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

Bronwyn Crowe[1], Bob Lindner[1] and Rick Llewellyn[2]

[1]School of Agricultural and Resource Economics, University of Western Australia, Perth Australia; **croweb@are.uwa.edu.au**

[2]Current address: CSIRO Sustainable Ecosystems, Adelaide, Australia.

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Abstract

The allocation of benefits from research and development of new herbicide uses is dependent on patent status. The agricultural chemical industry will preferentially invest in herbicide R&D that increases the use of on-patent herbicides from which a company can capture a price premium. The distribution of benefits from increased use of on-patent herbicide will alter over time, with grain growers benefiting at the expense of agrichemical companies once the patent expires. Public sector investment in herbicide R&D may also benefit the agrichemical industry. The size and allocation of the benefits from R&D into on-patent herbicides is analyzed using economic surplus techniques. Two case studies are examined. One involves research into the choice and application of herbicide for new wheat varieties. The second case study involves returns from R&D investment in research into an alternative for the commonly used off-patent herbicide trifluralin. The results from the case studies show that herbicide patent status may not have important implications for "public" R&D investment decisions.

JEL Codes: Q16, Q18, Q28

Introduction

The Australian grains industry relies on herbicides for cost-effective weed control, spending nearly 1 billion on herbicides in 2004 (APVMA, 2005) . The Grains Research and Development Corporation (GRDC) invests substantial sums of growers' funds 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 off-patent, or generic, herbicide use R&D because most of the benefits are widely distributed among many grain growers. For R&D that improves the effective and efficient use of on-patent proprietary herbicides, both the level of benefits, and the distribution of these benefits between consumers, grain growers, and agrichemical companies across time, are influenced by numerous factors, including in particular the limited duration monopoly conferred by the patent.

The return on investment for grain grower and/or taxpayer (public) funds spent on herbicide use R&D also depends on several factors, including whether adoption of research results in greater or lesser use of proprietary herbicides. Where herbicide use R&D only increases the use of off-patent herbicides, thereby increasing yield and/or reducing other farm costs, consumers and grain growers will be the primary beneficiaries from adoption of new herbicide use technology . Conversely, where such research leads to increased use of patented herbicides, the agrichemical companies, as well as grain growers and consumers, are likely to benefit from the R&D. In addition to the duration of an unexpired 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 resulting in increased sales of a patented herbicide, a superficially attractive option would be to rely on the agrichemical company to fund 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 not share any of the research benefits that arise once the herbicide goes off-patent. In addition, impediments to practicing first degree price discrimination further reduces their incentive to invest in the optimal amount of herbicide use R&D. Most 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. Consequently, grain growers may not realize all of the benefits potentially available from herbicide use R&D.

Publicly funded research bodies, such as industry research and development corporations, 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 how size of benefits from herbicide use R&D as well as the allocation of benefits between growers, agrichemical companies or consumers.

Evaluating returns from herbicide 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 analyzed 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 (Jones et al., 2000; Sinden et al., 2004; Vere et al., 2004) 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.

Case Studies

This section presents two case studies of the benefits and beneficiaries of herbicide use R&D in relation to the herbicide's patent status. These case studies are based on current and future possible investments by Australian publicly funded organizations. The first investigates optimal herbicide use in new wheat varieties. The second involves research into a new alternative to the pre-emergent herbicide trifluralin in wheat.

In both cases, impacts on wheat production only are considered for the Northern, Southern and Western cropping regions in the Australian cropping belt (Figure 1). Initial wheat production and consumption for each region is given in Table 1. Global consumption was assumed to equal global production. Both the initial wheat price and the cost of production were set at $249/tonne. No technology spillover to the rest of the world was assumed as changes to the patent status and registration of herbicide products in Australia would not influence other countries, or have flow on effects through price and production quantities. A discount rate of 5% was used.

Figure 1 Australian agro-ecological cropping zones and regions (GRDC).

Table 1 Regional production and consumption (ABARE, 2005a; ABARE, 2005b) and elasticity of supply and demand (Sinden et al., 2004).

Region	Production ('000t)	Consumption ('000t)	Elasticity of supply	Elasticity of demand
Western	6954	0	0.23	-
Southern	9909	0	0.26	-
Northern	2725	0	0.33	-
Aust Consumers	0	5127	-	0.50
ROW	583241	597702	0.50	6.17

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

The R&D projects described in Case Study 1 and 2 are based on research conducted by the Grains Research and Development Corporation, state departments of agriculture or primary industry and other publicly funded agricultural research organizations. Price premium estimates are based on interviews conducted with experts from the agrichemical industry and analysis of herbicide prices in Australia following patent expiry.

Case study 1. Screening for different herbicide tolerance in cultivars of winter cereals

Background

Herbicides used for selective weed control in-crop can result in phytotoxicity effects leading to crop yield loss. Variance in the tolerance of varieties to major herbicides can be high, with further variance caused by environmental factors such as season and soils. Herbicide companies are not required to provide information specific to new crop varieties and, unlike disease tolerance ratings generated by crop breeders, herbicide tolerance is not part of the variety development process. Yield losses of 10% in wheat varieties due to use of common herbicides are often recorded (Churchett et al., 2004; Osten, 2003). Symptoms of the yield-loss causing effects are often difficult to observe or unobservable. Conversely, in many cases visible effects of herbicide treatment are not associated with yield loss. Therefore, screening for herbicide tolerance and extension of this information is performed through a separate network of projects.

The With R&D Project Scenario

The R&D project consists of a national network of three herbicide screening projects that provide information about herbicide choice and application for new varieties of wheat. Growers and advisors use the information provided by the R&D project to avoid herbicide treatments that have a high risk of yield loss if applied to a new variety. It is common for the herbicide shift to be away from an older, off-patent, herbicide to a newer herbicide product (Churchett et al., 2004).

Three years of field trials are needed before any information about potential for yield loss in a wheat variety can be confirmed, and communicated to growers and advisors. It is assumed that all grain growing regions benefit from this network of herbicide tolerance screening projects due to the identification of potential yield loss for a new wheat variety that will be adopted in their region. With the information produced by the R&D project, growers shift to a recommended herbicide and avoid yield losses in the new wheat varieties, providing a 3.33% reduction in production costs. This level of benefit is intended to take into account that yield losses of 10% only occur one year in three, so the shift to the recommended herbicide will not result in a yield gain every year. The recommend herbicide is assumed to take 2 years to reach a maximum adoption of 2% in 2010. The R&D project is estimated to cost $300,000 p.a. for 3 years, from 2006 to 2009.

We assume that the recommended herbicide remains on-patent throughout the analysis period, from 2006 to 2015, while the alternative herbicide is off-patent. As the herbicide recommended by the R&D project is under patent, the agrichemical company is able to extract a price premium from the grower. This price premium reduces the production net benefit to the grower. Assuming the cost of the new herbicide is $15/ha and the agrichemical company is able to extract a 10% price premium, the benefit to the agrichemical company is $0.83/t or 0.33% of the wheat price. The net benefit to Australian production is therefore a 3.00% reduction in production costs (3.33%, less the herbicide company premium of 0.33%)

The Without the R&D Project Scenario

It is assumed that in the absence of herbicide screening R&D, a small area of the new variety will be grown in the year immediately after release by growers and/or agronomists, and some will be exposed to the damaging herbicide treatment. While this experience will generate information about the herbicide tolerance level, it will potentially be costly due to loss of potential yield. In the absence of the R&D project, it is assumed that information equivalent to that produced by the R&D project will be generated by 2009 and implemented from 2010. Adoption of the information and consequently the recommended herbicide will provide growers with a net benefit of 3.00%. As the dissemination of this information does not have the support of the R&D project, it is assumed to take 4 years to reach a maximum adoption of 2% in 2013.

Results

The total benefits to Australian grain growers of the information about the recommended herbicide, with and without the R&D project, are shown in Figure 2. The total NPV of benefits to Australian wheat growers due to the R&D project ($4,538,000) can be compared to assumed total NPV of R&D costs of $817,000 and an agrichemical company benefit of $502,000, Table 2. The benefit: cost ratio of the R&D project for "public" investment was 5.6, and the internal rate of return 80%, excluding the rest of the world. The private or agrichemical company investment benefit: cost ratio was 0.6 and the internal rate of return was -10%.

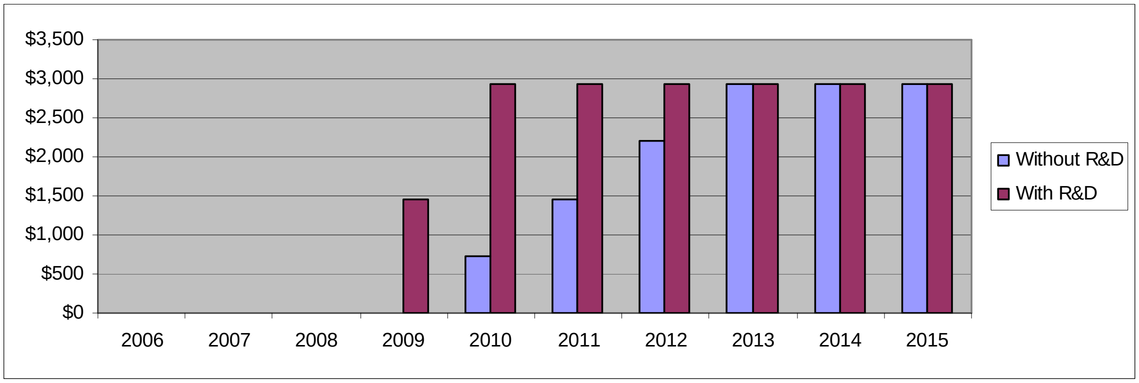

Figure 2 Time profile of benefit to Australian production from recommended herbicide with and without the R&D project ($'000).

Table 2 Australian grain growers, consumers and agrichemical company surplus from the herbicide screening project and the R&D projects cost ($'000)

Beneficiary	NPV
Western Region	$ 1,610
Southern Region	$ 2,296
Northern Region	$ 631
Agrichemical Company Surplus	$ 502
Total Producer Surplus	**$ 5,040**
Australian Consumer Surplus	$ 0
Total Surplus	**$ 5,040**
R&D Cost	**$ 817**

Case study 2. New herbicide R&D: the example of an alternative to trifluralin

Background

The loss of post-emergence herbicide options in wheat due to herbicide resistance has led to an increased reliance on pre-emergence herbicides, particularly Trifluralin. Resistance to Trifluralin is increasing, with new resistant annual ryegrass populations being identified in Australia Western and Southern Australia (Boutsalis, 2006; Owen et al., 2005). As the number of cases increases, there is growing recognition of the need for alternative herbicide options, particularly as effective pre-emergence herbicides like Trifluralin are very important in the increasing use of soil-conserving cropping systems such as no-till (D'Emden et al., 2006)

The use of herbicides which inhibit tubulin formation, primarily Trifluralin, has grown from 1 million ha in 1990 to approximately 6.9 million ha in 2003 (O'Connell, 2004). The generic trifluralin market is highly developed and price competitive, with over 20 registered suppliers in Australia. Trifluralin's high cost-effectiveness reduces the short-term incentive for herbicide companies to develop and register a product to substitute for trifluralin that does not offer significant relative advantage in the absence of herbicide resistance. Most current alternatives to trifluralin use pre-emergent in wheat pose a greater risk of crop damage and yield loss. Some growers currently choose to use these alternatives on a fraction of their wheat land.

The With R&D project Scenario

The aim of the R&D project is to identify an existing herbicide superior to current trifluralin alternatives that has not been registered for use in the Australian broadacre cropping market. The R&D project is intended to demonstrate the advantages of the new herbicide to growers and the agrichemical industry to assist commercial release and increase adoption. The new herbicide has no advantage over trifluralin as such, it is applied in situations were trifluralin resistance has developed and alternative herbicides must be used to control weeds. Adoption is assumed to occur among growers who would otherwise be using alternative pre-emergence options for wheat due to trifluralin resistant weeds. Trifluralin resistance is projected to develop as in Figure 3, with 2% of production affected in 2010 and 9% in 2015. After its release in 2008, the new herbicide is assumed to be applied to 50% of wheat production affected by Trifluralin resistance. The R&D investment is assumed to be $150k p.a., for 2006 and 2007.

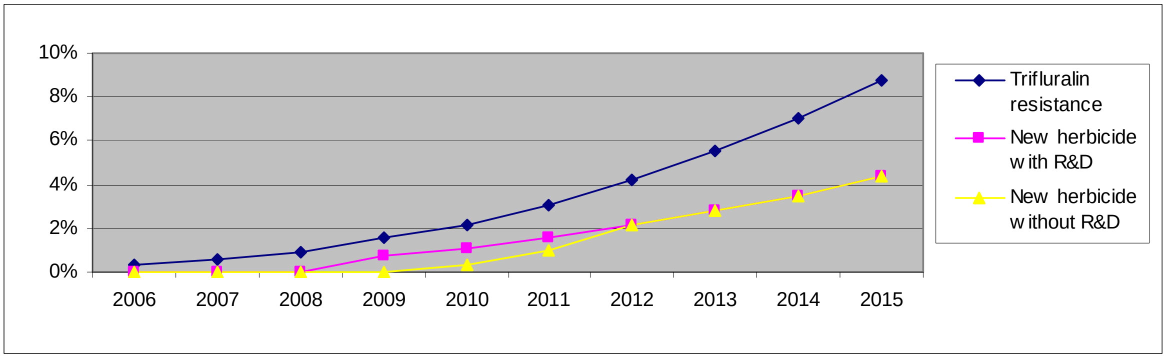

Figure 3 Proportion of Australian wheat production affected by trifluralin resistant weeds and treated with the new herbicide alternative to trifluralin with and without the R&D project.

The new herbicide is safer on the crop and more effective on weeds than the trifluralin alternatives currently on the market. As a result, the new herbicide provides a 5% yield advantage over current herbicides available to control Trifluralin resistant weeds. It is assumed a product superior to this herbicide is not released during the analysis period, 2006 to 2015.

The patent of the new herbicide is expected to be held by the agrichemical company for the duration of the analysis. The monopoly of supply this patent protection entails means the agrichemical company is able to extract a price premium from the market. As the new herbicide will be comparable to current herbicides available to control Trifluralin resistant weeds its price is assumed to be similar, $15/ha, including a 5% price premium. Meaning the agrichemical company captures a $0.75/ha price premium. The overall benefit of the new herbicide to growers is therefore 4.82%, being a 5% yield advantage less a $0.75/ha price premium or 0.18% cost increase.

The Without the R&D Scenario

Without the R&D project it is assumed the agrichemical company would register the new herbicide for use in broadacre cropping at the same point in time as with the R&D project;

commercial release in 2009. However, without the R&D project, adoption of the herbicide is lower initially as less independent information is available to growers. Adoption is initially 40% of wheat production affected by Trifluralin resistance (compared to 50% with R&D), increasing to 50% after 5 years as growers and agronomists discover the information produced by the R&D project. The benefit to growers and the price premium for the agrichemical company from the new herbicide are the same as with the R&D project, an overall benefit to growers of 4.82% and 0.18% to the agrichemical company.

Results

The time profile of benefits to Australian grain growers of the alternative to trifluralin with and without the R&D project is shown in Figure 4. The total NPV of benefits to Australian wheat growers for this period ($3,733,000) can be compared to the assumed total NPV of R&D costs of $279,000 and an agrichemical company benefit of $128,000, Table 3. The benefit: cost ratio of the R&D project for "public" investment was 13.4, and the internal rate of return 135%, excluding the rest of the world. The benefit: cost ratio from the agrichemical company perspective was 0.5 and the internal rate of return was -16%.

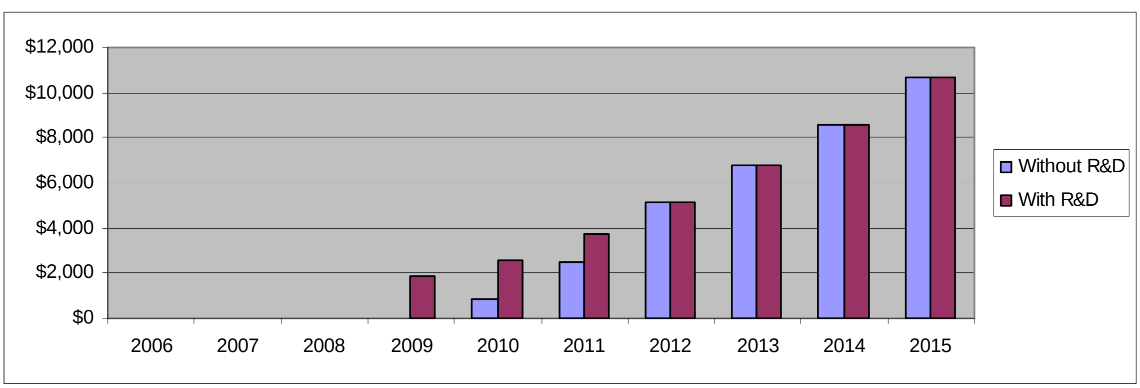

Figure 4 Time profile of benefits with and without R&D project to register a trifluralin alternative ($'000).

Table 3 Australian grain growers, consumers and agrichemical company surplus from the R&D project into a new alternative herbicide to trifluralin, and the R&D projects cost ($'000)

Beneficiary	**NPV**
Western Region	$ 1,872
Southern Region	$ 1,858
Northern Region	$ 0
Agrichemical Company Surplus	$ 128
Total Producer Surplus	**$ 3,861**
Australian Consumer Surplus	$ 0
Total Surplus	**$ 3,861**
R&D Cost	**$ 279**

Concluding comments

The distribution of benefits between Australian grain growers and agrichemical companies from R&D on more effective and efficient use of herbicide is determined by the patent status of the herbicide and the consequential ability of the agrichemical company to extract a price premium from the market. The R&D projects analyzed in Case Studies 1 and 2 were estimated to have high overall returns, with benefit: cost ratios of 5.6 and 13.4, and internal rates of return of 80% and 135% respectively. Australian grain producers were the chief beneficiaries of this R&D, receiving 90% of the benefits due to the R&D project of Case Study 1, and 97% in Case Study 2. Agrichemical companies were only minor beneficiaries, as they received 10% of total benefit for Case Study 1 and 3% for Case Study 2. Australian consumers receive no discernible benefit in Case Study 1 or 2.

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 chemical 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 almost all 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 generic herbicides, are often as cost effective for grain growers as patented herbicides. Hence, the scope for chemical 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 wheat 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 in the type of R&D projects analyzed in Case Studies 1 and 2 given the extremely low prospective rate of return on their investment, -10% and -16% respectively. Public and/or collective grower funded investment in such R&D projects therefore is 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, such as Case Study 1 and 2, should be determined by the net return on investment to Australian grain growers and consumers, disregarding possible benefits to the agrichemical industry due to the patent status of the herbicide.

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