Evaluating the economic impact of research

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Abstract

The most important outcomes of research from an investor's perspective are the benefits that will accrue to the investor. While the benefits can be economic, environmental, social or knowledge based, the Crown, multi-national corporations, and small businesses are especially interested in the economic benefits of investment in research and development.

Techniques enabling more effective evaluation of the benefits will allow investors to make more rational investment decisions. The use of Benefit Cost Analysis to evaluate more quantitatively the potential benefits of research is becoming increasingly important to public and private sector investors as a way of focusing on benefits rather than inputs.

The potential impact of yield improvement from the Crown-funded breeding programme for bread wheat in New Zealand is estimated by a benefit/cost analysis. By the fourth year, the benefits begin to outweigh the costs; after 10 years the added value of the benefits, less costs, would be $1.97 million annually. The benefit/cost ratio over 20 years with flow-on benefits would be 11:1, the Net Present Value of the project at a 10% discount rate would be $24 million and the internal rate of return, 64%.

Additional key words: *wheat breeding, genetic improvement, internal rate of return, benefit/cost ratio*

Introduction

In recent years there has been increasing competition in agricultural science for limited resources because the Crown has reduced expenditure on science and technology. Over the last decade expenditure in Research and Development (R&D) in New Zealand has declined by 27%, while spending has increased in other countries by 52% (Edwards, 1992). The decline has been accompanied by a reduction in Crown expenditure on technology transfer, and a shift to private sector funding. Although the Government has recently announced a modest increase in research expenditure, Government investment in agricultural research is seen to require a long-term commitment with high risk, a prospect that is not appealing politically (Chudleigh, 1992). The strategy developed by the Science and Technology Expert Persons (STEP) panel in 1992 is for expenditure on agricultural production research to be reduced, further while investment in research on food processing or added value would increase.

The most important outcomes, from an investor's perspective of research, are the benefits which will accrue to the investor. The Crown, multi-national corporations and small businesses are all interested in the question of "what will I get for my investment?". Yet, despite New Zealand's future relying heavily on the outcome of scientific activities, little is done to assess systematically either the potential returns from research before resource allocation or the benefits accruing from technology transfer after the research is completed.

Benefits can be measured in environmental, social, and economic terms. From the few studies on the benefits of research that have been completed in New Zealand (Dick, 1967; Scobie, 1984), and the many that have been documented overseas, it is clear that the returns from groups of projects are very high, typically 20% to 30% (Table 1). At a project level, the returns to industry and society are also high, typically in the range of 15-70% return on the investment dollar, occasionally the return is considerable. Professional agricultural technologists, however, rarely use the techniques available to demonstrate the worth of agricultural research in terms that are understood more easily by businessmen.

While the calculation of *ex post* economic benefits of research is relatively straightforward, the estimation of future returns from agricultural research has been described as something between a challenging task in applied economic analysis and a fledgling art form.

Table 1. Benefit cost analysis of agricultural science.

Project	IRR[1]	B/C ratio[2]	NPV[3] 10% dis	Comment
NZ Agricultural Research (Scobie *et al.*, 1986)	30%	2.8:1		
Wheat Research - Canada (Zentner *et al.*, 1984)	30-39%	3.3:1		62% of benefit to the producer - 38% benefit to the consumer.
CSIRO Division of Entomology	>18%	2.4:1		Benefits from successful projects matched against total costs of Division
ACIAR - 20 projects (Lee, 1991)		31:1	$817m	Average of 20 successful projects - benefits would have paid for 9 years operating costs
CSIRO (Johnston *et al.*,1992)				
Control of take all in wheat	179%	92:1	$575m	2 of 10 successful projects
Nematode resistant grapes	28%	25:1	$162m	
Chudleigh *et al.*, 1992				
Fertiliser application technology	113%	76:1	$61	
Wheat variety improvement	85%	3:1	$40	17 years
Crop & Food Research, 1993 Crown bread wheat breeding	64%	11:1	$24	20 years

[1] IRR - discount where present value of benefits equals the present value of costs
[2] B/C ratio - ratio of expected project benefits to expected project costs
[3] NPV discounted present value benefits minus the present value of costs

Nevertheless, the process of economic evaluation of the potential benefits of research is becoming increasingly important to investors in research as a way of focusing on benefits rather than inputs, as a guide to rational decision making.

Crown resource allocation

Peer review is a key component of resource allocation. Although there is no other process widely accepted for assessment of basic research, peer review is considered by many to give inconsistent results in the evaluation of applied research. Problems arise from internal strife and personal interests within the scientific community (Prinsley, 1992). Fears have been expressed by New Zealand scientists about the potential for ideas being plagiarised, young scientists being excluded for want of a track record and projects, rated highly for scientific content, not being approved because they fail to meet priorities set by the political process.

Better methods of evaluation must be found that use a combination of qualitative and quantitative approaches to establish the best use of resources. Such an approach is likely to involve quantitative analysis including Benefit/cost Analysis (BCA), followed by qualitative analysis and discussion to build consensus through an accountable process (Prinsley, 1992).

Private sector research funding

Private sector funding of research in New Zealand is low by international standards (Edwards, 1992). Most strategic planning in New Zealand businesses is undertaken by people with training in commerce and law rather than technology. Planners know or understand little about the process of research and innovation or how the benefits on research can impact on the future of a company. Scientists have more experience in explaining research achievements than client benefits. However, if scientists are to convince clients of the value of an investment, the scientists themselves must begin to express benefits in dollar terms.

Economic analysis

The most common form of economic analysis of R&D is benefit/cost analysis (BCA). BCA analyses equate the costs of research, development, and extension with the value of the benefits. The analysis treats R&D as a form of investment and examines the return on the investment either prospectively (*ex ante*) or historically (*ex post*). Projects with different costs, time horizons, probabilities of success, and economic impacts can be compared and evaluated against alternative investments.

Ex post evaluations are useful in measuring the effectiveness of the research and the value of the technology transfer, whereas *ex ante* evaluations assist decision makers to identify projects that are most likely to provide a return on investment. Economic evaluations have their limits in terms of accurately measuring the return on investment, but there is much to be gained from the methodical process of evaluation.

The limitations of the process include:

- evaluation of basic research where the results cannot be predicted - BCA is best at determining the economic benefits of near-market, applied research rather than more uncertain research projects in the early stages of R & D - one would have had difficulty doing a BCA on Gregor Mendel's pea project in the monastery garden,

- care must be taken to ensure dollar benefit figures are not taken too literally because their accuracy is uncertain - BCA is best used as a criterion for ranking programmes and projects in conjunction with other criteria,

- the technique has a limited ability to evaluate environmental and social factors, which are difficult to value in monetary terms.

Greer (1993) emphasises that decisions on resource allocation should not be based solely on investment advice generated from BCA. Scientists often fear that this may occur, but those who use the process emphasise that the economic ranking of projects is balanced by qualitative factors such as environmental factors, scientific excellence, industrial strategies, and other factors. People who use the logical process required in performing a BCA find the process is as important, perhaps more important, than the actual numerical result. The methodology requires researchers and managers to think systematically and quantitatively through factors that contribute to the costs and benefits of R & D. Frequently, the process can reveal major costs in production systems to which research resources can be directed for future gains in efficiency and quality.

BCA frequently draws together in-depth analysis of markets, prices, producer practice, environmental impact and other criteria that influence decision making. The rigour of *ex ante* BCA evaluations encourages scientists, economists, and technology transfer specialists to work together. It also encourages decision making that is based on realistic expected benefits rather than perceived developments, and can be a useful tool to monitor progress.

Johnston *et al.* (1992) concluded that the largest economic benefits are frequently associated with research that yields simple technologies that are quickly adopted and widely applicable and lead to significant cost reductions in the industry. A low and slow adoption rate can greatly reduce economic benefits. Uncovering the reasons for resistance to change and modifying research, development, and extension to suit could lead to even greater benefits from successful research.

A case study

A BCA was calculated for the costs and benefits of the FRST funded bread wheat breeding programme at Lincoln. The programme began in the 1930's and reliable historic data are available. The analysis looked at bread wheat breeding research from 1993 to 2002. The calculated benefits were based on the release of 5 cultivars during that time, with probability estimates made by the breeder (Table 2). Research effort put in before 1993 was assumed to be offset by research benefit accruing after 2002.

The pattern of uptake of new cultivars has been based on experience with 'typical cultivars' during the last 20 years, in the absence of better data (Table 3). The last new cultivar released in 2001 was assumed to hold its share rather than decline, in the absence of new cultivars.

Table 4 shows the result of the BCA calculation. If no further research is undertaken after 2002, the ongoing contribution of the genetic improvement will have been to raise the average yields of bread wheat from 4.9 t/ha to 5.526 t/ha. The genetic gain of the cultivars are based on data from old and new cultivar trials that indicated a 92% gain in yield over 72 years (unpublished data). It was assumed that the gains will be maintained at the 2002 level for 10 years. Thus the net value of benefits shown in Table 5 includes benefits for the years 2006 to 2013 which are not shown in Table 4.

Table 2. Assumptions used in the calculation of costs and benefits.

Wheat Price (5 year Average, 1993$/t)	280		
Total area (ha)	40000		
Gain per cultivar (%)	2.6		
No of new cultivars	5		
		Yield gain (%)	Probability of Release
	Cultivar 1	2.6	1.00
	Cultivar 2	5.1	0.99
	Cultivar 3	7.7	0.98
	Cultivar 4	10	0.95
	Cultivar 5	13	0.90
Yield without additional costs (t/ha)		4.9	
Costs per ha (GM costs independent of yield, $/ha)		380.38	
Costs per tonne (GM costs vary with yield, $/t)		31	
Additional Costs per tonne over 5 t ($/t)		114	

Table 3. Adoption rates of new cultivars.

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Cultivar 1	0.03	0.18	0.36	0.36	0.34	0.15	0.1	0.07	0				
Cultivar 2			0.03	0.18	0.36	0.36	0.32	0.2	0.1	0.07			
Cultivar 3					0.03	0.18	0.35	0.35	0.32	0.2	0.1	0.07	0
Cultivar 4							0.03	0.18	0.35	0.35	0.35	0.28	0.25
Cultivar 5									0.03	0.18	0.35	0.45	0.55
% of total Area	0.03	0.18	0.39	0.54	0.73	0.69	0.8	0.8	0.8	0.8	0.8	0.8	0.8

Average wheat farm gate price and yield over the last five seasons was used as the basis for the calculation. The 1993 area (40 000 ha) was used and held constant. On-farm wheat growing costs were based on the 1991 Wheat Growing Competition standard input costs. It was also assumed, that if wheat yields are to increase beyond 4.9 t/ha, increases in nitrogen fertiliser and irrigation will be required. These costs were also computed from the Wheat Growing Competition data.

The costs of the bread wheat breeding programme, quality assessment and extension costs were included.

Although there have been substantial benefits in quality improvement over the last 10 years particularly, these benefits were not included because the breeder expects to make fewer gains in the next decade. Some gains in flour extraction rate and other quality factors are likely to continue, but, these were not calculated in this example. The assumptions are summarised in Table 2. Discount rates were applied to allow for the opportunity costs of money.

Table 4 illustrates that by the fourth year, the benefits begin to outweigh the costs, and by 2002 when the research ceases, the added value of the benefits, less costs, is $1.977m annually. The benefit/cost ratio over the 20 years with flow on benefits is 10.8:1 (Table 5).

The net present value of the project at a 10% discount rate (present value benefits minus the present value of costs) was $23.77 million (Table 5). The internal rate of

Table 4. Calculation of costs and benefits, 1993-2005.

Year	1993	1994	1995	1996	1997	1998	1999	200	2001	2002	2003	2004	2005
Stage 1: Changes in net Producers Revenue $000													
Exp net benefits Var 1	20	122	244	244	230	101	68	47	0				
Exp net benefits Var 2	0	0	40	241	482	482	429	268	134	94	0		
Exp net benefits Var 3	0	0	0	0	60	358	696	696	636	398	199	139	0
Exp net benefits Var 4	0	0	0	0	0	0	80	477	928	928	928	742	663
Exp net benefits Var 5	0	0	0	0	0	0	0	0	99	597	1160	1492	1823
Stage 2: Estimation of Total Net Benefits $000													
Exp Total Net Benefits	34	204	461	730	1103	1253	1631	1848	2156	2374	2695	2731	2844
Genetic Imp Costs	204	204	204	204	204	204	204	204	204	204	0	0	0
Quality Ass Costs	87	87	87	87	87	87	87	87	87	87	0	0	0
Extension Costs	105	105	105	105	105	105	105	105	105	105	0	0	0
Project Cost Stream	397	397	397	397	397	397	397	397	397	397	0	0	0
Net Benefits Stream	-363	-193	64	333	705	856	1234	1450	1759	1977	2644	2731	2844

Table 5. Calculation of investment criteria, 1993-2013.

Discount rate = 10%	
Net Present Value Benefits ($M)	26.06
Net Present Value Costs ($M)	2.29
Net Present Value of Project ($M)	23.77
Benefit Cost Ratio	11.4:1
Discount rate = 5%	
Net Present Value Benefits ($M)	30.54
Net present Value Costs ($M)	2.82
Net Present Value of Project ($M)	27.72
Benefit Cost Ratio	10.8:1
Internal Rate of Return	64.0%

return (discount where present value of benefits equals the present value of costs) was 64%.

Conclusion

The social and economic benefits of agricultural research can be higher than those earned on many ordinary business investments. Producers and processors benefit from the research, and consumers capture considerable social returns from increased economic activity, improved products, and from environmental enhancement.

If agricultural technologists are to market their technology more effectively they will need to do so by selling the benefits. They will need to make it clear to research investors - public and private - that the research, development and extension is an attractive investment. If agricultural scientists adopt the BCA approach developed by agricultural economists, they may find that their communication with the business world is more effective and productive.

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