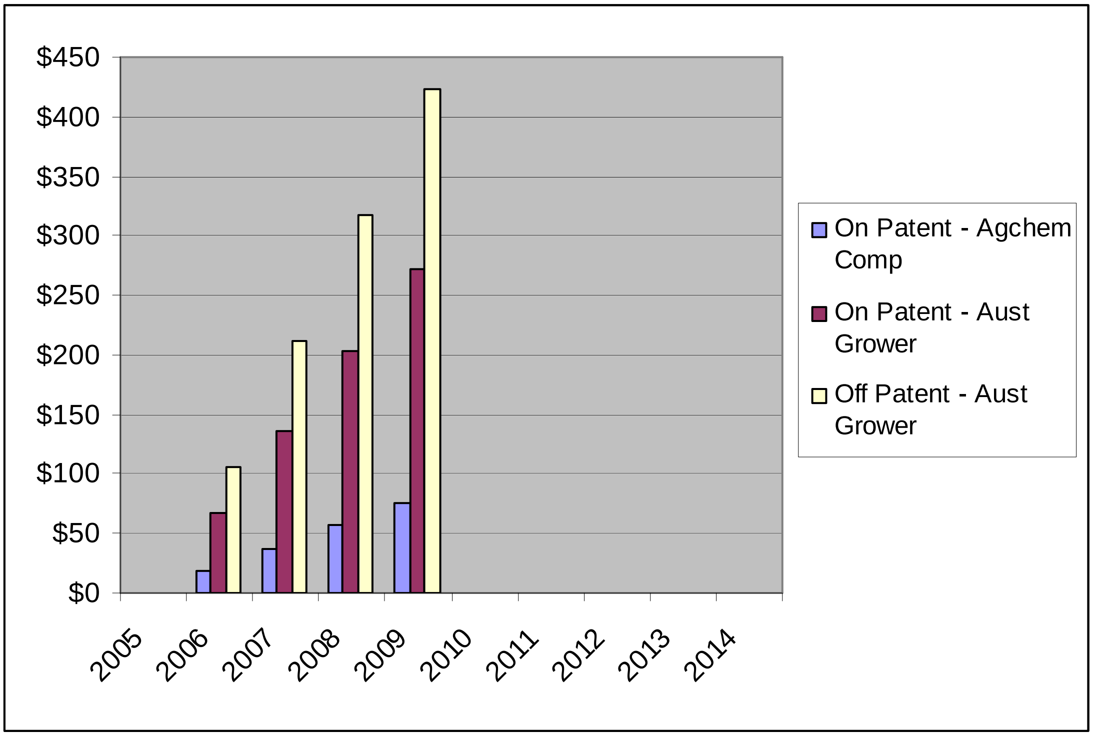

Figure 5 Time profile of benefit from the R&D project to Australian grain growers and the agrichemical company holding the new herbicide patent, when the herbicide is on- and off-patent ($k).

Sensitivity Analysis

The effect of altering the time taken for adoption of the new herbicide and to disseminate the results of the R&D project, as well as the net benefit to growers of adopting the new herbicide, on the producer benefits of the R&D project are shown in Figure 6. The net present value of benefits from adoption of the new herbicide in 3 years, rather than 4, doubled for both the grain growers and the agrichemical company. Increasing the time taken to conduct the R&D project from 1 year to 3, decreased both the benefit to grain growers and the agrichemical company by 10%. Altering the yield advantage and cost penalty as if the next best alternative were Simazine at 1 l/ha rather than 2 l/ha, resulting in a net benefit to growers of 13.1%, near quadrupled the benefit to growers, while the benefit to the agrichemical company remained stable. When maximum adoption of the new herbicide occurred after 3 years the public B/C ratio and IRR becomes 3.1 and 99% respectively, while the private B:C ratio was 0.9 and IRR -3%. If the R&D project begins dissemination of information after 3 years, the public B:C ratio became 1.4 and IRR 14%, while the private B:C ratio was 0.4 and IRR -17%. Increasing the net benefit to growers to 13.1% increased the B:C ratio to 5.3 and the IRR to 143%.

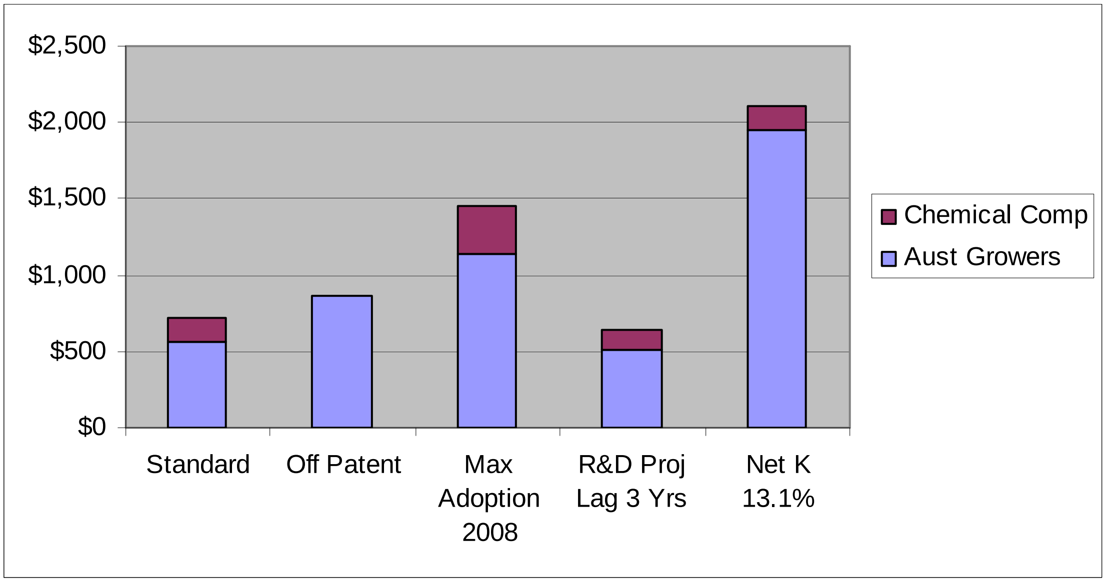

Figure 6 Sensitivity of total Australian producer surplus (PV $k) to a decrease in the time taken to reach maximum adoption, an increase in the time taken to conduct the R&D project and the net benefit to growers of adopting the new herbicide.

The impact on grain grower and agrichemical company benefits from the R&D project of changes to the price premium captured by the agrichemical company and the cost of the herbicide are shown in Figure 7. Increasing the price premium the agrichemical company was able to capture by 150%, from 20% of the herbicide price to 50%, increased the benefit of the R&D project to the chemical company by 150% and reduced the benefit to grain growers by 42%. Decreasing the price of the herbicide by 40%, to $15/ha, decreased the benefit to the agrichemical company by 40%, and increased the benefit to grain growers by 67%. In the higher price premium scenario the public B:C ratio was 0.9 and IRR 0%, while the private investment became much more attractive, a B:C ratio of 1.1 and IRR 8%. Decreasing the price of the herbicide changed the public B:C ratio to 2.6 and IRR to 64%, and the private B:C ratio to 0.3 and IRR of -47%.

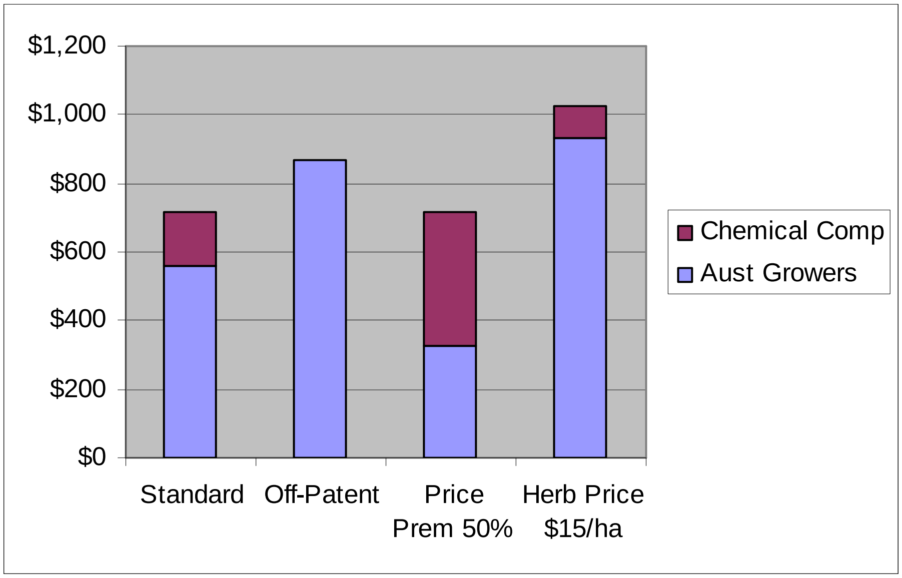

Figure 7 Sensitivity of total Australian producer surplus (PV $k) to changes in price premium and price of the hypothetical new herbicide for chickpeas.

Concluding comments

The distribution of benefits between Australian grain growers and agrichemical companies from more effective and efficient use of herbicide is determined by the patent status of the herbicide and the ability of the agrichemical company to extract a price premium from the market. The R&D project analysed in the case study of more rapid adoption of a new herbicide for chickpeas was estimated to have good returns, with a benefit: cost ratio of 1.5, and an internal rate of return of 28%. Australian grain producers were the chief beneficiaries of this R&D, receiving 78% of the benefits due to the R&D project. Agrichemical companies were minor beneficiaries, as they received 22% of total benefit. Australian consumers and the rest of the world's consumers and producers received no benefit or cost from the R&D project, as there was nil impact on the global price of chickpeas.

The distribution of benefits in these two case studies differs markedly from the findings of Qaim and Traxler (2005) for patented Roundup Ready soybeans, where the patent holder received 34% of the benefit, and consumers received 53%, but grain growers received only 13%. Similarly, Falck-Zepeda et al. (2000) estimated that seed and biotechnology firms captured 26% of the benefits from another patented technology, Bt cotton. In this case though, grain growers received 50% of the benefits, while consumers received the remaining 24%.

This comparison between the findings of previous studies with our results highlights the very limited extent to which agrichemical companies have been able to appropriate benefits from "public" R&D investment in herbicide use in Australia vis-à-vis their share of more recent patented biotechnological innovations. As with other types of agricultural R&D for the grain industry, grain growers not only collectively fund much of the cost of herbicide use R&D, but also capture most of the benefits.

Unlike the market for new biotech innovations, the Australian market for herbicides is highly competitive. Alternative methods of weed control, including a number of off-patent herbicides, are often nearly as cost effective for grain growers as on-patent herbicides. Hence, the scope for agrichemical companies to charge significant price premiums for patented herbicides is severely constrained. Second, in contrast to global production of cotton and soybeans, the fact that Australia exports most of its grain production explains why grain growers, rather than consumers, appropriate the lion's share of the benefits from herbicide use R&D.

For these reasons, an agrichemical company is unlikely to invest heavily in the type of R&D project analysed in the case study given the extremely low rate of return on their investment, -30%. Sensitivity analysis revealed agrichemical companies would only find this R&D project a viable investment where a patented herbicide is more widely adopted among Australian grain growers, the price premium captured is high, and/ or the price of the herbicide is high. Current investment by public organisations, such as the GRDC and state government departments of primary industry, rarely involves R&D projects with these characteristics so it is unlikely public funds would be allocated to R&D providing substantial benefits to private agrichemical companies.

Public and/or collective grower funded investment in R&D projects such as this case study is therefore required if grain growers and consumers are to benefit from such projects. The allocation of "public" investment funds to various herbicide use R&D projects, should be determined by the net return on investment to Australian grain growers and consumers, and disregard possible benefits the patent status of the herbicide may provide to agrichemical companies.

Acknowledgements

The research presented in this paper is part of a larger project supported by the Grains Research and Development Corporation. We are grateful to Stephen Powles and the staff of the Western Australian Herbicide Resistance Initiative for their assistance with this research.

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