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Does agricultural extension pay? A case study for a new crop, lupins, in Western Australia

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Abstract

Compared to studies evaluating the benefits from agricultural research, there are relatively few empirical studies of the net economic benefits of agricultural extension, and even fewer that consider both public and private sector extension effort. In this study we examine regional differences in the adoption of lupins in Western Australia (WA) in order to estimate the net economic benefits of public and private sector extension. Impacts of extension and other variables on adoption were analysed for 40 shires using multivariate regression analysis. The results suggest that both public and private extension activities influenced farmer uptake of lupins, particularly by bringing forward the start time of the diffusion curve. Economic benefits of extension, based on the statistical analysis, were combined with costs of extension estimated from public sector records and surveys of private sector extension agents and used to estimate the net present value of extension investments by the public and private sectors in the study area.

JEL classification: Q16; O30; D61; C22

Keywords: Returns to agricultural extension; Private sector; Public sector; Cost–benefit analysis; Adoption and diffusion

1. Introduction

Around the world, governments, aid bodies and agribusiness invest considerable funds in extension. For example, Huffman and Evenson (1993) and Knutson and Outlaw (1994) estimate that in excess of 1 billion US$ (bUS$) is spent annually on agricultural extension by government agencies in the US. Maalouf et al. (1991) make an estimate of 6 bUS$ per year (and 600,000 extension workers) spent globally on servicing the extension needs of farmers. The involvement of the World Bank in funding Green World Technology in developing countries has resulted in studies that attempt to directly evaluate the effectiveness of extension services to farmers in these countries (Feder et al., 1987; Polson and Spencer, 1991; Hussain et al., 1994).

There is considerable evidence that the returns to research investments are high (Evenson et al., 1979; Edwards and Freebairn, 1981; Huffman and Evenson, 1993). There is, however, less consensus on the size of returns to extension investments. Those studies that have been conducted (e.g. Huffman, 1978; Feder et al., 1987) have yielded equivocal results, with internal rates of return estimated in the

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range zero to as high as 110%. A review by Evenson and Kislev (1975) suggested that overall returns from extension are approximately the same as those from research, while Huffman (1978) concluded that past studies showed that returns to extension investments were 'modest or better'. A review by Birkhauser et al. (1988), cited in World Bank (1990), showed rates of return to extension in developing countries ranging from 13 to 500% in Brazil, 75 to 90% in Paraquay, and 14 to 15% in India. Rates of return to extension investment in the US were estimated to be greater than 100% and internationally, returns were shown to be between 34 and <80%. A more recent study by Huffman and Evenson (1993) estimated rates of return to public extension investments in the US between 1950 and 1982 at 20% overall, ranging from 40% in the crop sector to negative returns in the livestock sector. This overall rate of return was approximately half of that estimated for research and development (both in the public and private sectors).

Returns to research and extension have been measured using two different approaches. The most widely used technique is that pioneered by Griliches (1960) which involves the estimation of an agricultural production function and uses regression analysis to isolate the contribution of research. The second technique involves the calculation of economic surplus by estimating the long-run supply curve and uses cost–benefit analysis to measure the average productivity of research.

Research on the economic benefits of extension faces a number of difficulties, the most serious of which has been an inability to seperate the effects of extension from contributions to productivity from other sources, notably from research and human capital (Huffman, 1978; Norton et al., 1984; Huffman and Evenson, 1993). Additionally, there are difficulties associated with assessing both extension expenditure and the output resulting from those expenditures. As concluded by Baxter et al. (1989, p. 51):

> No government or public extension service is readily able to indicate the total recurrent and capital cost of its extension operations. Even when approximations can be made, there remain legitimate questions about which parts of an agricultural service system as a whole, and its administration, constitute 'extension' expenditure.

The rates of return to investments in extension activities in Australia have not been documented, and there have been few studies elsewhere. Despite this, there is a world-wide trend towards the privatisation of agricultural extension services (Rivera and Gustafson, 1991), exemplified by recent developments in New Zealand and, to a lesser extent, in Australia (Marsh and Pannell, 1998). This trend appears related to factors such as the declining relative importance of agriculture in the economy, budget pressures on governments, and privatisation policies for services seen to have important 'private-good' characteristics.

The reintroduction of lupins into Western Australian farming systems in 1979 and their subsequent widespread adoption after a major extension campaign provides an ideal subject for a temporal diffusion study designed to investigate the influence of extension on the adoption process. The research and development work associated with this new crop was largely confined to Western Australia (WA),[2] which means that the effect of external influences can be considered minimal. Information about the productive capabilities of lupins, their role in the Western Australian farming system, and management techniques required to grow them successfully were extended vigorously by the State Department of Agriculture and the new crop was adopted rapidly by farmers in the 1980s. This comparatively recent and concise history means that it is possible to access reasonable shire-level records that cover the work associated with the development, associated basic and applied research, and extension of this crop.

Lupins have proven to be an innovation that is highly profitable and compatible with Western Australian farming systems. Furthermore, the diffusion process was suspected to be largely complete for a considerable part of the State, preventing the type of methodology problems associated with data from incomplete diffusion patterns that are discussed by Lindner (1987). The highly profitable nature of the new legume crop and its rapid adoption means that the debate regarding the role of extension for innovations perceived as 'unprofitable' (for example, conservation practices) raised by Pampel and van Es (1977) and Napier et al. (1984) is not an issue in this case.

[2] A history of the development of the sweet white-flowering lupin is provided by Gladstones (1982).

In this study the returns to extension were estimated based on differences in farmers' net returns over time 'with and without' extension. Where extension effort was found by a multivariate regression analyses to have an effect on adoption, the estimated model was used to estimate the 'without' extension scenario. This approach has previously been used ex ante (Edwards and Freebairn, 1981; Norton et al., 1987; Gross et al., 1991) to measure the benefits of shortening the adoption process, but the authors are unaware of any similar ex-post analysis.

Costs associated with both public and private extension effort were estimated. In this respect this study attempts to address one of the major biases present in many other studies (Huffman, 1978) which measure returns to extension without accounting for private extension input.

2. Background on lupins in Western Australia

Few new industries have been adopted so rapidly and successfully as the lupin industry in Western Australia. The area planted to sweet narrow-leafed lupins (*Lupinus angustifolius*) in WA grew from less than 100,000 ha in 1980 to an initial peak of 877,000 ha in 1987. By 1992, the area planted had dropped to 822,000 ha but it gradually climbed again exceeding 1 million hectares in 1996. The first sweet white-flowering lupin (cultivar uniwhite) was released in 1967 and promoted as a legume crop especially suitable for sandplain soils in the heavier rainfall areas of the northern wheatbelt. By 1973, the area planted to lupins was 120,000 ha but a combination of poor management practices by farmers and droughts in 1976 and 1977 saw lupins lose favour. By 1978, the area planted had fallen to 40,000 ha. In 1979, a higher yielding cultivar (Illyarrie) was released and a major extension effort by the Department of Agriculture's Geraldton district office in the northern wheatbelt area commenced. This extension effort is credited with contributing to the rejuvenation of the lupin industry during the 1980s (Nelson, 1987).

In 1981 the Department of Agriculture commenced trials and extension activities in the Merredin region to demonstrate that lupins could play a valuable role in farming systems in drier areas of the wheatbelt. The remainder of the 1980s saw the rapid adoption of lupins throughout the agricultural area of Western Australia, the release of further improved varieties, the development of overseas markets for the new crop, and considerable trial and extension effort by both the public and private sectors put into the developing lupin industry.

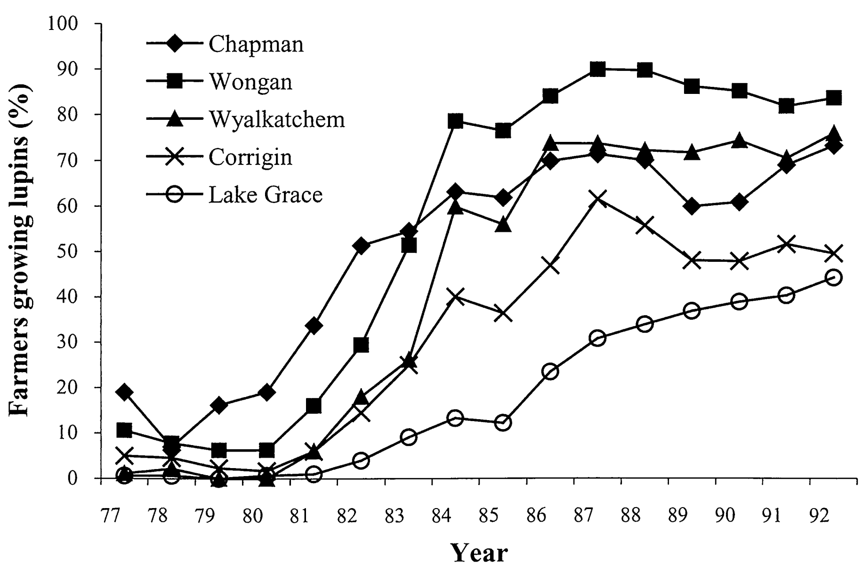

Fig. 1. Diffusion curves for lupins in selected shires of Western Australia.

The uptake of the new crop varied widely between regions. Fig. 1 shows the percentage of farmers growing lupins over time in each of five shires in the Western Australian wheatbelt, from Chapman Valley in the north, then progressively southeast through Wongan-Ballidu, Wyalkatchem, Corrigin, and Lake Grace. All the shires illustrated, except Lake Grace, appear to have gone through a complete diffusion process, and reached a ceiling level of adoption. This is the case for the majority of the 40 shires in the study. The shires shown in Fig. 1 illustrate differences in the adoption of lupins that can be seen in different areas of the state. For each of the five shires there are differing times when the adoption process commenced, differing ceiling levels of adoption reached and differing rates of adoption to reach the ceiling. Obviously, a great number of factors influence these differences, and one of the initial aims of this study is to attempt to segregate and quantify the effect of extension activities on the adoption process.

3. The impact of extension on the adoption of lupins

A methodology similar to that pioneered by Griliches (1957) is used to estimate start times, rates, and ceiling levels of adoption in 40 shires of the northern and central wheatbelt. These shires represent most of the major lupin growing areas in the State, although some southern shires not included in the study have lupin enterprises of growing importance. These estimates are then used as dependent variables in multivariate regression analyses, in an attempt to determine factors influencing the diffusion process. The estimates of start years for the shires are listed as part of Table 2 (column A).

Data was collated on an individual shire basis. By examining adoption behaviour at the shire-level (rather than the usual national or state level) it was hoped that this greater than usual detail would better allow detection of the impacts of extension. A considerable number of possible independent variables were investigated (see Marsh et al., 2000, for more details), in the following general areas:

- estimates of percentages of soils suitable for lupins in the shire;
- measures of climatic variability;
- measures pertaining to lupin yields;
- measures of scale;
- variables to capture the extent of cropping intensity in the shire;
- variables to capture farmer experience with growing lupins;
- measures of distance from information sources;
- measures of Department of Agriculture extension activities; and
- measures of private sector extension activity.

These variables reflect factors that have been shown to influence the adoption of technologies. Suitable soils, climatic variability and lupin yields all affect the potential profitability of the technology in a particular location, and profitability is known to be a major factor affecting the uptake of new technologies (Griliches, 1957; Ruttan, 1977; Lindner, 1987; Feder and Umali, 1993; Rogers, 1995). Measures of scale and cropping intensity capture relative profitability of the technology for a particular farm business. Classic studies by Griliches (1957) and Mansfield (1961) both identified that the size of the business, and hence expected return from the new innovation, are related to earlier adoption and faster rates of adoption. Farmer knowledge and experience plays an important role in the adoption process (Feder and Slade, 1984; Lindner, 1987). Feder and Slade (1984) suggest that a certain critical level of cumulative information must be attained before adoption takes place. Distance from information sources has also been suggested as a factor that influences adoption (Lindner et al., 1982; Noonan and Gorddard, 1995). Finally, extension activities have been explored by a number of researchers and found in some cases to influence adoption (e.g. Feder et al., 1987; Harper et al., 1990; Polson and Spencer, 1991; Strauss et al., 1991; Abler et al., 1992; Grisley, 1994; Hussain et al., 1994).

The selection of variables for inclusion in models describing characteristics of the adoption curves was conducted by investigating a number of models and selecting those in which standard statistical tests indicated that parameters were significantly different from zero. The models investigated only included variables that were supported by adoption and diffusion theory, as previously outlined. Nevertheless, it is true that the procedure used invalidates strict interpretations of in-

Table 1
Start time regression results and variable definitions

Regressors	Coefficient	Standard error	T ratio (P)
Intercept	82.0215	0.45791	179.1218 (0.0)***
Crop%	−1.4684	0.96221	−1.5260 (.137)
Lupin Farmers 1978	−3.7991	1.0925	−3.4776 (.001)***
Field Days 1980	−0.2251	0.11476	−1.9614 (.059)*
Adviser Distance 1979	0.017679	0.0080027	2.2091 (.034)**
Geraldton	−1.4585	0.26774	−5.4475 (.000)***
Consultant 1	−0.67502	0.30781	−2.1929 (.036)**
Merredin	−0.43980	0.18019	−2.4407 (.020)**

Variable	Definition
Dependent variable (start time)	The time in years when the percentage of farmers in the shire growing lupins was equal to a level calculated as the minimum percentage of farmers growing lupins plus 10% of the difference between that minimum and the maximum percentage of farmers that grew lupins
Crop%	Percentage of farmland in the shire in crop, averaged for the years 1980–1984
Lupin Farmers 1978	Percentage of farmers in the shire growing lupins in 1978
Field Days 1980	Cumulative count of Field Days, meetings and seminars, featuring lupins either wholly or partly, held in the shire up to and including the year 1980
Adviser Distance 1979	Ratio of the distance of the shire from the Agriculture WA district office to the numbers of advisers working in that office in 1979
Geraldton	Dummy variable for shires in Agriculture WA's Geraldton advisory district
Consultant 1	Dummy variable for the shires in which Consultant 1 was operating
Merredin	Dummy variable for shires in Agriculture WA's Merredin advisory district

Model 1: $R^2 = 0.84$; $R\text{-bar}^2 = 0.80$ (sample size = 40).
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

ferential statistics generated in the statistical regressions. In recognition of this, we have not attempted to use the statistics to conduct rigorous tests of model parameters. Rather, we have used the statistics as indicators of the appropriateness of inclusion of variables, with the overall objective of obtaining a model that fits the data well, rather than one that supports strict statistical inferences.

Regression results and definitions for the significant independent variables in this regression are given in Table 1 (a more detailed presentation of the statistical results is provided by Marsh et al., 2000). Results from the multivariate regression analyses suggest that extension did affect the start time of the adoption of lupins in the study area. Approximately 70% of the variability in start time was accounted for by four variables, two of which, Field Days 1980 and Adviser Distance 1979, are measures of extension activity. A third variable, Lupin Farmers 1978, describes the percentage of farmers who have previous experience with the technology. The remaining variable, Crop%, is a measure of the profitability of cropping in the area compared to alternative grazing enterprises. All variables had the expected sign, and diagnostic tests indicated that functional form and heteroscedasticity are not problems for the model. The addition of three dummy variables, namely Geraldton, Merredin and Consultant 1, which take account of major extension efforts by the Department of Agriculture in the Geraldton and Merredin areas, and the activities of a private consultant, result in the model describing over 80% of the variability in start time. The significance of these variables suggests that concerted extension activity by either the public or the private sector, as occurred in these areas, does influence adoption start times.

Other results, not reported here, indicate that extension was not a factor influencing ceiling levels of adoption of lupins. Significant variables in that analysis were those describing yields, rainfall and percentage of the shire cropped (Marsh, 1996). These are all variables which measure the production environment and impact on profitability. These findings are supported by previous research. Likewise, the evidence from the regression analysis of adoption rate also points to the overwhelming influence of profitability factors on the rate of adoption of lupins (Marsh, 1996). Any influence of extension on rate of adoption of lupins in different areas was too low to be clearly identified by our analysis.

4. Method used to estimate the costs and benefits of lupin extension

4.1. Estimates of benefits attributable to lupin extension in the study area

Using the coefficients from model 1 (see Table 1), three calculations were made. The function was solved for Y (the start time) using the actual values of the coefficients, and then with the coefficients for extension variables (Field Days 1980, Geraldton, Merredin and Consultant 1) set to zero. The coefficient for Adviser Distance 1979 was not set to zero for this initial calculation (version 1 in Table 2) as it could not be simply omitted in combination with the other extension variables to produce an interpretable result. To calculate the impact of the Adviser Distance 1979 variable on the start time, the value of this variable for each shire was adjusted to the value that it would take if there had been only one adviser in the district office. The rationale for this approach is that with only one adviser it could be hypothesised that there would be effectively no, or minimal, extension activities undertaken. This adjusted variable value (equal to the distance from the Department of Agriculture district office) was then used to solve for the start time using the calculated coefficient for Adviser Distance 1979 in model 1 and with coefficients of other extension variables set to zero as before (version 2 in Table 2).

Column A in Table 2 gives the actual value of the dependent variable (start year). Column B gives the fitted value of start year according to model 1. Columns C and D give the estimated start time from the regression when the coefficients on the extension variables (Field Days 1980, Geraldton, Merredin and Consultant 1) are set to zero, and the difference in years from the initial estimate, respectively. The effect of removing the extension variables results in a delay in the start time ranging from 0 to 2.13 year. Similarly, columns E and F report start times and differences when extension variables are set to zero as before, and the value of Adviser Distance 1979 for each shire is calculated assuming only one adviser. Delays in start time are now more pronounced, ranging from 0.35 to 3.01 years.

Other variables influencing start times in model 1 other than extension variables are Crop% (the percentage of farmland in the shire that is cropped) and Lupin Farmers 1978 (the percentage of farmers in the shire growing lupins in 1978). Crop% is a measure of relative profitability, in the sense that it quantifies the extent of all cropping enterprises in each shire. Lupin Farmers 1978 captures farmer experience with growing lupins in the 1970s. This variable very probably reflects to some extent the location and results of early lupin extension. Since they do not account for this effect, the differences in start time calculated in Table 2 could underestimate the role played by extension in bringing forward the start time of the adoption process.

To assess the dollar benefits associated with earlier (or delayed with no extension) start times, the delayed start times were translated into delays in the areas planted to lupins in different shires, equivalent to the delay in each shire. The areas planted to lupins, after adjustment according to the delay in starting times, were calculated for each year for each shire for the years 1979–1992 inclusive. Details of the total area planted to lupins in the study area, and calculations of the adjusted area after accounting for the delayed start in the absence of extension, are detailed in Marsh (1996) and available from the authors on request.

These areas were then given dollar values. The value of lupins cannot simply be estimated by returns from the harvested grain, because grown in rotation with cereals lupins give substantial benefit to the overall cropping system (Nelson, 1993). Factors such as the disease break for cereals, nitrogen fixation by lupins and the value of stubble and lupin grain for stock feed must be considered, or the profitability of lupins will be substantially underestimated. Accordingly, the benefits from lupin adoption need to be estimated at a farm level rather than an enterprise or rotation level.

The model of an integrated dryland agricultural system (MIDAS model) provides a means of assessing the impact of single crops on whole farm profitability on Western Australian eastern wheatbelt farms (Kingwell

Table 2
Start times of adoption

Shire	Start year		Effect of extension variables on start year			
	A: start year used in the estimation	B: start year estimated by model 1	C: without extension (version 1[a])	D: delay in years (C–B)	E: without extension (version 2[b])	F: delay in years (E–B)
Geraldton district office						
1. Chap Valley	78.70	79.06	81.20	2.13	81.73	2.66
2. Greenough	79.01	79.30	81.21	1.91	81.61	2.31
3. Irwin	79.04	78.79	80.47	1.68	81.60	2.81
4. Mingenew	78.98	78.99	80.67	1.68	82.00	3.01
5. Morawa	81.52	81.47	81.70	0.23	83.55	2.08
6. Mullewa	80.25	80.80	81.25	0.45	82.38	1.58
7. Northampton	79.04	79.25	81.38	2.13	82.18	2.93
Lake Grace district office						
8. Kondinin	81.49	81.99	81.99	0.00	82.70	0.71
9. Kulin	81.67	81.87	81.87	0.00	82.33	0.46
10. Lake Grace	82.08	81.63	81.63	0.00	81.98	0.35
Merredin district office						
11. Bruce Rock	81.31	81.11	81.55	0.44	82.26	1.15
12. Corrigin	81.20	80.99	81.66	0.66	82.78	1.78
13. Kellerberrin	81.34	81.08	81.52	0.44	82.05	0.97
14. Koorda	81.26	81.48	81.92	0.44	83.45	1.97
15. Merredin	80.53	80.92	81.36	0.44	81.60	0.68
16. Mt Marshall	81.30	81.28	81.71	0.44	82.89	1.62
17. Mukinbudin	81.26	81.13	81.57	0.44	82.45	1.32
18. Narembeen	81.44	81.21	81.65	0.44	82.47	1.26
19. Nungarin	81.27	80.89	81.33	0.44	81.80	0.91
20. Trayning	81.08	81.03	81.47	0.44	82.18	1.15
21. Westonia	80.71	80.92	81.36	0.44	81.95	1.03
22. Yilgarn	80.93	81.22	81.66	0.44	82.55	1.32
Moora district office						
23. Dalwallinu	81.01	81.28	81.28	0.00	82.28	0.99
24. Dandaragan	80.71	80.80	81.03	0.23	81.76	0.95
25. Moora	80.76	80.73	81.07	0.34	81.40	0.67
26. Vic Plains	80.72	81.21	81.32	0.11	82.11	0.91
27. Wongan	80.86	81.25	81.25	0.00	82.31	1.06
Northam district office						
28. Beverley	82.03	81.73	81.73	0.00	82.53	0.80
29. Cunderdin	80.62	80.41	81.31	0.90	81.97	1.56
30. Dowerin	80.59	80.80	81.48	0.68	82.47	1.67
31. Goomalling	81.33	81.56	81.57	0.01	82.23	0.67
32. Northam	81.63	81.14	81.37	0.23	81.57	0.42
33. Quairading	81.54	81.70	81.70	0.00	82.76	1.06
34. Tammin	80.73	81.22	81.66	0.44	82.72	1.50
35. Wyalkatchem	81.13	81.01	81.45	0.44	82.64	1.63
36. York	81.97	81.10	81.32	0.23	81.72	0.62
Three Springs district office						
37. Carnamah	80.73	81.16	81.38	0.23	81.65	0.49
38. Coorow	81.21	81.82	81.27	0.45	81.80	0.98
39. Perenjori	82.21	81.69	81.69	0.00	82.22	0.53
40. Three Springs	79.85	80.37	80.82	0.45	80.95	0.58

[a] Based on impact of the Field Days 1980, Geraldton, Merredin and Consultant 1 variables only.

[b] Based on the impact of the Field Days 1980, Geraldton, Merredin and Consultant 1 as well as the Adviser Distance 1979 variables.

and Pannell, 1987). A number of estimates of the contribution made by lupins to overall farm profitability, ranging from 27 to over 60 US$/ha, have been made using this model (Ewing et al., 1987; Pannell and Bathgate, 1991; Kingwell, 1991). Three values of dollar benefit per hectare (45, 30 and 15 US$) are used in this analysis and these were assumed constant over time. Given the nature of the index of farm prices to farm costs, this assumption is not unreasonable. The possibility of a negative demand price response to increasing supply was considered, but lupins substituted directly for existing feed grains in the existing large feed grain market, so a high elasticity of demand was considered realistic. In support of this assumption, we note that the price for lupins did not decrease significantly as the adoption level and production increased.

A number of different scenarios are used to estimate the benefits of lupin extension in the study area. Benefits are estimated over the period 1979–1989. The year 1979 corresponds with the release of the new variety, and by 1988 the 'without' extension situation had caught up (in terms of hectares planted) with actual lupin plantings. Initially the two delayed estimates of start time (versions 1 and 2) are used to calculate benefits for the three different values for a hectare of lupins, at two different real discount rates, giving 12 possible benefit estimates.

These estimates assume unrealistically that the full benefit from a hectare of lupins was immediately available to farmers from the first year of planting. Another set of estimates hypothesis an effect of extension on the time when farmers achieved full benefit from a hectare of lupins. The methodology we use to investigate adoption rates does not allow us to measure the role of extension in educating farmers about the production potential of the new crop. Extension could have played a role in helping farmers achieve the production capability of the new crop through extension agents' role as 'problem solvers'. Taped interviews made during the course of this study with extension personnel working in the Merredin area emphasise this point. They indicate that extension personnel worked closely with farmers who were growing lupins for the first time to assess management techniques and the reasons for crop failure and success.

To account for these hypothesised effects of extension, estimates are made in which the full benefits from a hectare of lupins were not achieved until 1983 in the absence of extension. In this scenario, it is assumed that the problem solving contribution of extension agents brought forward the realisation of full benefits by adopting farmers by 4 years to 1979. In the absence of extension, the per hectare benefit to farmers in 1979 is assumed to be half the full benefit, increasing linearly over the next 3 years and reaching the full benefit in 1983. Another set of estimates assumes that without extension the full benefit from a hectare of lupins was not achieved until 1989. For these estimates, the benefit in 1979 is again assumed to be half the full benefit, increasing linearly over the next 10 years and reaching the full benefit in 1989.

4.2. Estimates of public sector costs associated with lupin extension in the study area

The Department of Agriculture was the only major public sector player involved in the extension of lupins. As discussed in Section 1, there are inherent difficulties associated with costing overall, let alone single enterprise, extension effort. Additionally, changes in accounting systems used and a lack of partitioning of costs make it difficult to gain a clear picture of the Department of Agriculture's spending by enterprise and region in the 1980s. Total spending for the Department of Agriculture, extension spending and R&D spending are obtained from annual reports as detailed in Marsh (1996). Records are obtained for total spending by region for the years 1985/1986–1991/1992. Estimates for spending on extension in the study area are then made in three categories as outlined below. Details of the figures obtained are reported in Marsh (1996) and available from the authors on request.

4.2.1. Estimate of regional spending (excluding salaries)

The breakdown of figures for regional spending obtained for the years 1985/1986–1989/1990 is used to obtain values for regional office costs (minus salaries) in the study area, and a proportion of these costs are allocated to lupins. Dollars spent by northern area district offices, northern area research stations, central area district offices and central area research stations, are each expressed as a percentage of total Department of Agriculture spending for these 5 years. The average of these percentages is then used to obtain dollar values for years other than 1985/1986–1989/1990.

The proportion allocated to lupins is estimated in the following manner. For each year the number of lupin trials in the four areas listed above is expressed as a percentage of the total number of trials conducted in these areas. Trial numbers were obtained from hard-copy records and the Department of Agriculture's Research Information System. These percentages are then used as estimates of the percentage of district office effort going towards lupin extension.

4.2.2. Estimate of district office extension

This calculation is intended to account for the regional salary component that should be allocated to lupin extension. It is estimated as a percentage of the Department of Agriculture's total estimated expenditure on extension. For each year the number of lupin trials conducted by the district offices in the study area (but not including trials conducted on research stations) is expressed as a percentage of the total number of trials conducted by the Department of Agriculture. These percentages are then used to obtain dollar values from total extension spending.

4.2.3. Estimate of the extension component of applied lupin research

Much lupin trial work is applied rather than basic research and contains a considerable extension component. This calculation is intended to account for the extension component of trial work conducted by research stations and district offices, where personnel involved include research personnel based in the Department of Agriculture's head office. Their salaries would comprise part of the R&D component of the Department's expenditure. For each year the number of lupin trials conducted by the district offices and research stations in the study area is expressed as a percentage of total Department of Agriculture trials. This percentage is then used to obtain dollar values from total R&D spending, 30% of which is deemed to be extension expenditure. This percentage is based on a 'rule of thumb' used by the Department of Agriculture for breaking down expenditure, which allocates 50% to R&D, 30% to extension and 20% to regulatory activities.

4.3. Estimates of private sector costs for lupin extension in the study area

Private sector costs associated with lupin extension in the 1980s are very minimal. This would no longer be expected to be the case. Discussions with private sector personnel persuade us that the inability of public bodies to isolate extension costs commented on by Baxter et al. (1989) applies also to any estimates of private sector extension costs. Private sector costs are ascertained in three areas. Details of the figures obtained are reported in Marsh (1996) and available from the authors on request.

4.3.1. Private farm management consultants

A number of private farm management consultants are known to be active in the study area. To investigate their involvement with extending the new lupin technologies, a one page mail survey was conducted of private consultants working in the study area. Estimates of the time spent by private consultants on lupin extension are derived from these survey results. From the information on when they had commenced to consult in the study area and their nominated percentages of time spent extending information on lupins, an estimate of the number of 'full-time consultant equivalents' (FTE) is calculated for each year. The average percentage time spent on lupin extension is used for those consultants who did not report a percentage.

To produce a value for a private consultant FTE, income information from a survey of consultants in WA conducted by Bedbrook (1995) is used. Bedbrook reports that, on average, these consultants charged 97 US$ per hour for 25 chargeable hours per week. Gross annual income is calculated assuming that consultants work 48 weeks per year, and this figure, along with the estimates of consultant FTEs spent on lupin extension, is used to calculate the cost of to lupin extension undertaken by private consultants.

4.3.2. Agribusiness

A number of agribusiness firms have invested in research and extension related to lupins, although extension investments can be considered minimal during the 1980s.

In the early 1980s, CSBP & Farmers Ltd. was the only company involved in supplying fertiliser to farmers. This firm conducts fertiliser trials and provides fertiliser recommendations to farmers based on the results of soil and plant tests. They also have field officers (resident at various rural locations) and agronomists, and produce a number of publications. Estimates for the investment in extension made by CSBP are derived from figures obtained from a personal interview with a company representative. For the purposes of this study, the costs associated with product development are assumed to be research and development, rather than extension related, investments. Of other costs, an arbitrary 50:50 split is made between R&D and extension investment. CSBP estimated that 10% of the soil and plant tests that they conducted for farmers were for lupin crops, so 10% of their total extension costs have been attributed to lupin extension.

The development of minimum tillage and weed control technologies for use in WA agricultural systems in the late 1970s/early 1980s was actively undertaken by the chemical companies involved (Rhone-Poulenc, May & Baker and ICI). It was these technologies which enabled the early sowing of lupins and adequate control of weeds in the growing crop, both factors crucial to their management for optimal yield. Despite a number of approaches, it proved very difficult to obtain information from the companies involved. Information from Department of Agriculture staff based in Merredin in the early 1980s indicate that a field officer with ICI worked closely with them in setting up and monitoring trials in the Merredin area, and was used as an 'expert' speaker at Department of Agriculture Field Days and meetings in this area. Accordingly, an arbitrary estimate of 0.25 FTE is costed to lupin extension for the years 1981, 1982 and 1983.

Although the involvement of agribusiness in extension, through the employment of agronomists attached to marketing companies, is now quite considerable, this is a comparatively recent development in WA, and was not the case in the early 1980s (Prinsley et al., 1994). Both SBS Rural Iama and Rural Traders Cooperative were not active in WA at this time and the contributions of stockfirm companies Elders Ltd. and Wesfarmers Rural to lupin extension in specific areas in the 1980s are judged to have been minimal.

4.3.3. Marketing bodies

The marketing of lupins in WA in the 1980s was the sole responsibility of the Grain Pool of WA. This semi-government agency had the task of developing markets for an essentially new and unknown crop. To achieve this, the Grain Pool invested a considerable amount of money into market development and research associated with the nutritive value of lupins for livestock and human foods. Having obtained markets for the new crop, the Grain Pool was then faced with the necessity of providing buyers with a continuous supply, and became involved, both directly and through sponsorship, with extension activities to farmers. The main extension role undertaken in the 1980s was involvement in Field Days and grower seminars, and through media releases and regular publications. After 1990, this commitment to lupin extension was increased by the Grain Pool's funding of a Specialist Lupin Extension Officer and the production of the monthly newsletter 'Lupin Logic'.

For the purposes of this study, the lupin extension contribution for direct grower contact by the Grain Pool staff through seminars, Field Days and individual grower contact is said to be 5% of five FTEs per year from 1983 to 1987, and 5% of seven FTEs per year from 1988 onwards. Additional costs are attributed to specific extension activities in the study area. An FTE is assumed to cost an amount equivalent to a mid-range level 5 public service employee. This value is also used for costing agribusiness staffing contributions to extension activities. No attempt has been made to account for the extension component of investments associated with the market development of lupins to potential overseas buyers. The extension that has been valued for this analysis is that more directly aimed at farmers in WA.

5. Results and discussion

The estimates of benefits of lupin extension are given in Table 3. These benefits reflect the difference between the value of the actual hectares grown and the estimated hectares grown in the absence of extension under a number of different scenarios. The three levels of 'assumed impact of extension on benefit per hectare' (zero, low and high) correspond to full benefits per hectare in the absence of extension being achieved in 1979, 1983 and 1989, respectively.

The estimates of the benefits and costs of extension spending in the study area are expressed in 1992–1993

Table 3
Estimates of the benefits of lupin extension in the study area, 1979–1989 (in 1992–1993 mUS$)

Lupin on-farm benefits ($/ha)	Assumed impact of extension on benefit per ha	Impact of extension on adoption version 1[a]		Impact of extension on adoption version 2[a]	
		Discount rate (%)		Discount rate (%)	
		5	10	5	10
45	Zero	23.7	36.5	56.5	84.3
	Low	27.8	43.6	59.7	89.8
	High	57.8	85.7	82.4	121.3
30	Zero	15.8	24.4	37.7	56.2
	Low	18.5	29.1	39.8	59.9
	High	38.5	57.1	55.0	80.9
15	Zero	7.9	12.2	18.8	28.1
	Low	9.3	14.5	19.9	29.9
	High	19.3	28.6	27.5	40.4

[a] Versions 1 and 2 are explained in Table 2.

dollars (corresponding to the end of the study period) using two real discount rates: 5 and 10%. Costs of the extension of the lupin technology (release of the new variety Illyarrie and improved management techniques) are calculated, as for benefits, over the years 1979–1989. Overall estimates of lupin extension costs in the study area are totalled in Table 4. Using these total costs, benefit–cost ratios are calculated for the scenarios presented in Table 3 (see Table 5).

Based only on statistically estimated effects (i.e. assuming that the only effect of extension was to bring forward the start time of adoption) and using the estimate with extension variables (Field Days 1980, Geraldton, Merredin and Consultant 1) set to zero and adjusted for Adviser Distance 1979 (version 2 in Table 5), the benefit–cost ratio of extension expenditure appears to be at least 1. Using what we consider to be realistic values for the on-farm benefits of lupins, the benefit–cost ratio is clearly greater than 1. Of the significant extension variables in the regression, Adviser Distance 1979 was the least robust (Marsh et al., 2000). If the Adviser Distance 1979 variable is left unadjusted in the benefit calculations (version 1 in Table 5), and we assume zero impact on benefit per hectare, the benefit–cost ratio is only greater than 1 for the higher (45 US$/ha) assumed value of on-farm benefits. If extension had additional unmeasured impacts on the on-farm benefits of lupins per hectare for the first 4 or 10 years of the period, the benefit–cost ratios are substantially higher in all cases. On balance it appears likely that the net benefits of expenditure on lupin extension were positive.

Table 4
Estimated total lupin extension costs in the study area, 1979–1989 (in 1992–1993 US$)

	Discount rate (%)	
	5	10
Public sector: Agriculture WA		
Regional costs (minus salaries)	3448585	4664549
Component of extension spending	6225276	8259712
Component of R&D spending	8659502	11683259
Private sector		
Private consultants	1336385	1336385
CSBP	553616	625073
Grain Pool	87423	93331
Other	28995	28995
Total costs	20339782	26691305

Although the measurable private sector impact on adoption of lupins was limited to the influence of one variable, which in itself only affected two shires, the benefit–cost ratio was calculated for the private sector using the same general approach as above (see Table 6). In doing this, costs attributable to all private consultants were included, arguably resulting in an underestimation of the benefit–cost ratio. The calculations were made only for the scenario in which extension has no impact on the benefits of lupins per hectare. Overall, the estimated benefit–cost ratios for

Table 5
Benefit–cost ratios of lupin extension in the study area, 1979–1989

On-farm benefits of lupins ($/ha)	Assumed impact of extension on benefit per ha	Benefit–cost ratio extension version 1[a]		Benefit–cost ratio extension version 2[a]	
		Discount rate (%)		Discount rate (%)	
		5	10	5	10
45	Zero	1.17	1.37	2.78	3.16
	Low	1.37	1.63	2.94	3.36
	High	2.85	3.21	4.06	4.54
30	Zero	0.78	0.91	1.86	2.10
	Low	0.91	1.09	1.96	2.24
	High	1.90	2.14	2.71	3.03
15	Zero	0.39	0.46	0.93	1.05
	Low	0.46	0.54	0.98	1.12
	High	0.95	1.07	1.35	1.51

[a] Versions 1 and 2 are explained in Table 2.

the private sector are similar to those for the public sector based on version 1 in Table 5, and somewhat less than those based on version 2. Given the limitations of the methods, we would caution against drawing general conclusions from a comparison of these results.

The diffusion pattern associated with the adoption of lupins could well be considered as representing an extreme case. As outlined in Section 2, lupins have proven to be a very successful crop innovation, and the extension campaign conducted by the Department of Agriculture was widely perceived to have been very successful. Considering this, the statistically detectable effects of extension might be considered surprisingly small. However, as discussed in Section 3, the overriding influence of economic factors on the adoption process is well established, and it is perhaps encouraging that any measurable benefit at all from extension activities, for such a profitable crop innovation, can be isolated using multivariate regression analysis.

Table 6
Benefit–cost ratios for private sector lupin extension in the study area, 1979–1989

Lupin on-farm benefits ($/ha)	Discount rate (%)	
	5	10
45	1.25	1.87
30	0.84	1.25
15	0.42	0.63

The methodology used in this study cannot capture all the benefits of extension. One of these, the likelihood of extension having an impact on on-farm production capacity, has been investigated using hypothetical changes in benefit per hectare of lupins. As discussed in Section 1, most evaluation fails to capture the contribution of extension to human capital, and this study is no exception (except in our hypothetical analyses). A further key value of extension not captured by this study is its benefit to research through choice of research topics and specific research methodology.

The estimates of the costs and benefits of extension in this study can be expected to have accuracy limitations. As well as the difficulties associated with attributing costs to regions and enterprises discussed above, it is often difficult to decide how to deal with the overhead costs of maintaining an extension service. However, benefits have been calculated over a range of possible situations, lending credibility to our statement that on balance it does appear likely that the net benefits of expenditure on lupin extension were positive. This is despite the fact that statistically detectable benefits were limited to changes in the start time of the diffusion curve. This effect was sufficient for a benefit–cost ratio of at least one in most scenerios.

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