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COST EFFECTIVE *EX-ANTE* PROJECT EVALUATION

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Contributed paper at the 36th Annual Conference
of the Australian Agricultural Economics Society,
Australian National University, Canberra
10-12 February

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COST EFFECTIVE EX-ANTE PROJECT EVALUATION¹

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The CSIRO Institute of Animal Production and Processing has been developing economic evaluation techniques to assist in the selection of research projects. Most involve fairly standard applications of spreadsheet models to estimate gains to individual representative firms from the adoption of new technologies and then to aggregate these gains through an Edwards and Freebairn approach to estimate total welfare gains and their distribution between producers and consumers. One of the greatest improvements in cost effectiveness has resulted from modelling the impact of a range of alternative technologies on an industry at the same time.

However several developments in the way CSIRO have applied these models have allowed us to reduce the time and cost in doing evaluations, the consistency with which evaluation results can be compared and their acceptance by those with no formal economic training. Other modifications have made the models more easy to use while retaining their robustness.

In these models an allowance has been made for the increasing responsiveness of producers to research innovations through time. Because gains stemming from productivity improvements in the primary or processing sectors of an industry are gradually passed onto consumers through time, use of just one measure of supply responsiveness will either under or over estimate the gains to that sector, depending on the time period to which the measure relates. Account has also been taken of the possibility of obtaining the technology elsewhere at some time in the future. If such a possibility exists, then ignoring it could result in estimated benefits to the industry being grossly over stated. The final modification included in the model was to incorporate a method of economic risk analysis so that uncertainty surrounding variable estimates could be used to add value to prospective project evaluations rather than detract from their perceived accuracy.

¹ Contributed paper presented at the 36th Annual conference of the Australian Agricultural Economics Society, Australian National University, Canberra, 10-12 February, 1992.

COST EFFECTIVE EX-ANTE PROJECT EVALUATION²

BACKGROUND

In recent times CSIRO has placed greater emphasis on taking account of stakeholder interests in scientific research and development. To this end, CSIRO has widened its evaluation review process with each of the six Institutes developing review processes appropriate for the areas of research with which they deal.

At the organisation level a "Priority Setting Framework" has been developed and is based on group census techniques (CPO 1990). The method allows the "attractiveness" of research and development in specific areas to be assessed against the "feasibility" of successfully doing the research and development in Australia. This method has been of immense value in identifying R &D opportunities and allocating expenditures accordingly.

At the more applied end of the research spectrum, the Institute of Animal Production and Processing (IAPP) has developed ex-ante evaluation models to assist in the estimation of the expected payoff from specific research proposals³. Throughout the course of a research program, many opportunities for the commercial development of technologies are identified and the evaluation models can be used to assess their commercial viability. Because a great number of research programs are undertaken within IAPP each year, it is essential that evaluation models are cost effective in their application, provide consistent estimates of project pay off and are robust.

The ex-ante evaluation models which have been developed in IAPP are based on the framework developed by Edwards and Freebairn (1984), and several modifications have been made to improve the accuracy of the results obtained. By setting up spreadsheet driven generic models for specific industries, it has been possible to undertake evaluation of research proposals in a cost effective manner. Furthermore, it has been relatively straight forward to build sophisticated models which can be easily understood by non-economists, should such an understanding be required.

IAPP's approach has differed from that of Page and Walsh (1991) in that in pursuing the need for widespread acceptance of the models by non-economists we have not traded off accuracy for simplicity. Many "Back of the Hand" analyses ignore the impact of increased productivity on output prices and rely simply on the estimation of output changes which could result from technological improvements. Davis and Bantilan (1991) show that care is needed in the estimation of supply shifts resulting

² The informal comments provided by Mr Drew Collins from ABARE are greatly appreciated.
Naturally however, all remaining errors in this paper are the responsibility of the authors.

³ IAPP also undertakes ex-poste analyses. A portfolio of ex-poste and ex-ante evaluations are being undertaken each year to allow better priority setting, better focussing and management of research programs through time, better management of technology transfer to speed adoption and commercialisation and to attract more research funds through more effective marketing of our services to both private firms and public agencies.

from technological change. Yield increases resulting from technological change need to be translated into cost decreases taking into account enterprise substitution effects. Thus, in cases where supply and demand interactions are considered the use of horizontal supply shift assumptions can reduce the accuracy of the evaluation. In comparison, vertical supply shift assumptions reduce the *scope for error* [and enhances the] *understanding of the impact of the technological change* (Davis & Bantilan 1991, p. 13).

The main benefit however, of using the Edwards & Freebairn (1994) framework is that the distribution of research benefits across different producer and consumer groups can be identified. Because many Australian agricultural industries are export oriented, some of the gains from productivity improvements in Australia are appropriated by overseas consumers. When research is being financed partly or wholly by industry groups, say for example through one of the many research and development corporations in Australia, it is appropriate to evaluate the gains to the industry group concerned as well as consumer benefits generated domestically or overseas.

For the evaluation models developed within IAPP, three main modifications to the Edwards & Freebairn framework have been made. The first modification was to allow for the increasing responsiveness of supply through time rather than using one measure of supply response across all periods in which benefits are likely to be generated. The second modification was to allow for the possibility that the research would be undertaken by another organisation, and the third was to incorporate methods of risk analysis into the evaluation models. It is not the intention of this paper to explain in the detail the structure of IAPP's evaluation models, but rather to concentrate on the modifications stated above. For illustrative purposes, gains from productivity improvements in the Australian wool industry are considered.

RESPONSIVENESS OF SUPPLY

Through time the responsiveness of supply increases as suppliers are more able to increase production levels and alter the mix of inputs used. However, in the application of the framework to research evaluation problems only one measure of supply response is generally considered (see for example, Farquharson (1991), Gross et al (1991), Chudleigh (1991) and Haynes et al (1986)). In a similar modelling approach, both Mullen & Alston (1990) and Morris et al (1991) also made the assumption that the responsiveness of supply is constant through time. (As an aside, Mullen and Alston (1990 p. 107) demonstrated that under a parallel supply shift assumption the choice of the functional form of supply leads to only *small errors of approximation* and therefore the Edwards & Freebairn framework is more *robust than previously thought*.)

Under the Edwards & Freebairn framework it can be shown that the reduction in price following a productivity gain which results in a vertical shift downwards of the supply curve is greater the more responsive is the supply response relative to the responsiveness of demand. If it is assumed that both supply and demand are linear,

the supply shift is parallel and the cost saving is given by K, then the new equilibrium price (P^1) can be expressed as follows :

$$(1) \quad P^1 = [(K/E_d)/((1/E_s)-(1/E_d))] + P^0 ,$$

where P^0 is the pre-shift equilibrium price of output and E_s and E_d are supply and demand elasticities respectively. Given that E_d is negative, then as E_s increases (becomes more responsive) P^1 approaches ($P^0 - K$). Conversely, as E_s decreases, P^1 approaches P^0 .

Using the Edwards & Freebairn (1984) derivation of the gain in producer surplus (ΔPS) :

$$(2) \quad \Delta PS = 0.5[K - (P^0 - P^1)](Q^0 - Q^1) ,$$

it can be shown that as P^1 approaches ($P^0 - K$), ΔPS approaches zero.

If projects are evaluated from CSIRO's perspective, the gains to overseas consumers should be ignored as they do not represent a return to CSIRO stakeholders who are the people of Australia. The extent to which gains to CSIRO stakeholders are over or under stated by including gains to overseas consumers in estimation of total benefits, will depend on the time period considered in the evaluation and the measure of supply response used. To illustrate these potential differences the Australian wide sheep lice model developed by Taleb and Collins (1992) was used to estimate the gains to producers in Australia from a 10% increase in wool cut per sheep in the wheat-sheep zone, assuming that no additional production costs were incurred. Results are presented in Table 1 for a one off permanent increase of 10%.

The results presented in Table 1 are consistent with the findings of Edwards and Freebairn (1982) who were able to show that as the responsiveness of supply increases relative to the responsiveness of demand a smaller portion of the total gains will be captured within the producing sector. In situations where long run supply elasticities are used, the gains to the producing sector will be understated, more so the shorter the evaluation period used. On the other hand, if short run elasticities are used, total gains will be overstated. However, as the evaluation period is shortened, the extent of the over estimation is reduced and can in fact underestimate the gain over a very short time period.

In reality, adoption of new technologies is rarely instantaneous across all producers and tends to occur at a gradual pace through time (Rogers 1983). When project evaluations are undertaken it is the usual practice to estimate welfare gains at the annual average rate of adoption and then multiply these gains by the cumulative level of adoption in each year to derive an estimate of gains through time. If annual measures of supply response are used this method will give incorrect results. This is because a supply elasticity measures the responsiveness of supply in a given year

from the year in which the productivity gain first occurred. This problem can be better appreciated by examining the uptake of a technology over a three year period, as reported in Table 2.

Table 1 : Producer surplus gains from a 10% increase in wool cut per head in the wheat sheep zone : Under different measures of supply response ^(a) : \$m

Year	Annual E _s	5 year E _s	Long run E _s
1	407	331	248
2	393	331	248
3	372	331	248
4	350	331	248
5	331	331	248
6	315	331	248
7	303	331	248
8	294	331	248
9	287	331	248
10	280	331	248
11	273	331	248
12	269	331	248
13	264	331	248
14	261	331	248
15	257	331	248
16	254	331	248
17	253	331	248
18	250	331	248
19	249	331	248
20	248	331	248
TOTAL	5912	6620	4960

(a) Elasticity estimates were taken from Dewbre et al (1985).

Note : Annual benefits are not discounted.

Table 2 : Gains from the adoption of a new technology over a three year period

Producers adopting technology ^a (%)	Year 1	Year 2	Year 3
33 (a = 1)	PS ¹ ₁	PS ² ₁	PS ³ ₁
33 (a = 2)		PS ¹ ₂	PS ² ₂
34 (a = 3)			PS ³ ₁
TOTAL GAIN	PS¹₁	PS²₁ + PS¹₁	PS³₁ + PS²₂ + PS¹₃

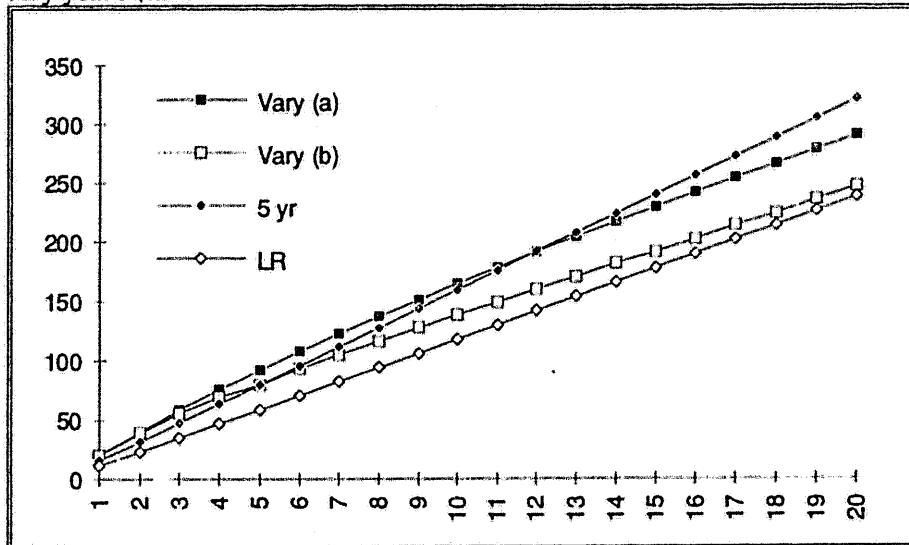
(a) It has been assumed that 33% of producers adopt the technology in year 1, 33% in year 2 and 34% in year3.

In any given year (t) producer surplus (PS^t₁) is given by the sum of the surplus accruing to those people (a) adopting the technology in that and previous years. In year three for example there will be a number of producers adopting the technology

for the first time and the appropriate supply elasticity to use for this group is E_s^t , where $t=1$. Also in that year there will be a number of producers who had adopted the technology in year $t=1$ ($a=1$), and their gain in year three will be based on a supply elasticity E_s^t , where $t=3$. The total gain generated in any given year is simply the addition of surpluses accruing to each group of individuals adopting the technology in any given year ($\sum_{a=1}^t [PS_{sa}^t]$). The differences in estimated gains are illustrated in Figure 1 using the same productivity gain estimate used previously, but under an adoption rate of 5% a year over a twenty year period.

The extent that gains are either over or under stated will depend on the evaluation period considered and the assumed annual measure of supply response used in the analysis. The total gains generated under a varying supply elasticity assumption for each year and for each group of adopters was estimated at \$3326m over the twenty year period. In contrast, as shown in Figure 1, when no allowance was made for the different groups adopting at different times (ie. only one measure of E_s^t was used in each year) the total gain was estimated at only \$2825. For comparative purposes, the gain in producer surplus is also provided using a 5 year and long run measure of E_s in each year over the twenty year period considered.

Figure 1 : Estimates of producer surplus under different supply elasticity assumptions
: By year : \$mil.



(a) E_s varied by year and group of adopters.

(b) E_s varied by year only.

However, a problem arises when the Edwards & Freebairn framework is used and supply response is varied through time. In the framework gains through time are based on shifts in equilibrium levels of output and prices from an initial equilibrium in $t=0$. The gains accruing in year $t=3$ to first time adopters ($a=1$) should be based on equilibrium condition that would exist in $t=2$. Consequently, in an evaluation where adoption is assumed to occur gradually through time, the supply curve needs to be

repositioned every time a new group of producers are assumed to adopt the technology.

R&D IN OTHER ORGANISATIONS

The second modification which has been made to the Edwards & Freebairn framework was to incorporate the possibility that any technological improvement could be made commercially available from other sources. From the viewpoint of CSIRO stakeholders it does not matter which Australian organisation actually undertakes the R&D and gets the technology into the market place. Any benefits generated from the development and marketing of new technologies will be the same irrespective of which organisation makes it commercially available. Furthermore, because it is the price of the technology which affects gains to users, not who supplies the technology, it makes no difference to the users whether or not the technology is developed domestically or internationally. This is an important consideration for funding organisations where the stakeholders are solely the users of any potential technological improvement.

Gross et al (1991) addressed this issue in their study on the gains from accelerating the commercial development of a technology. In the study they looked at the gains which could be made from injecting additional funds into a R&D project so that a commercial product could be developed sooner. If an evaluation is based on a comparison of an organisation either doing the R&D now or at a later date, or intensifying the current R&D effort, then both the advancement in time of costs and benefits need to be considered. This would be the case in public organisations where one organisation, such as CSIRO, may be considering doing the R&D at an earlier date than another publicly funded organisation. That is, in situations where the stakeholders of each organisation are the same. However, it should be noted that if there is a constraint on the amount of available capital, an allowance should be made to account for the different level of annual expenditure between doing the project sooner rather than later (Gittinger 1982).

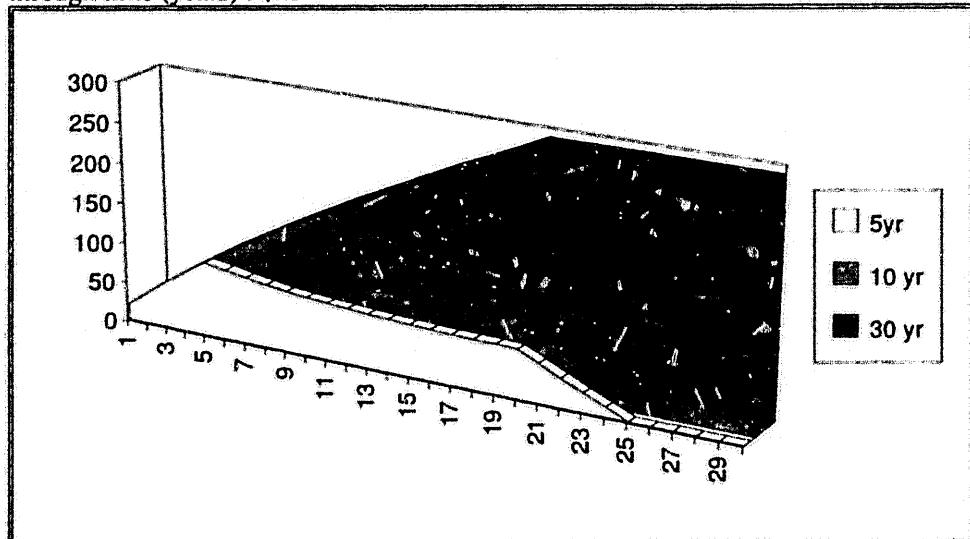
If an evaluation is to be made, based on a comparison of either doing or not doing the R&D within one organisation, and the stakeholders are the potential users, then only the delay of benefits should be considered in the "without" R&D case. The implicit assumption here is that the benefits would still be attained by the user group at some time in the future without them having to undertake or finance the R&D. This is also the case if the technology is expected to be made available in the future from overseas sources.

In evaluation models developed by IAPP, the possibility of identified users obtaining technological improvements without the need for any public funding has been termed the research lead time. In many instances the research lead time will be long, reflecting the international lead CSIRO or other Australian research organisations have in a given area of research, or the lack of R&D being carried out overseas because, for example, the research problem may be unique to Australia.

In Figure 2 the impact of different research lead times on project benefits is illustrated using the example considered previously of a 10% increase in wool cut per head in the Australian wheat-sheep zone. As can be seen in Figure 2 there is a substantial reduction in estimated project benefits, as measured by the economic gains to Australia, when short research lead times exist.

In situations where technology obsolescence (Lindner 1989) occurs before the end of the research lead time, the latter will have no bearing on the evaluation results.

Figure 2 : Impact of different research lead times on estimated annual project benefits through time (years) : \$m



RISK ANALYSIS

The greatest problem facing analysts embarking on an ex-ante evaluation is not the availability of easy to use and robust models, but rather, uncertainty surrounding many of the key parameters which are required for the evaluation. Normally in an evaluation, the effect of uncertainty is handled through sensitivity analysis. Individual parameters are varied one at a time and the impact on evaluation results recorded. Inferences are then made on the "risks" associated with the project. However, when there are two or more uncertain variables in the analysis, changing one variable and holding the other variables constant can give misleading results (Department of Finance 1991).

To overcome the problem of a lack of certainty surrounding future events, a risk analysis software program @RISK (Palisade Corporation 1990) was used in conjunction with the evaluation models developed by IAPP. The program is used as an add-in to either LOTUS123 or EXCEL and enables estimated probability

distributions to be specified for uncertain parameters. A Monte Carlo simulation procedure (or Latin Hypercube) is then used iteratively to select points at random from each specified cumulative probability distribution. At each iteration the spreadsheet is re-solved and new solutions obtained. By carrying out a large number of iterations it is possible to derive frequency distributions for measures of project performance, such as net present value, benefit/cost ratio and internal rate of return.

Apart from the ease at which the risk analysis program can be incorporated into spread sheet driven evaluation models, estimated probability distributions can usually be easily obtained. The information required for the range of probability distributions available with @RISK is minimal. For example, if a triangular probability distribution is assumed, subjective judgements are only required for the upper and lower limit of the distribution and the value of the mode. In the case of a normal probability distribution, estimates are only required for the mean and standard deviation. A good application of @RISK to farm level decision making can be found in Farquharson (1991).

Using the increase in wool cut per head example discussed previously, an evaluation was carried out on a hypothetical R&D project, costing \$5m over 5 years, to achieve the increase in wool cut. For illustrative purposes several assumptions regarding the value and probability distribution of key variables have been made. These assumptions are reported in Table 3. Three probability distributions were used, a triangular (Tri), uniform (Uni) and normal (Norm). The distributions were incorporated into the wool evaluation spreadsheet and solved to estimate the net present value and benefit cost ratio of the proposed investment. A real discount rate of 5% was also assumed.

Table 3 : Evaluation assumption

Parameter	Fn	Mean	SD	Min	Mode	Max
Productivity gain (%)	Tri	17	-	5	20	25
R&D success (%)	Tri	57	-	30	60	80
Adoption lag (years)	Uni	15	-	10	-	20
Adoption rate (%)	Norm	5	1	-	-	-
Adoption ceiling (%)	Tri	55	-	25	60	80
Research lead time (years)	Tri	12	-	5	10	20

Note : Fn stands for probability distribution functions triangular (Tri), uniform (Uni) and normal (Norm). SD stands for standard deviation.

The distribution of expected project net benefits is illustrated in Figure 3. The variation around the mean is indicated in each year by the top 90% and bottom 10% of values. A visual appraisal of the distribution of returns, or measures of project performance (see Figure 4), can provide decision makers with a better understanding of the underlying "upside" and "downside" risks of the investment. The statistical

output of the @RISK simulation also allows a more rigorous analysis of the results, and their distribution, should such rigour be required.

Figure 3 : Expected net project benefits through time

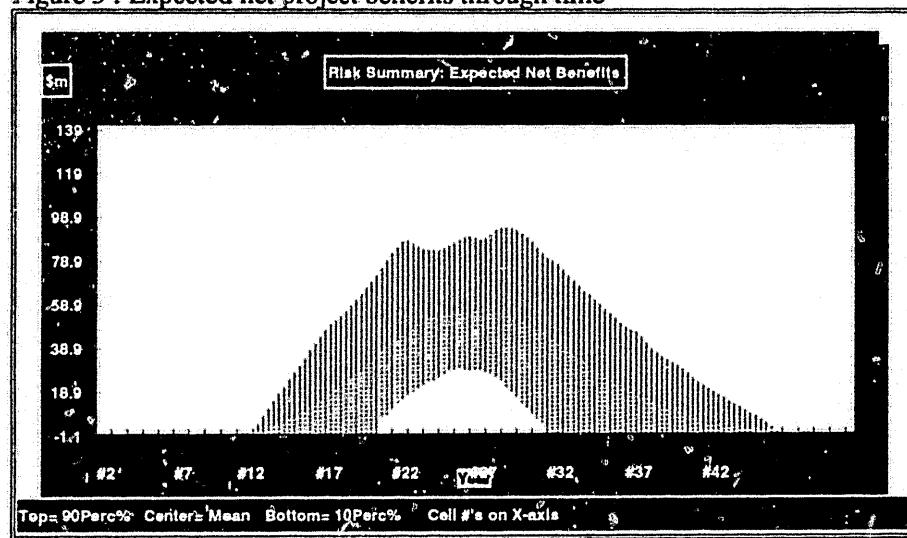
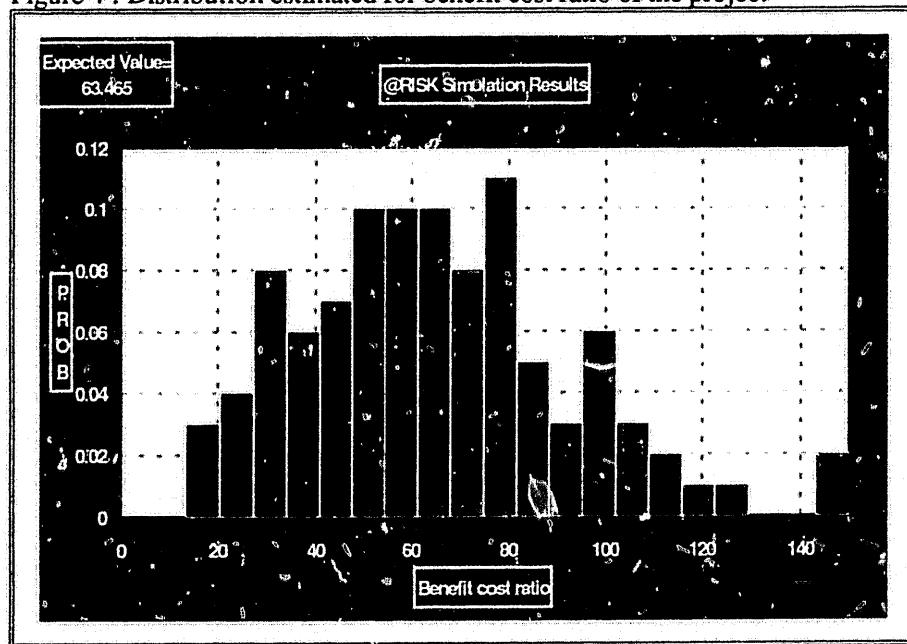


Figure 4 : Distribution estimated for benefit cost ratio of the project



CONCLUDING COMMENTS

With the sophistication of spreadsheet programs over the past decade it has been possible to build evaluation models which are robust and usable by non-economists. The strength of these models lies in the degree of sophistication which can be included and the speed at which they can be run. Apart from being able to reduce the costs of doing ex-ante evaluations, a rigorous approach increases the likelihood that better information is collected in the first place. To assist researchers in the collection of information, IAPP has developed generic models for the Australian sheep and cattle industries. Detailed information on production forms the base up on which all evaluations are carried out. In an evaluation, the likely impact of a given R&D project on the industry is simulated, and returns to the relevant stakeholders estimated.

The models developed by IAPP are based on the Edwards & Freebairn framework. It has been possible to incorporate the changing responsiveness of supply through time into these models to better account for the capture of benefits to Australian producers and consumers through time. If a medium term measure of supply response (say 5 years) is used in an evaluation then it is possible that the estimation of benefits could be grossly over stated. The extent of the error will depend on the time period under consideration. Allowances have also been made for the possibility of obtaining R&D outputs elsewhere, thereby avoiding the loss over estimation of benefits which can be attributed to a particular R&D project if R&D being carried out in other organisations is ignored. To account for the uncertainty surrounding future events a risk analysis program has been used to assess the underlying risks of proposed projects.

Further cost savings, or more widespread use of evaluation models, could be achieved if much of the base information was readily available to analysts. Duplication of effort in collecting base data could be avoided if there was greater coordination between organisations undertaking ex-ante project evaluation. Furthermore, consistency between organisations would benefit those people making broader decision on R&D funding allocations⁴.

⁴ CSIRO has been working with ACIAR, ABARE, NSW Agriculture, the MRC, the WRDC and several universities to achieve greater co-ordination, and would welcome further interaction on these matters.

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