Evaluating Research, Development and Extension: Practical insights from the Queensland Department of Primary Industries and Fisheries

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Introduction

It is well acknowledged that growth in public funding for agricultural research, development, and extension (RD&E) has slowed in the past 20 to 30 years. Growth rates in China, Latin America, Africa, and the UK more than halved from the period 1976-1985 to 1985-1995, while growth rates in the US and France also decreased, albeit less markedly (Pal & Byerlee 2003). Similar trends have been reported for Canada (Carew 2001) and across clusters of developed and developing countries for the period 1971-1981 to 1981-1991 (Alston, Pardey, Roseboom 1998). This trend is discernable despite a median rate of return of 44 percent among those research evaluations conducted since the seminal papers by Schultz (1953) and Griliches (1958) (Alston, Chan-Kang, Marra, Pardey, and Wyatt 2000). Australia has not been exempt from these funding patterns with evidence of little growth in public expenditure on agricultural research since the mid-1970s (Mullen, 2007). Although historical returns to research have been sound, there is currently an environment of diminishing public funds for agricultural RD&E and increasing concerns over the accountability of public spending. In this context, the prioritisation of existing funds has become increasingly topical amongst funding agencies.

The Queensland Department of Primary Industries and Fisheries (DPI&F) has an annual budget of $366 million (2006/07), of which around one third is allocated to RD&E. As an economic development agency, the Department has a vision of profitable primary industries with a mission to maximise the economic potential of Queensland's primary industries on a sustainable basis. Research funds are distributed across 13 research programs including both commodity-based programs such as cropping and livestock as well as cross-industry programs such as enabling technologies and value-added foods. In 2005 the Department undertook a major restructure, realigning its business configuration to that of an investor/deliverer model. An aim of the design was to clearly delineate the roles of strategic priority setting and service delivery while fostering collaboration between the two groups. In the context of RD&E the structure consists of an RD&E program investment group, a multidisciplinary team including a unique investment manager for each research program as well as several economists, along with a larger science delivery group. As part of the realignment the Department instigated a rolling evaluation process of these research programs. To date, the evaluations of the Beef RD&E program and the Feedgrains and Fodder RD&E program have been completed. The Intensive Animals RD&E program evaluation is expected to be completed early in 2008. The primary purpose of the evaluation process was to assess the likely future economic impact of the current suite of investments within and across Programs and to comment on the desirability of the continuation of existing research themes into the future.

In line with a focus on future outcomes and research prioritisation, an ex-ante approach estimating changes in economic surplus was favoured over an econometric analysis of historical returns to research. While numerous studies have employed this methodology in the assessment of agricultural RD&E, the authors found little evidence of it having been systematically employed to compare and contrast all investments within and across a number of research programs. One notable exception is a study by Araji, Sim, and Gardner (1978) looking at ex-ante returns across 9 commodity groups in western US agricultural research stations.

The objective of this paper is to show that: a framework for the economic evaluation of agricultural research must develop dynamically to keep up with changing approaches to science, and that the usefulness of economics in a research prioritisation agenda relies upon effective communication with non-economist stakeholders. Section I illustrates the theoretical framework underlying each of the assessments. The use of a uniform evaluation framework across different research programs presents some methodological challenges and section II presents a range of emerging research themes for which this framework may be difficult to apply. Section III further explores some of the questions facing agricultural economists in the evaluation of these novel research themes. The interface between economist, scientists, and research management in the prioritisation process is described in section IV, with a focus on the role of the economist in this broader policy setting.

I. Theoretical framework for evaluation

Data Collection

For the evaluations carried out to date, data were collected from a DPI&F database of active research projects in the Department. For a given research program, a list of projects contained within the program were compiled and categorised into outcome based research themes such as grazing land management, sorghum breeding or Eastern Farming Systems. The collection of projects into research themes enables comparison of project rates of return within a theme area, rather than looking at the work of the individual scientists working in a RD&E program in isolation. In early program evaluations, several related projects within a theme area were occasionally collapsed into a single analysis reporting a combined rate of return.

Cost estimation

Project costs were measured in current dollars and were derived from budgets contained in research contracts. Costs, outputs and potential outcomes were verified through direct consultation with project leaders. Where direct consultation revealed that staff allocations or operating costs differed from the original budget, these modifications were incorporated. Where the realisation of industry outcomes could be attributed to several research projects, rather than an isolated project, research costs were calculated as the combined total across all relevant projects. In several projects with an international focus some component of the project costs did not directly contribute to benefits for Australian primary industries. Only those costs and benefits that had direct relevance for Australian primary industries were considered in the analyses. Direct project costs were inflated to account for additional corporate overhead costs associated with the administration and management of the research project. Corporate overheads were calculated as 1.77 times the salaries and wages of research staff before salaries and wages on-costs were added. Corporate overheads were added to the budgets of all agencies employing staff to work on the project. Where substantial costs, beyond those funded in the research project, were likely to be incurred for the development and extension of the research, and these costs could be identified, they were incorporated into total project costs. Costs were discounted to the current year using a five percent discount rate.

Benefit estimation

The quantification of research benefits is based on a model of research induced supply shift (Alston, Norton, Pardey 1995)(Masters, 1996). Some explicit simplifying assumptions were applied across all analyses. With some exceptions, benefits were estimated at both the Queensland and national level. The model assumed a homogenous product targeting a single market with research benefits measured at the farm level. Benefits were not disaggregated vertically or horizontally. Supply and demand functions were assumed to be linear and shift in parallel in response to a research induced technology change. Competitive market clearing was assumed with no market distortions. In many analyses, a simplifying assumption that the elasticity of supply was equal to one and elasticity of demand was equal to zero was applied. Where estimates of elasticities were available they were used in the analyses. All results were tested for sensitivity to the elasticity values applied.

Yield changes and changes in input costs were calculated from detailed farm budgets, collated using industry average data from farm surveys and the best estimates of research and extension staff. Equilibrium price and output data were sourced, where possible, from industry level data distributed by the Australian Bureau of Statistics (ABS) and the Australian Bureau of Agricultural Resource Economics (ABARE). Benefit estimation was generally modelled over a 30 year timeframe from the year the research commenced. Adoption lags were determined through consultation with researchers and increased linearly until maximum adoption is obtained. In each analysis benefits *with* the research are considered net of a counterfactual *without* scenario (Lindner, 2006). Net benefits were discounted to the current year using a five percent discount rate.

The value of the individual research projects was encapsulated in two economic indicators: Net Present Value and Benefit Cost Ratio.

II. Novel research themes: examining the research framework

The assumption of a research induced shift in supply is particularly suited to established, commodity-based industries. Of the 292 studies reviewed by Alston et. al (2000), almost 50 percent of the publications presented an estimate of the value of yield enhancement, and 32.5 percent estimated the value of crop and livestock management. Only 3.4 percent of studies estimated the value of basic research and 5.1 percent were concerned with natural resource management. In this paper, we propose three broad areas of research that appear less frequently in research evaluation literature: environmental “licence to operate” research, research to mitigate risk, and basic research. Three case studies from projects within the evaluation of the Intensive Animals RD&E program - pigs, poultry, aquaculture, dairy - are presented. The first two demonstrate novel adaptations of the evaluation framework outlined in section I. The third project illustrates that, even under the objective framework outlined in section I, the quantification of benefits from basic research rely on subjective value judgements intrinsic in the model system.

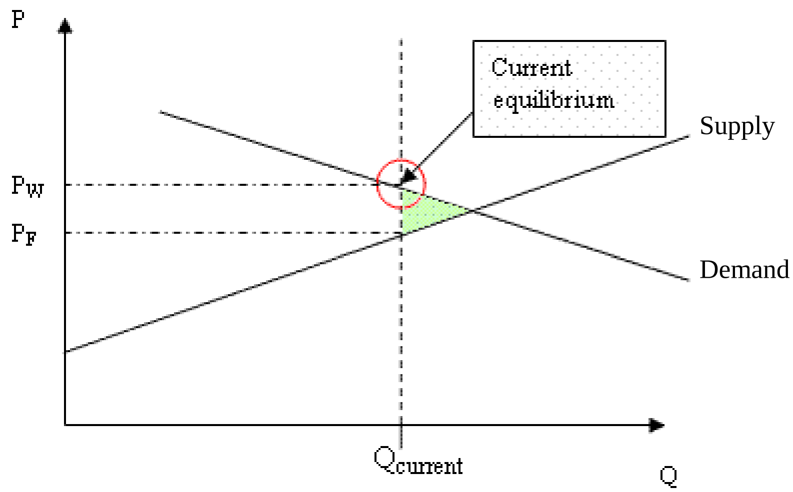
Bioremediation[1] in prawn aquaculture ponds

Prawn aquaculture is a growing industry in Queensland and accounts for almost 80 percent of national production. Prawns are grown in approximately one hectare earthen ponds around the Queensland coastline. The two dominant aquaculture species, black tiger and banana prawns, grow in saline environments and ponds are flushed several times a week in the peak growing season. The discharge of this wastewater from intensive and pond-based aquaculture systems is of concern to environmental regulators as the water typically contains suspended and dissolved nutrients, including nitrogen and phosphates.

[1] Bioremediation is the use of living organisms, primarily microorganisms, to degrade the environmental contaminants into less toxic forms.

DPI&F scientists have been researching cost-effective methods for the bioremediation of nutrients. This is in response to an increasingly stringent regulatory environment under which the distribution of further aquaculture licences is carefully administered by the relevant environmental agencies. Research benefits are not defined by productivity changes arising from the application of research, but can be viewed as ‘licence to operate’ benefits. The Queensland Environmental Protection Agency currently limits production to existing output levels by restricting the supply of aquaculture licences. In doing so, it creates an artificial equilibrium at P_W, the price the consumers are willing to pay at the current production level, which is higher than P_F, the marginal cost of production to the farmers (Figure 1).

Figure 1: Static model of surplus change when EPA licence quota relaxed



Economic benefits were measured as the change in economic surplus when supply was able to exceed the existing truncated level, $Q_{current}$. In this model the marginal cost at $Q_{current}$ was approximated by current average industry production costs while the marginal benefit was taken to be the industry price. Increases in supply were modelled dynamically, assuming a 2.5 percent increase in output each year until the equilibrium was attained. Supply and demand curves were assumed to be linear with elasticities of supply and demand equal to one at the truncated production level.

Mitigation of risk: developing a vaccine for Glässer’s disease in pigs

The gross annual value of Australian pig production is around $900 million, of which around 25 percent can be attributed to Queensland. Efficiency in production systems is becoming more vital as Canada, Denmark, and the US continue to take an increasing share of the Australian market, as well as Asian export markets, for pig meat. Glässer's disease is a generalised bacterial infection in pigs that significantly limits the productive output of farms. An outbreak of Glässer's disease can lead to significant increases in weaner mortalities and poor performance during grow out. DPI&F researchers are developing a vaccine that will protect against all strains of the bacteria, as opposed to current commercial vaccines which target specific strains.

Disease outbreaks are temporally specific, have a limited window of impact, and occur sporadically. Under these conditions, it is difficult to assign disease prevention technologies to an average productivity increase over time, although such an approach has been adopted in past studies (CIE, 1998). In the analysis of Glässer's disease, outbreaks were assumed to occur once every three years. Changes in production at the farm level incorporated the temporary increase in mortality as well as the lingering impact on growth rate and herd productivity. The value of the research in a disease year was measured as the change in economic surplus arising from annual yields and associated costs with and without the DPI&F vaccine. No value was assigned to the research in a non-disease year.

Digestibility of tropical grasses: reducing lignin content in kikuyu

Kikuyu as a pasture species is integral in dairy production systems across Queensland and northern NSW and is also utilised in some beef production systems in coastal regions. Kikuyu is also a member of the family of C_4 tropical grasses which are characterised by low levels of ruminant digestibility. It has been shown that low digestibility is linked to high levels of lignin in the forage.[2] DPI&F molecular biologists are conducting novel research to identify and select for mutant genes involved in lignin biosynthesis and to ultimately develop a kikuyu cultivar with improved digestibility. To date, no country has achieved the goal of producing a tropical grass with high digestibility.

In the evaluation of this project the scope of benefits was limited to the value of an improved digestibility kikuyu to existing dairy and beef industries.[3] This can be justified in light of the fact that these benefits could be objectively quantified. However, such a limited scope may underestimate the true value of the research. In reality, a technique for improving digestibility in all new tropical grass

[2] Lignin is an amorphous polymer related to cellulose that provides rigidity and together with cellulose forms the woody cell walls of plants and the cementing material between them.

[3] While pasture benefits have previously been measured as the change in economic surplus arising from an increase in demand for a more productive input (Duncan, 1972), a more conventional approach approximating the yield increase in dairy and beef production systems was employed in the analysis conducted.

cultivars will have longer lasting and more sizeable impacts than releasing a new variety of a single pasture species. Taking this one step further, DPI&F scientists highlighted the value of digestible tropical grasses for Australia in the context of climate change and methane emissions. Limiting the value of the research to quantifiable short-term benefits represented a value judgement by professional economists. It seems that other economists have also made such value judgements with expected returns from basic research estimated to be lower than applied research projects (White, 1990).

The probability of research success is a particularly important variable in the evaluation of basic research. In all evaluations it was assumed that the research project would be 100 percent successful. Where the inherent risk involved in basic research is not accounted for, the research portfolio may be biased towards high risk projects (Bardsley, 1999). However, to charge an economist with the task of assigning probability of success to basic research projects would be speculative at best. The professional economist makes a clear subjective choice when deciding not to, and where the economist lacks the relevant scientific expertise may be well advised to follow this path.

III. Methodological implications: interpreting the data

Several themes arise from the examination of projects in section II. Firstly, adaptation of the methodological framework has implications for the internal consistency of the approach. Is it appropriate to compare surplus measures calculated under different model systems? There is a trade off between realism in assumptions and consistency across analyses. While bioremediation may be most appropriately described as a licence to operate scenario, is the surplus measurement in this model system directly comparable with benefits from increased productivity? Similarly, one may model the benefits from vaccine development in an even more sophisticated risk assessment model than the Glässer's model shown here, but will the results be comparable with a model of increasing yield? Secondly, even under the objective model system described in section I, the estimated value of research benefits can be influenced by subjective values. Environmental benefit is incorporated only where it can be shown to increase productivity. As a result, projects targeting natural resource management have historically displayed lower rates of return (Alston et. al., 2000) and continue to do so in our analytical framework.

Other factors influencing the interpretation of research benefit, not specific to the case studies presented in this paper, have been discussed and modelled at length. There is a considerable body of literature assessing the distributional impacts across research projects, especially in an environment of increasing private research collaboration (Fuglie 1995)(Price, Lin, and Falck-Zepeda 1995) (Gray, Malla, and Tran 2005)(Gehlhar 2002)(Mounter, Griffith, Piggott, and Mullen 2005). The impact of market distortions also features (Kim and Sumner 2005). Heisey and Morris provide a comprehensive overview of research outcomes not directly convertible to yield benefits in plant breeding research (2002).

As research programs become more complex and move away from a traditional cropping and livestock focus, agricultural economists will be confronted with new modelling challenges. The appropriateness of a 'one-size-fits-all' approach will be called into question. For example, evaluations on the horizon for DPI&F research programs include: lifestyle horticulture, value-added foods, and enabling technologies. These programs will increasingly incorporate themes such as amenity value, quality improvements, environment, and long term (and uncertain) opportunities such as genetic modification. If the role of the agricultural economist is to inform research prioritisation, then how is economic impact to be compared across eclectic research programs? In the following section, the role of DPI&F agricultural economists in the research prioritisation process is explored, with particular focus on the play between methodological judgements and prioritisation decisions.

IV. The role of the economist in research policy formation

Evaluation context

The economic evaluation of research programs at DPI&F occurs within a broader program evaluation framework. These evaluations have been led by the RD&E program investment group and are conducted in collaboration with science delivery management. Economists report to the investment manager for a particular research program. The role of the economist is to assess the economic value being derived from themes within the research portfolio, in light of industry trends and growth potential. The investment manager reviews such factors as: broad industry objectives; the role for RD&E relative to other industry development tools; institutional capacity including infrastructure, skills capability and management structure; and DPI&F's comparative advantage relative to other RD&E providers.

Given the differing focus in each of the two components of the program evaluation, the communication channels differ. Economists work directly with project leaders to assess the likely impact of the current suite of investments. The results of this analysis are conveyed to investment managers. Investment managers liaise with relevant stakeholders: industry representatives, other RD&E providers, as well as DPI&F counterparts in science management. Relationships and effective communications are important at all levels but the two areas of direct interest to economists are presented here: the relationship with project leaders and the relationship with the investment manager for the RD&E program.

Communication with project leaders

Communication with project leaders has the potential to breed tension. Program selection is often related to budgetary pressures, and as the program evaluation agenda progresses there is an increasing awareness across the Department that the outcomes of the evaluations *will* impact on the future research direction. In theory, as the agenda progresses, this could lead to moral hazard on the part of project leaders. However, in general, project leaders have been extremely forthcoming with information relating to their research.

Perhaps of more concern to the economist is the lack of acceptance from project leaders of the validity of the economic model being utilised in the assessment of their work. In the assessment of the Intensive Animals RD&E program, scientists have raised concerns over the following factors: the reductionist nature of the model, that the model undervalues environmental and social benefits, and that discounting limits the value assigned to infant industries. The focus of the economic evaluation on direct economic impact tends to alienate project leaders whose primary focus is on maintaining the environmental sustainability of primary industries or who are seeking a primarily social benefit, for example odour reduction in intensive animals industries.

Another key concern is that project leaders often have little faith in the estimates they provide to economists and consequently have little faith in the conclusions drawn from economic evaluations, although post-evaluation feedback indicates that some project leaders are more inclined to consider the economic impact of their work in the formulation of future research targets. All the same, unless project leaders feel that the assessment of their projects has been reasonable, their voices can seriously undermine the recommendations being developed on the basis of the evaluations. Faith in the modelling system is likely to be challenged even further as evaluations move into programs where research benefits are not well captured in the current model system.

Communication with investment managers

Investment managers predominantly have a research or research management background and bring knowledge of project management, research development, and scientific expertise. Where the investment manager has a science background, economists must accept the increased responsibility of communicating their research findings clearly. There is a danger that the benefit cost ratio is the only indicator that gains the attention of investment managers, and given the reflections on methodological interpretation presented earlier in this paper, the economist must accept the important task of effectively communicating model assumptions. Investment managers must be confident in their understanding of the economic evaluation so that they may informatively relay evaluation results to science management.

Conclusion

Economists do clearly have an important role in research evaluation. They can provide clear and verifiable evidence of the likelihood that a research portfolio will lead to profitability for primary industries and have positive social benefit. Where the economist's role is to confer a professional opinion on a group of non-economist stakeholders, attention must be drawn to the assumptions inherent in our profession and the modelling system used. Project leaders, in particular, may be uncomfortable with some of these assumptions and must be given the opportunity to voice their concerns through other channels such as science or investment management. On the other hand, it is also the role of the economist to promote an awareness of the economic rationale.

Agricultural research is increasingly branching away from traditional commodity-based areas. In this changing research environment it is important that agricultural economists continue to develop the research evaluation framework so that it can effectively capture benefits from emerging research portfolios and that it can be used to prioritise amongst differing research portfolios.

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