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Assessing Research Priorities in Beef Cattle Breeding

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Agricultural Research and Development (R & D) organisations in Australia are moving to a more detailed assessment of R & D priorities within the broad research evaluation and project identification process. The subject of this paper is a detailed look at the priority-setting process and an application of financial budgeting to a particular group of project priorities developed from consultative processes.

The particular topic is beef cattle breeding and genetics research in a government R & D agency. A review of recent contributions to research priority-setting issues in Australia was included in the paper. Then a particular group of priority areas was assessed using farm-level budgeting techniques. A discussion of the advantages and shortcomings of this approach is also included.

1. Introduction

This paper has been prepared within the framework of a research evaluation and review process. The focus is on the forward-looking task of setting research priorities and ranking a number of potential R & D projects. Included is a discussion of a number of issues in setting research priorities and a review of methods of making economic assessments. It is recognised that a number of factors bear on decisions to select and fund research projects, this paper is an attempt to provide decision-makers with better information as a basis for their decisions.

2. Issues in setting research priorities

The setting of research priorities and allocation of research resources is an important task for R & D organisations such as NSW Agriculture. This task is becoming more important because of constraints on available funds for research and an increasing requirement by society that funds be used as beneficially as possible. The discussion is focussed mainly on issues in setting research priorities but also refers to the resource allocation process. A number of recent contributions to these issues in the Australian context are reviewed below.

In 1981 the Australian Science and Technology Council (ASTEC) held a workshop on National Objectives and Research Priorities (ASTEC 1981). This constituted a structured round of consultations between users and providers of scientific and technological information. The method of setting priorities involved first determining a statement of national objectives (sorted into priority order and including dependencies between objectives). Next the contributions that R & D can make to these objectives were assessed in terms of scientific and technological disciplines. The relevance of R & D in each discipline in achieving objectives emerged from consensus in discussion by panels of specialists in major fields (including 'providers' and 'users' of R & D). An overall relevance assessment was then made, including a cross-support or relevance index and a dependence index. This approach to setting national objectives provided an overall framework within which more specific programs and projects could be discussed. However ASTEC (1981) acknowledged that the priority setting step at the political level might place a different emphasis on economic, social and political factors than ASTEC.

Kerin and Cook (1989) discussed policies for reshaping government programs and attitudes towards research, innovation and competitiveness. They recognised the need to undertake regular and systematic investigations of the economic and scientific merit of R & D activities supported by government funds. Besides *ex post* (i.e. after the event) evaluation of projects, they identified the need to undertake research into *ex ante* (i.e. before the event) evaluation methods. In particular this included assessing the costs and benefits of alternative R & D proposals and the factors relevant in deciding on projects, including the probability of success, the size of the industry, the likelihood of adoption, and the applicability to Australian conditions. Such information would provide a valuable database to assist decision-making and priority-setting for the allocation of future R & D funds.

The Bureau of Rural Resources (BRR) conducted a workshop on Research Priorities and Resource Allocation for Rural R & D (BRR 1989). The workshop was organised in two parts in an attempt to address issues affecting (1) priority setting, and (2) the resource allocation decision. Research priorities are an input to the resource allocation decision, and the latter may be affected by broader issues including:

- the resources available for rural R & D;
- political imperatives;
- economic considerations; and
- the interests of the disparate groups involved in funding or carrying out research and the users of research output.

Kerin (1989) described the difference between setting research priorities and allocating resources as the former being the wish and the latter being the reality. He acknowledged that priority setting for research is an extremely complex and difficult question. In resource allocation decisions he quoted three methodologies used in the OECD:

- peer review;
- economic analysis; and
- process evaluation.

Process evaluation is the relatively new study of the structures and mechanisms whereby research is organised and carried out. It deals with the analysis of systems that should deliver scientific outcomes and maintain scientific capacity. It is concerned with the analysis of financial and infrastructural resources, and the related policies and options for improving the interactions in complex systems. Process evaluation can play a central role in research policy issues. Process evaluation is not common in Australia. Attempts to establish and collect reliable data on rural R & D have been unsuccessful in this country and analysis of such data are rare.

Richardson (1989) commented on recent changes in R & D direction and warned against shifting research priorities towards value-adding export industries unless a strong case can be made that they are capable of quickly becoming efficient and competitive industries on an international scale. At a national level, he advocated focussing 'a significant share of R & D effort on maintaining or enhancing the competitiveness of already-efficient industries and industries where Australia has a significant comparative advantage. He also canvassed the issue of diverting more funds to commercialisation and adoption of technology arising from past research and commented that, in the past, wool production research has been excessively influenced by scientists' perceptions of the needs of the industry.

Johnston (1989) discussed economic criteria and procedures for assisting the allocation of resources to research. He indicated that the allocation of scarce research resources can be guided by the principles of benefit-cost analysis and outlined briefly the economic case for government involvement in R & D activity (i.e. based on 'market failure' in research investment). He also identified different types of research evaluation and commented in some detail on one *ex post* evaluation of the CSIRO Division of Entomology using benefit-cost analysis. A number of important factors in assessing gains from research were also mentioned. These include accounting for price effects (the impact on price paid by consumers from an increase in production generated by a new R & D technology), incorporating the possibility of the new technology being capable of transfer to overseas producers competing with Australian producers and accounting for externalities.

Ex ante evaluations can be useful in demonstrating the potential benefits and costs of planned or incomplete projects and thence to indicate a priority for the R & D project in comparison with other projects. Data on a number of factors are required for these evaluations and co-operation with scientists is virtually essential in undertaking this sort of analysis. Johnson (1989) suggested that information on the following variables is required:

- the level and cost of resources to be committed to research, development and evaluation of the new technology;
- the cost saving associated with the use of the technology in each industry;
- the international transferability of the technology;
- the probability of success;
- the expected life of the technology;
- the adoption rate and ceiling level of adoption;
- the key economic parameters of the industries (elasticities, prices and quantities); and
- the existence of key external benefits and costs to be accounted for.

Kingma (1984) discussed the increasing use of studies into payoffs from research in setting research priorities, in particular the use of economic surplus models for this purpose. These models use changes in economic surplus based on neoclassical economic theory to measure (*ex ante*) welfare changes as estimates of magnitudes of payoffs from research in different industries. Kingma (1984) criticised the use of these predictive market models for the long run (*ex ante*) evaluation of technological change. He queried the use of neoclassical economic theory as a normative or predictive device and also wondered whether the *ceteris paribus* conditions for these models hold in terms of non-marginal structural changes. The question for him was whether these models adequately describe 'the process of innovation, adoption and the effects of technological change'. However, he concluded that the use of these types of models can still be appropriate for single research projects where the *ceteris paribus* conditions underlying the models can be shown to be applicable.

Once the *ex ante* evaluations are completed projects can be ranked according to their potential net economic benefits (by measures of net present value (NPV), benefit-cost ratio (BCR) or internal rate of return (IRR)). These rankings can then be used in conjunction with other information in deciding on research resource allocation. Other factors which can be used in assessing new proposals are relevance, feasibility and scientific merit (Young and James 1989).

While some of the information required in making *ex ante* assessments may be subjective in nature, project managers are already implicitly making many of these judgements and the benefit-cost analysis is a means of formalising this process. This type of analysis is at a more detailed level than that discussed by ASTEC (1981) and it relates to applied research rather than basic research programs. However, the undertaking of this type of analysis is being increasingly used by industry funding bodies (e.g. Australian Meat and Livestock Research and Development Corporation 1989).

The philosophy of the CSIRO in determining research priorities was described by Young, Kretschmer and MacRae (1991):

> The level of resourcing of a research area should be a function of both its attractiveness to Australia (i.e. the likely magnitude of the national benefit arising from successful conduct of the research) and feasibility (i.e. the capacity of Australia/CSIRO to make significant technical progress in a timely and competitive manner).

The CSIRO Assessment Framework is based on a measure of the return to Australia from R & D, which is influenced by attractiveness to Australia and feasibility. These criteria can be further subdivided. Attractiveness to Australia depends on the criteria of potential benefits and Australia's ability to capture benefits, and feasibility depends on R & D potential and R & D capacity. Research areas are judged by all four criteria needing to be satisfied before R & D is undertaken (Young et al. 1991).

In summary, the task of setting research priorities can be helped by *ex ante* economic analyses that indicate the relative potential returns to alternative projects. These analyses can be a useful input to the R & D manager in making resource allocation decisions. However, other factors are also likely to be important in making those decisions. These include the total resources available for R & D, political considerations and the interests of groups involved in funding or carrying out research and the users of the research output (i.e. the stakeholders).

3. Quantitative methods for assessing gains from new technologies

Anderson and Parton (1983) and Parton, Anderson and Makeham (1984) reviewed evaluation techniques for research projects. They categorised these techniques in increasing order of data requirements as:

- rules of thumb;
- scoring models;
- production function, systems and mathematical programming models; and,
- benefit-cost approaches.

The availability of data will generally determine the type of analysis possible - 'with basic research, the amount and reliability of data on the project are lower than with applied research' (Anderson and Parton 1983). Generally the aim of analysis is to show which allocation of scarce research resources to alternative projects will yield the greatest value. The analysis is therefore an *ex ante* assessment.

Rules of thumb are intuitive methods, simple and low cost (with low use of data). Two particular rules of thumb are **precedence** (base this years funding on the previous years level plus or minus) and **congruence** (where funds are allocated across resource areas in accordance with the value of agricultural production for each area or industry). Problems with these approaches are that new lines of activity which are small in value but with potential for growth may be overlooked. Also these approaches do not allow detailed scrutiny of individual projects.

Scoring models can be used to rank projects according to a number of attributes. Reviewers are asked to assess each project for each attribute and then averaging across reviewers is undertaken to enable an overall score to be determined. Attributes and/or reviewers can be weighted if necessary according to the degree of importance or experience respectively. The scores are used to rank projects for selection according to the research budget. Anderson and Parton (1983) state that scoring models can be very useful in appraising basic research and comparing basic and applied research projects.

Production function/systems/mathematical programming approaches all conceptually involve constructing a model to represent the agricultural production sector where productivity is represented as a function of research inputs. Using this model the impact of varying the research inputs on productivity, and so on production and farm incomes, is observed (Anderson and Parton 1983). The main differences between the three approaches are in different emphasis on specification of the production and research impact components of the models.

These models are generally applied at more highly aggregated levels than scoring models and are often used in a conditionally normative manner to show the implications of pursuing particular lines of research. They depend on detailed data and are only applicable to applied research.

The benefit-cost approach generally involves 'panels of scientific reviewers who estimate, for each project under review, the time pattern of future benefits and costs, and probabilities of success in the research, development and adoption stages' (Anderson and Parton 1983). This approach involves discounting of cash flows over time and can also include probabilistic assessments of probability distributions of times for completion and levels of benefit. Financial measures of return can be calculated for comparison between projects. The use of economic surplus models to estimate the net social benefits of research is allied to this benefit-cost approach. The comments of Kingma (1984) on this type of analysis were discussed above.

According to Anderson and Parton (1983) technology assessment is an extension of the net social benefit approach with the objective of determining 'ex ante the broad social, economic and environmental consequences of investing in various lines of research'. With regard to the applicability of the benefit-cost method, they indicate that even practitioners are guarded in their enthusiasm about its extensive use. One drawback is the time taken by research scientists to make the required subjective estimates. That time is at the expense of their actual research time. The key to the approach is the co-operation of scientists.

The benefit-cost approach has the advantages of consistency and of being able to be kept at a relatively simple level. Against this is the fact that the analysis is no better than the subjective judgements made about outcomes, and that for many kinds of projects the costs and benefits cannot be measured very accurately.

Because of these issues there has been a shift towards developing information systems within which the techniques are used. 'The quest has been to establish information systems which will enable good research-allocation decisions to be made using various evaluation techniques' (Anderson and Parton 1983, p.173).

In making judgements about the amount of resources that should be devoted to evaluation Anderson and Parton (1983) discussed whether the Rural Industry Research Funds in Australia should use some of these evaluation techniques in their decision-making. They concluded that a fairly elaborate scoring system might be the best scheme to assist in evaluation for a large industry (e.g. wool), rather than an evaluation of benefits and costs for each project.

Griffith, Vere and Vernon (1988) also discussed approaches to examining the impacts of new technologies. These approaches included farm-level impacts and market-level models. Farm-level impacts can be assessed by budgeting methods or linear programming models and the market-level assessments include use of economic surplus models and market simulation models.

A number of analyses with economic surplus models have recently been reported. An example is that of Mullen, Alston and Wohlgenant (1989) in which an equilibrium displacement model of the world wool top industry is used to estimate returns to the Australian wool industry from productivity improvements in farm production, in top making and in textile manufacturing.

4. Economic assessment of potential research projects

In the review of beef cattle breeding research within NSW Agriculture a group of potential research projects were identified by surveys of scientists, advisory officers and beef industry personnel. To help prioritise these proposals, *ex ante* benefit-cost analyses were undertaken using estimates of scientific R & D outcomes and project resource requirements. These analyses were considered to be valuable for R & D managers in setting research priorities and in making resource allocation decisions.

The surveys of research officers, advisory staff and industry representatives on future beef cattle breeding research priorities identified the following broad topics as highest priority:

(i) meat yield,
(ii) meat quality,
(iii) efficiency of feed use,
(iv) calving ease, and
(v) female fertility.

The potential economic benefits of genetic improvement in each of the above topics was determined using enterprise gross margin analyses and the application of a simple industry model representing the NSW beef herd. These potential benefits were then compared to the estimated costs of conducting R & D programs directed at each topic. The NPV of benefits less R & D costs, BCR and IRR of each research investment were determined for each potential research program.

4.1 Gross margin analyses

Gross margin analyses were conducted using the Cattle Cash model developed by Bootle (1991). This model calculates gross margins and feed requirements for alternative beef cattle enterprises. A representative base herd was defined using production parameters obtained from the Trangie R & D Angus high growth rate herd (Parnell *et al.* 1990) and current economic information (husbandry expenses, sale prices etc.). The effect of variations in these base herd production parameters on enterprise gross margins was examined to evaluate the anticipated results of genetic improvement in each of the production characteristics above. The following beef enterprises were defined:

A. Base herd

Self-replacing commercial herd of 100 Angus cattle in central NSW turning off steers and surplus heifers at 12 months of age and surplus breeding cows at 8 years of age. It was assumed that 1 replacement bull was purchased each year, and 3 bulls were used per 100 cows.

B. Meat yield herd

Similar to base herd, but with sale prices for yearling steers and heifers increased by 10% to represent the premium paid for cattle with a 5% improvement in meat yield. A prominent Queensland feedlotter has calculated that a 1% variation in bone out yield alters an animal's value by 2 to 3 cents/kg liveweight (Cameron 1991). Based on this figure a 5% increase in meat yield is worth close to a 10% increase in sale price. It was also assumed that the cost of each replacement bull would increase by $500 to represent the higher cost of breeding bulls with improved genetic merit for carcase yield.

C. Meat quality herd

Similar to base herd, but with sale prices for yearling steers and heifers increased by 10% to represent the premium paid for cattle with a 30% increase in the proportion of higher quality carcases (i.e. grades B4,B3) relative to lower quality carcases (i.e. grades B2,B1). This premium was estimated from information provided by Greg Chappell (pers. comm., 1991) who suggested that B3 to B4 quality carcases were worth approximately 33% more than B1 to B2 quality carcases for the Japanese market. It was also assumed that the cost of each replacement bull would increase by $500 to represent the higher cost of breeding bulls with improved genetic merit for meat quality.

D. Efficiency herd

Similar to base herd, but with a 15% improvement in the efficiency of feed use for maintenance, a 3% improvement in the efficiency of feed use for growth and production (e.g. pregnancy, lactation), a 5% increase in the weight of yearling steers and heifers and a 3% increase in cow weight. These parameters were estimated from the results of the growth and efficiency research already conducted at Trangie (Parnell et al. 1990). Herd size was adjusted so that the efficiency herd had the same feed requirements as the base herd. It was also assumed that the cost of each replacement bull would increase by $1000 to represent the higher cost of breeding bulls with improved genetic merit for the efficiency of feed use.

E. Calving ease herd

Similar to base herd, but with a reduction in the rate of calving difficulty in heifers from the base herd level of 10% to 0%. It was assumed that this resulted in a reduction in calf mortality from the base herd level of 6% to 2%, and a reduction in cow mortality from the base herd level of 3.5% to 1.5%. Herd size was adjusted so that the calving ease herd had the same feed requirements as the base herd. It was also assumed that the cost of each replacement bull would increase by $500 to represent the higher cost of breeding bulls with improved genetic merit for calving ease.

F. Fertility herd

Similar to base herd, but with an increase in the calving rate by 10% (from the base herd level of 85% to an improved level of 94%). Herd size was adjusted so that the fertility herd had the same feed requirements as the base herd. It was also assumed that the cost of each replacement bull would increase by $500 to represent the higher cost of breeding bulls with improved genetic merit for daughter fertility.

Appendix 1 contains the enterprise gross margin budget and total annual feed requirements for the base herd defined above. Table 1 shows the enterprise gross margins calculated for each of the herds and the calculated net value of a 1% genetic improvement in each trait after correction for differences in herd feed requirements.

Table 1
Estimated enterprise gross margins for base herd and genetically improved herds (as defined in text).

	Gross margin ($/cow)	Gross margin ($/base cow)[1]	Improvement over base herd ($/cow)	Net value of 1 percent genetic improvement ($/cow)
Base herd	273	273	-	
Meat yield herd	293	293	20	$4.00
Meat quality herd	293	293	20	$0.66
Efficiency herd	277	[illegible]	52	$3.46
Calving ease herd	297	299	26	$2.60
Fertility herd	299	286	13	$1.30

[1] i.e. corrected to the same feed requirements of the base herd

4.2 Industry benefit-cost analyses

A model of the NSW beef herd was used to estimate the potential industry value of genetic improvement in each of the production characteristics considered above in the enterprise gross margin analyses. This model determined the NPV, BCR and IRR for a range of discount rates (time preference factors) and various levels of assumed influence of the research on the projected industry benefits. It was assumed that the future herd size in the NSW beef industry would remain at 2.5 million commercial breeding cows. The adoption of the research results by industry was expressed through the assumed proportion of bulls used in commercial herds that were sourced from seedstock herds selecting for the production characteristic being examined. Conservative rates of genetic improvement in seedstock herds and levels of adoption by commercial herds were assumed in all analyses. The rate of genetic improvement in commercial herds was assumed to lag 5 years behind the rate of genetic improvement in seedstock herds.

It was assumed that research programs would commence in 1992 and all R & D costs and industry benefits were expressed in 1992 dollars. The value of industry benefits was projected forward until the year 2050 to account for the long-term cumulative gains achieved from genetic improvement.

R & D costs included the estimated labour, capital and operating costs required to conduct a suitable research program, with on-going commitment of advisory input throughout the entire time horizon of each analysis. It was assumed that research and advisory staff would cost $100,000 each, and that support staff would cost $50,000 each. Operating costs and capital requirements were estimated net of income received from the breeding herd(s) used for the research. Further details of the assumptions and results of each individual analysis are described below. The NSW industry benefit-cost analysis for the meat yield analysis is shown in Appendix 1.

In conducting this aggregate analysis no account was taken of price changes as a result of any increased supply of product. The price changes included were estimates from scientists and/or beef industry personnel if the R & D projects were successful.

4.2.1 Genetic improvement of meat yield

It was estimated that a suitable R & D program to investigate and demonstrate the implications of selection for improved meat yield would require the equivalent of 2 full-time research/advisory officers and 2 support staff for a 15 year period. Operating costs (net of herd income) were estimated to be $130,000 per annum. An initial capital outlay of $50,000 to purchase equipment (e.g. ultra-sound scanner, computers, abattoir equipment) and a further capital outlay of $15,000 every 3 years was included. An on-going advisory input of 1 staff and $25,000 operating expenses per annum was also included. Using a 7% discount rate the present value of the total cost of the R & D program was estimated to be $4.94 million.

Genetic improvement in seedstock herds adopting selection for meat yield was assumed to commence in the 6th year of the project at the rate of .05% per annum. The annual rate of genetic improvement was then assumed to increase each year by .05% increments to a maximum of .5% improvement per annum. The proportion of commercial bulls sourced from seedstock herds selecting for improved meat yield was assumed to be 0% until the 10th year of the program after which it increased by 5% per annum up to a maximum of 30%.

With a discount rate of 7% per annum the NPV of the R & D program up to the year 2050 was estimated to be $103.25 million if all the industry benefits were attributed to the R & D program. If only one half of the benefits were attributed to the R & D program, or alternatively, if the industry adoption rate was only one half as great as was assumed above, then the corresponding NPV would be $49.16 million, with a BCR of 10.96 and an IRR of 18.95%. Figure 1(a) shows the estimated cumulative NPV of the R & D program over the time horizon considered in the evaluation, for different levels of influence on industry benefits. The estimated IRR at different levels of project influence is shown in Figure 1(b).

4.2.2 Genetic improvement of meat quality

The costs of a suitable R & D program to investigate and demonstrate the implications of selection for meat quality were assumed to be the same as those estimated for meat yield, as were the assumed rates of genetic improvement in seedstock herds selecting for improved meat quality and the assumed adoption rates by commercial herds.

With a discount rate of 7% per annum the NPV of the R & D program up to the year 2050 was estimated to be $12.48 million if all the industry benefits were attributed to the R & D program. If only one half of the benefits were attributed to the R & D program, or alternatively, if the industry adoption rate was only one half as great as was assumed above, then the corresponding NPV would be $3.78 million, with a BCR of 1.77 and an IRR of 9.33%.

Figure 2(a) shows the estimated cumulative NPV of the R & D program over the time horizon considered in the evaluation, for different levels of influence on industry benefits. The estimated IRR at different levels of project influence is shown in Figure 2(b).

4.2.3 Genetic improvement of feed conversion efficiency

It was estimated that a suitable R & D program to investigate and demonstrate the implications of selection for improved feed conversion efficiency would require the equivalent of 2 full-time research/advisory officers and 5 support staff for a 15 year period. Operating costs (net of herd income) were estimated to be $130,000 per annum. An initial capital outlay of $300,000 to purchase equipment (e.g. automated feeding equipment, computers) and a further capital outlay of $10,000 every 3 years was included. An on-going advisory input of 1 staff and $25,000 operating expenses per annum was also included. Using a 7% discount rate the present value of the total cost of the R & D program was estimated to be $6.72 million.

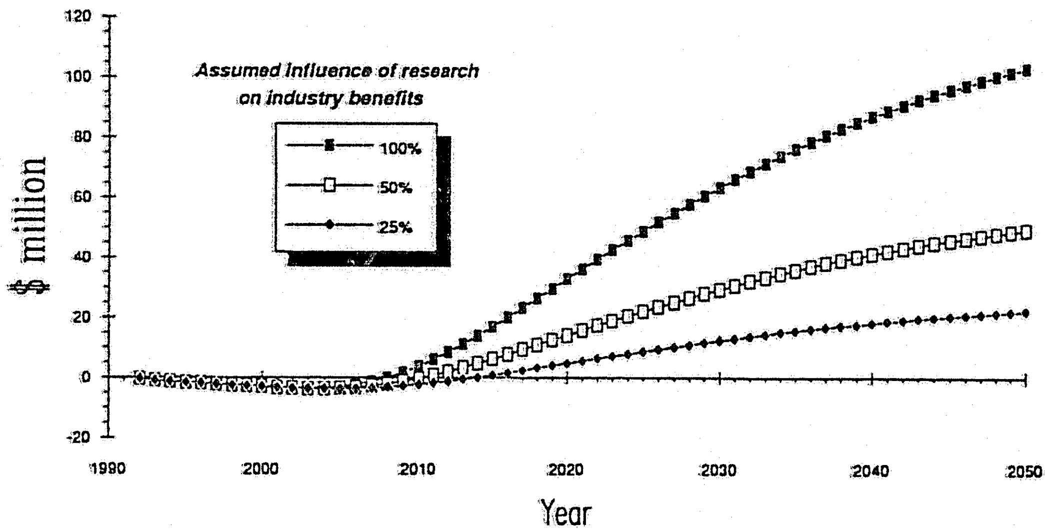
Genetic improvement in seedstock herds adopting selection for feed conversion efficiency was assumed to commence in the 9th year of the project at the rate of .1% per annum. The annual rate of genetic improvement was then assumed to increase each year by .1% increments to a maximum of 1% improvement per annum. The proportion of commercial bulls sourced from seedstock herds selecting for improved feed conversion efficiency was assumed to be 0% until the 10th year of the program after which it increased by 2% per annum up to a maximum of 30%.

With a discount rate of 7% per annum the NPV of the R & D program up to the year 2050 was estimated to be $135.93 million if all the industry benefits were attributed to the R & D program. If only one half of the benefits were attributed to the R & D program, or alternatively, if the industry adoption rate was only one half as great as was assumed above, then the corresponding NPV would be $64.61 million, with a BCR of 10.62 and an IRR of 16.75%. Figure 3(a) shows the estimated cumulative NPV of the R & D program over the time horizon considered in the evaluation, for different levels of influence on industry benefits. The estimated IRR at different levels of project influence is shown in Figure 3(b).

4.2.4 Genetic improvement of calving ease

It was estimated that a suitable R & D program to investigate and demonstrate the implications of selection for improved calving ease would require the equivalent of 1.5 full-time

(a) Estimated Cummulative Net Present Value of Benefits less Costs
(assuming 7% discount rate)



(b) Estimated Internal Rate of Return

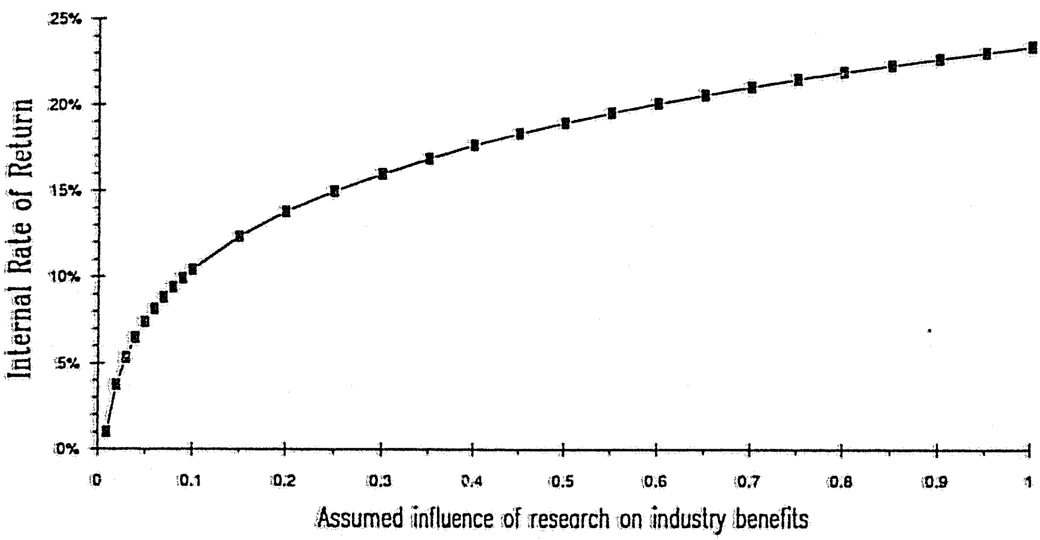
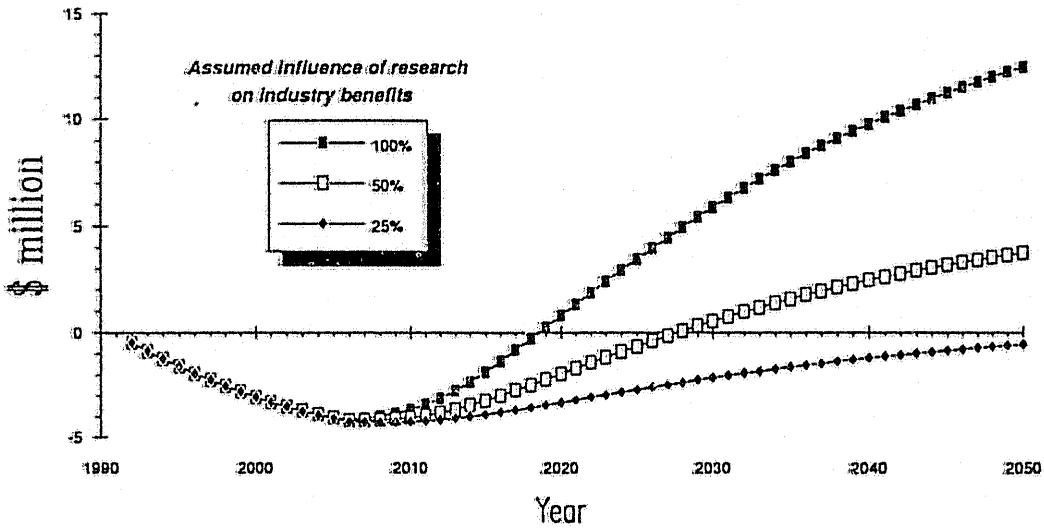


Figure 1

Benefit-Cost Analysis of Meat Yield Research

(a) Estimated Cummulative Net Present Value of Benefits less Costs
(assuming 7% discount rate)



(b) Estimated Internal Rate of Return

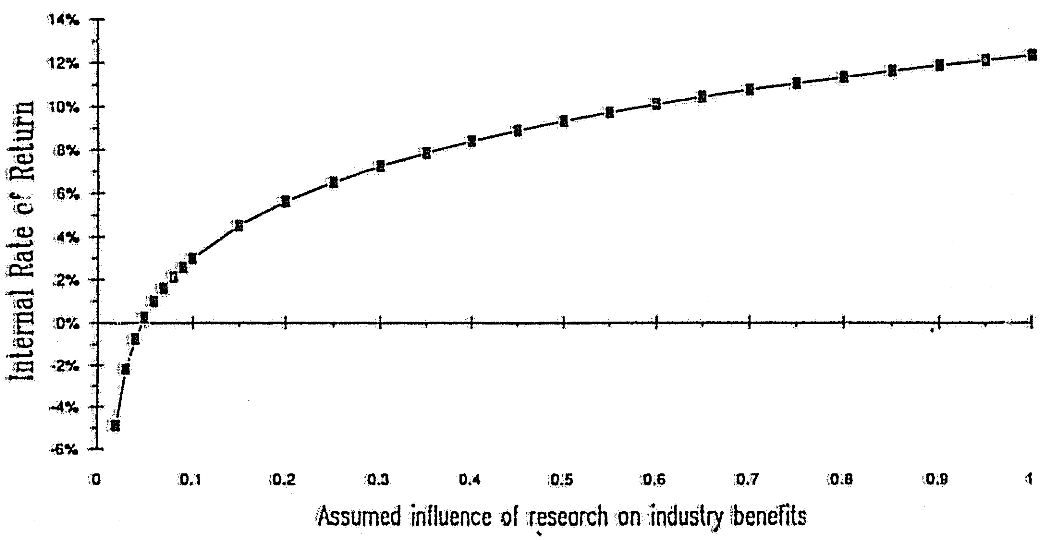
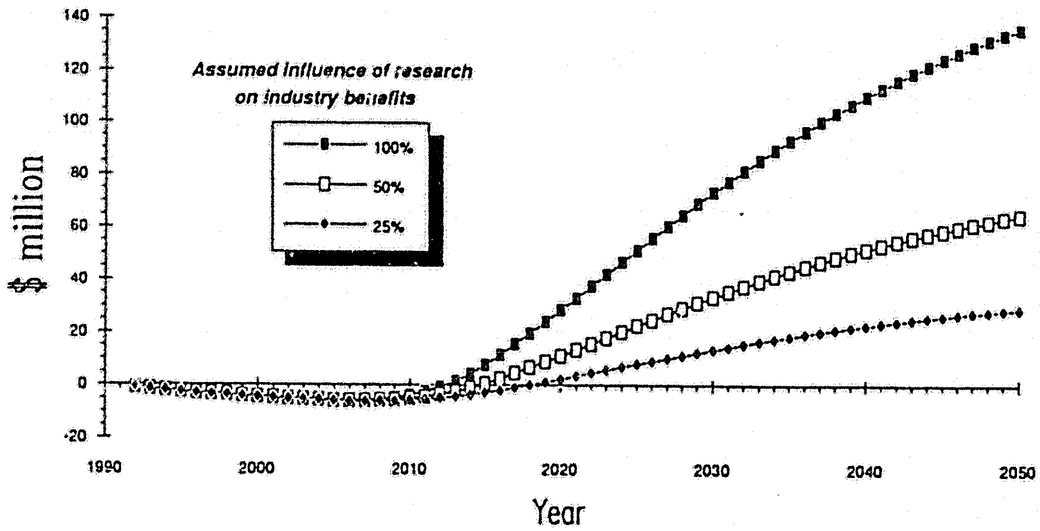


Figure 2

Benefit-Cost Analysis of Mea. Quality Research

(a) Estimated Cummulative Net Present Value of Benefits less Costs
(assuming 7% discount rate)



b) Estimated Internal Rate of Return

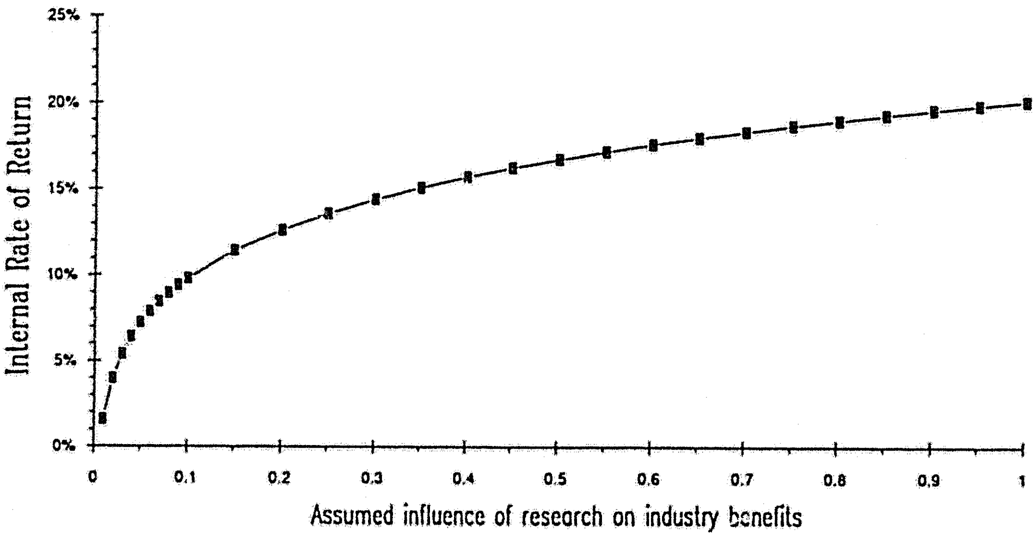


Figure 3

Benefit-Cost Analysis of Feed Conversion Efficiency Research

research/advisory officers and 2 support staff for a 15 year period. Operating costs (net of herd income) were estimated to be $130,000 per annum. An initial capital outlay of $50,000 to purchase equipment and a further capital outlay of $15,000 every 3 years was included. An on-going advisory input of 1 staff and $25,000 operating expenses per annum was also included. Using a 7% discount rate the present value of the total cost of the R & D program was estimated to be $4.52 million.

Genetic improvement in seedstock herds adopting selection for calving ease was assumed to commence in the 9th year of the project at the rate of .02% per annum. The annual rate of genetic improvement was then assumed to increase each year by .02% increments to a maximum of .25% improvement per annum. The proportion of commercial bulls sourced from seedstock herds selecting for improved calving ease was assumed to be 0% until the 10th year of the program after which it increased by 2% per annum up to a maximum of 30%.

With a discount rate of 7% per annum the NPV of the R & D program up to the year 2050 was estimated to be $20.14 million if all the industry benefits were attributed to the R & D program. If only one half of the benefits were attributed to the R & D program, or alternatively, if the industry adoption rate was only one half as great as was assumed above,then the corresponding NPV would be $7.81 million, with a BCR of 2.73 and an IRR of 10.88%. Figure 4(a) shows the estimated cumulative NPV of the R & D program over the time horizon considered in the evaluation, for different levels of influence on industry benefits. The estimated IRR at different levels of project influence is shown in Figure 4(b).

4.2.5 Genetic improvement of fertility

The costs of a suitable R & D program to investigate and demonstrate the implications of selection for female fertility were assumed to be the same as those estimated for calving ease, as were the assumed rates of genetic improvement in seedstock herds selecting for improved female fertility and the assumed adoption rates by commercial herds.

With a discount rate of 7% per annum the NPV of the R & D program up to the year 2050 was estimated to be $7.81 million if all the industry benefits were attributed to the R & D program. If only one half of the benefits were attributed to the R & D program, or alternatively, if the industry adoption rate was only one half as great as was assumed above, then the corresponding NPV would be $1.65 million, with a BCR of 1.4 and an IRR of 8.17%. Figure 5(a) shows the estimated cumulative NPV of the R & D program over the time horizon considered in the evaluation, for different levels of influence on industry benefits. The estimated IRR at different levels of project influence is shown in Figure 5(b).

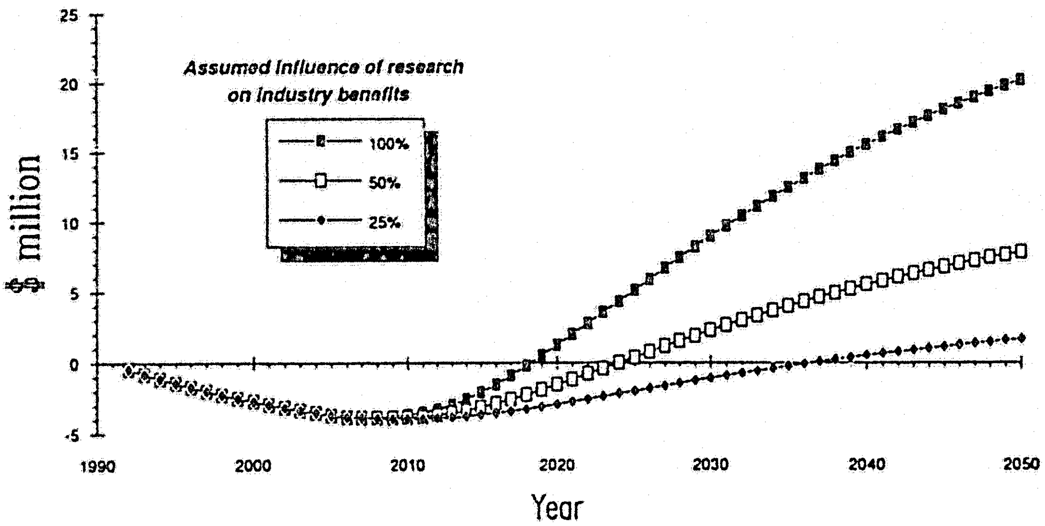
5. Summary and conclusions

The estimated NPV, BCRs and IRRs for each of the alternative R&D programs examined are summarised in Table 2. While all of the potential R & D programs had favourable NPV, BCR and IRR values, the programs directed at the genetic improvement of feed conversion efficiency and meat yield clearly gave the greatest predicted economic returns.

A number of points can be made about the analysis of identified R & D topics in this paper. The method of financial budgeting applied is relatively simple and low-cost and dependent crucially on scientific and R & D management input. The analysis was consistent over all R & D topics and accounted for the likely time pattern of R & D costs and industry uptake. However, it only addressed impacts on the NSW beef industry, and so the analysis of potential net benefits is probably conservative.

The use of cost-benefit analysis rather than economic surplus types of models means that no price response from changed input product supply is incorporated. However, in some of the R

(a) Estimated Cummulat've Net Present Value of Benefits less Costs
(assuming 7% discount rate)



(b) Estimated Internal Rate of Return

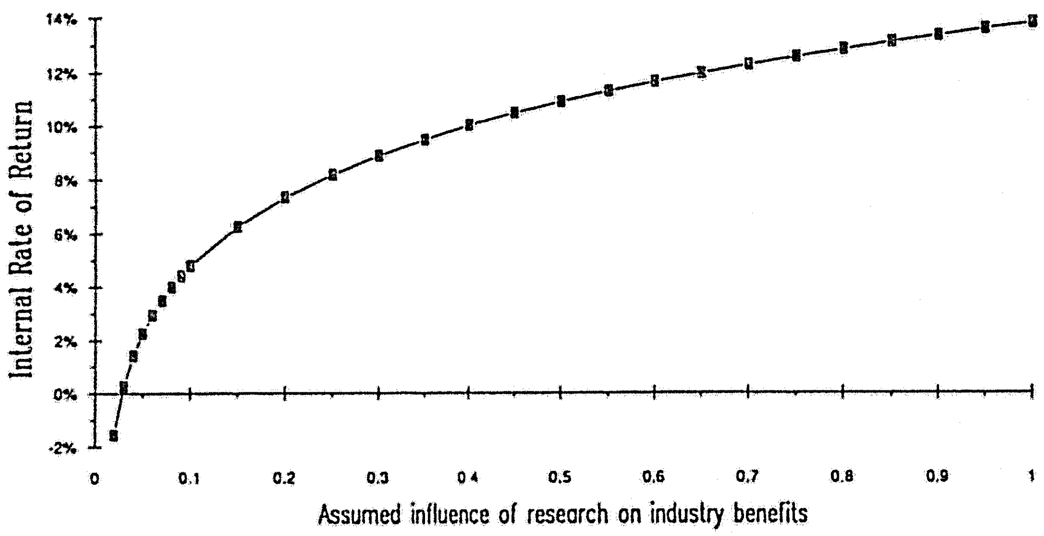
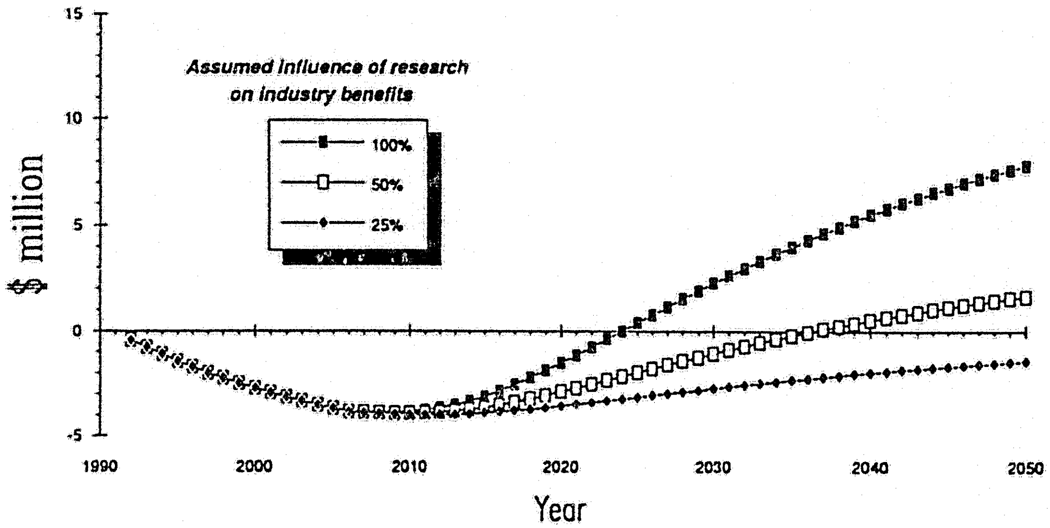


Figure 4

Benefit-Cost Analysis of Calving Ease Research

(a) Estimated Cummulative Net Present Value of Benefits less Costs
(assuming 7% discount rate)



(b) Estimated Internal Rate of Return

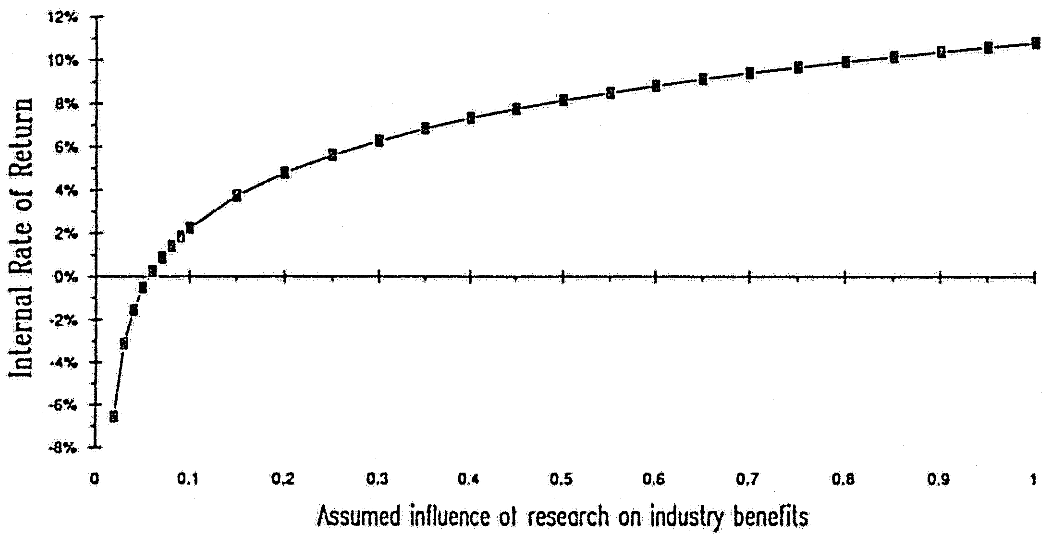


Figure 5

Benefit-Cost Analysis of Fertility Research

Table 2
Summary of economic analyses of alternative R & D programs

Assumed influence of research .... Economic response	50% of benefit			100% of benefit		
	NPV[1] $m	BCR[2]	IRR[3] %	NPV[1] $m	BCR[2]	IRR[3] %
Meat yield	49.2	11.0	19.0	103.3	21.9	23.5
Meat quality	3.8	1.8	9.3	12.5	3.5	12.4
Efficiency	64.6	10.6	16.8	135.9	21.2	20.2
Calving ease	7.8	2.7	10.9	20.1	5.5	13.8
Fertility	1.6	1.4	8.2	7.8	2.7	10.9

[1] NPV = Net present value of benefits less R & D costs (@ 7% discount rate)
[2] BCR = Benefit cost ratio (@ 7% discount rate)
[3] IRR = Internal rate of return from R & D investment

& D topics (eg meat quality) it may be argued that the nature of the product could be changed by R & D.

A related point is that some potential benefits from these R & D topics could possibly be transferred overseas. No account has been taken of this type of impact in the analysis presented here.

The analysis in this paper did not incorporate the probability of scientific success. However, Figures 1 to 5 (b) do show the impact of different levels of influence of research on beef industry practices and the IRRs at low levels of influence may provide some proxy value for the impact of R & D failure. The analysis has also not considered potential externalities involved in the particular R & D topics. There may be positive or negative effects external to the topics which could help to distinguish between them.

Overall the analysis here has probably provided a simple and consistent (although still partial) assessment of the potential financial benefits and costs of some identified R & D topics. It should provide an important input to R & D investment decisions, but other factors will also influence any R & D allocation outcome.

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Appendix 1. Gross margin analysis for "base" herd

Income:

				Budget ($)
38	steers	$455.00	/head	17480.17
22	heifers	$364.00	/head	7954.42
12	C.f.a. cows	$540.00	/head	6747.97
1	C.f.a. bull/s	$715.00	/head	715.00
		A. Total income		$32,897.56

Annual operational expenses:

Replacement stock:

1	Bull @	$2,500	.	2500.00

Husbandry operations:

Operation	Number	Stock class	Number of doses	Cost / head $	
1.Vaccination:	101	Cows	1	0.24	24.27
Coopers 5 in 1	3	Bulls	1	0.24	0.72
	16	Progeny >12 M.O.	1	0.24	3.87
	83	calves	2	0.24	39.82
2. Drenching:	101	Cows	0	1.40	0.00
Valbazen-Cattle	3	Bulls	0	2.08	0.00
	16	Progeny >12 M.O.	0	0.92	0.00
	83	calves	1	0.48	39.82
3. Lice Control	101	Cows	0	1.69	0.00
Tiguvon-Spot On	3	Bulls	0	2.50	0.00
	16	Progeny >12 M.O.	0	1.11	0.00
	83	calves	1	0.58	47.83

Other costs:	eartags		$0.91	/cow	92.03
Transport costs:					
	73 sale cattle	@ $5.00 /head	average transport cost		365.00
Rural lands protection board rates (fixed cost, levied on DSE carrying capacity):					
	1675 DSE units	@	$0.122	/DSE	204.39
Other husbandry costs:		$250.00 pa			250.00
Sale costs:					
	4% charged on sale cattle, plus the		$6.25 AMLC transaction levy.		1772.15
	73 sale cattle @	$2.55 /head	saleyard charge and tail tags		186.15
Feed costs:	0	0 tonnes p.a.	$0	/tonne	0.00
Pasture maintenance	$0 P.A.	Feed supplements	$35 P.A.		
Irrigation costs	$0 P.A.	Other feed costs	$0 P.A.		35.00
		B. Total operational expenses:			$5,571.55

		Gross margin (A - B)	$27,326.01
Total herd		**Gross margin/cow**	$273.26
feed requirements:	1675 DSEs	**Gross margin/DSE**	$16.31

Note: - DSE stands for dry sheep equivalent (ie a 50 kg merino wether). One DSE = 3012 MJ ME.

Benefit-Cost Analysis of Meat Yield Research

Year		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Compound Factor	(@ 7.00% discount rate)	1.000	0.935	0.873	0.816	0.763	0.713	0.666	0.623	0.582	0.544	0.508
R & D Costs												
Research & Advisory Staff (No. positions)		2	2	2	2	2	2	2	2	2	2	2
Support Staff (No. positions)		2	2	2	2	2	2	2	2	2	2	2
Net Operating Costs ($)		130000	130000	130000	130000	130000	130000	130000	130000	130000	130000	130000
Capital ($)		50000			15000			15000			15000	
Annual Present Value of Total Costs ($million)	(@ 7.00% discount rate)	0.480	0.402	0.378	0.363	0.328	0.307	0.297	0.268	0.250	0.242	0.219
Cummulative Present Value of Total Costs ($million)	(@ 7.00% discount rate)	0.450	0.882	1.257	1.621	1.949	2.255	2.552	2.820	3.070	3.312	3.531

Value of Genetic Improvement in Meat Yield to the NSW Beef Industry

Estimated Net Value per Breeding Cow of a 1 % Improvement in Meat Yield $4.00

		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Breeding Cow Numbers in NSW (million)		2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500
Annual Genetic Improvement in Seedstock herds (%)		0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.15	0.20	0.25	0.30
Cummulative Genetic Improvement in Seedstock Herds (%)		0.00	0.00	0.00	0.00	0.00	0.05	0.15	0.30	0.50	0.75	1.05
Proportion of Commercial Bulls obtained from Seedstock Herds Selecting for Improved Meat Yield		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.10
Annual Genetic Improvement in Commercial Herds (%) N.b. lag of 5 years behind Seedstock Herds		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Cummulative Genetic Improvement in Commercial Herds (%)		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Annual Present Value of Benefits ($million)	(@ 7.00% discount rate)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.025
Cummulative Present Value of Benefits ($million)	(@ 7.00% discount rate)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.025
Cummulative Net Present Value of Benefits less Costs ($million)	(@ 7.00% discount rate)	-0.480	-0.862	-1.257	-1.621	-1.949	-2.255	-2.552	-2.820	-3.070	-3.312	-3.505

Benefits of Research

Total Net Present Value of Benefits less Costs ($million) & (Benefit/Cost ratio)

Assumed Influence of Research on Industry Benefits → Discount Rates (Time preference factors) ↓	1%		5%		10%		15%		20%		25%		30%	
25%	-2.144	(0.008)	-2.074	(0.040)	-1.988	(0.080)	-1.901	(0.120)	-1.815	(0.160)	-1.728	(0.200)	-1.641	(0.240)
20%	-2.487	(0.017)	[illegible]	(0.084)	-2.102	(0.169)	-1.888	(0.253)	-1.675	(0.338)	-1.461	(0.422)	-1.247	(0.507)
15%	-2.960	(0.040)	[illegible]	(0.199)	-1.857	(0.397)	-1.245	(0.596)	-0.632	(0.795)	-0.020	(0.994)	0.593	(1.192)
10%	-3.566	(0.109)	[illegible]	(0.546)	0.368	(1.092)	2.553	(1.638)	4.738	(2.184)	6.923	(2.730)	9.108	(3.275)
7%	-3.853	(0.219)	[illegible]	(1.096)	5.834	(2.192)	11.293	(3.289)	16.703	(4.385)	22.112	(5.481)	27.522	(6.577)
5%	-3.766	(0.361)	4.746	(1.805)	15.385	(3.610)	26.025	(5.416)	36.664	(7.221)	47.304	(9.026)	57.943	(10.831)
4%	-3.496	(0.466)	8.723	(2.332)	23.986	(4.663)	39.269	(6.995)	54.542	(9.326)	69.816	(11.658)	85.089	(13.990)
3%	-2.934	(0.603)	14.689	(3.015)	37.168	(6.030)	59.447	(9.044)	81.726	(12.059)	104.005	(15.074)	126.284	(18.089)
2%	-1.867	(0.778)	24.536	(3.889)	57.564	(7.778)	90.593	(11.667)	123.621	(15.557)	156.649	(19.446)	189.677	(23.335)
1%	-0.030	(0.997)	39.781	(4.985)	89.544	(9.970)	139.308	(14.955)	189.071	(19.939)	238.835	(24.924)	288.599	(29.909)
0%	3.179	(1.264)	64.134	(6.318)	140.328	([illegible])	216.521	(18.954)	292.715	(25.272)	368.909	(31.589)	445.103	(37.907)
Internal Rate of Return (%)	0.99%		7.38%		10.40%		12.33%		13.78%		14.97%		15.97%	

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	......	2050
0.475	0.444	0.415	0.388	0.362	0.339	0.317	0.296	0.277	0.258	0.242	0.226	0.211	0.197	0.184	0.172	0.161	0.150	......	0.020
2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1
2	2	2	2																
130000	130000	130000	130000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000		25000
	15000																		
0.204	0.196	0.178	0.167	0.045	0.042	0.040	0.037	0.035	0.032	0.030	0.028	0.026	0.025	0.023	0.022	0.020	0.019	......	0.002
3.735	3.932	4.111	4.278	4.323	4.365	4.405	4.442	4.476	4.509	4.539	4.567	4.593	4.618	4.641	4.663	4.683	4.702	......	4.935

2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	......	2.500
0.35	0.40	0.45	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	......	0.50
1.40	1.80	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	7.75	8.25	8.75	9.25	9.75	......	24.75
0.15	0.20	0.25	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30		0.30
0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	......	0.50
0.15	0.30	0.50	0.75	1.05	1.40	1.80	2.25	2.75	3.25	3.75	4.25	4.75	5.25	5.75	6.25	6.75	7.25	......	22.25
0.107	0.268	0.519	0.873	1.142	1.423	1.710	1.997	2.281	2.520	2.717	2.878	3.006	3.105	3.178	3.229	3.259	3.271	......	1.319
0.132	0.399	0.917	1.790	2.932	4.354	6.064	8.061	10.342	12.862	15.579	18.457	21.463	24.568	27.746	30.975	34.233	37.505	......	108.189
-3.603	-3.524	-3.193	-2.488	-1.391	-0.011	1.659	3.619	5.866	8.353	11.040	13.890	16.869	19.850	23.105	26.312	29.551	32.803	......	103.254

40%		50%		60%		70%		80%		90%		100%	
-1.468	(0.321)	-1.295	(0.401)	-1.122	(0.481)	-0.949	(0.561)	-0.775	(0.641)	-0.602	(0.721)	-0.429	(0.801)
-0.820	(0.676)	-0.392	(0.845)	0.035	(1.014)	0.463	(1.183)	0.890	(1.352)	1.318	(1.521)	1.745	(1.690)
1.818	(1.590)	3.043	(1.987)	4.268	(2.385)	5.493	(2.782)	6.718	(3.180)	7.944	(3.577)	9.169	(3.974)
13.479	(4.367)	17.849	(5.459)	22.219	(6.551)	26.590	(7.643)	30.960	(8.735)	35.330	(9.826)	39.701	(10.918)
38.341	(8.769)	49.160	(10.8[illegible])	59.979	(13.154)	70.797	(15.346)	81.616	(17.539)	92.435	(19.731)	103.254	(21.923)
79.222	(14.442)	100.501	(18.0[illegible]	121.780	(21.663)	143.059	(25.273)	164.337	(28.884)	185.616	(32.494)	206.895	(36.104)
115.635	(18.653)	146.182	(23.3[illegible]	176.728	(27.979)	207.274	(32.642)	237.821	(37.306)	268.367	(41.969)	298.914	(46.632)
170.842	(24.118)	215.400	(30.[illegible]	259.958	(36.177)	304.516	(42.207)	349.074	(48.236)	393.632	(54.266)	438.190	(60.295)
255.734	(31.113)	321.791	(38.[illegible]	[illegible]87,847	(46.670)	[illegible]53,904	(54.448)	519.961	(62.227)	586.017	(70.005)	652.074	(77.783)
388.126	(39.879)	487.853	(49.[illegible]	[illegible]37,160	(59.818)	6[illegible]8.707	(69.788)	786.234	(79.758)	885.761	(89.728)	985.289	(99.697)
597.490	(50.543)	749.878	(63.[illegible]	[illegible].265	(75.815)	105[illegible].653	(88.450)	1207.040	(101.088)	1359.428	(113.722)	1511.815	(126.358)
17.62%		18.95%		[illegible]3%		21.0[illegible]%		21.95%		22.74%		23.45%	