# EVALUATING THE EVALUATIONS
## Lessons from ex-post evaluation in IAPP

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Contributed paper at the 37th Annual Conference of the
Australian Agricultural Economics Society
The University of Sydney, Sydney, 9-11 February 1993

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## ABSTRACT

The CSIRO Institute of Animal Production and Processing has undertaken many ex-post evaluations to determine the economic payoff from past R&D investments and to assist in the selection of future research projects. The degree of complexity required in an evaluation will depend on the evaluation objectives. A balance is required between the level of theoretical complexity included in the evaluation and the extent to which the financial benefit actually gained by users of R&D outputs is understood. In this study the economic gains from SIRO Layer and AUSPIG pig production decision support software technologies are estimated. Using these two evaluations as examples, the impact on evaluation results from relaxing key assumptions is examined.

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## Introduction

The evaluation of individual research projects has gained increased prominence over the past decade. Behind this increase has been an increasing need for research organisations to be made accountable to their stakeholders and to be able to demonstrate that priority setting processes are both objective and rigorous in their coverage of potential research opportunities.

Ex-post evaluations can provide an indication of the value for money from past research expenditure, but can provide no assurance that future expenditures will be profitable. Unfortunately, as noted by OECD (1987, p12), *the question of value for money from investments in scientific research is increasingly asked in ex-post evaluations*. This is not to say that ex-ante evaluations are not being carried out, but rather that *ex-ante evaluations are still largely the preserve of expert consensus* (internal) *while ex-post evaluations are increasingly becoming the preserve of a cadre of professional* (external) *evaluators* (OECD 1987, p12).

What does an ex-post evaluation provide to decision makers interested in the future allocation of research budgets? In themselves they provide very little because they do not indicate whether or not previous research expenditures were optimal in generating the benefits observed from the use of research outcomes. Information on market structure and operation would be valuable to decision makers if future funding in that area is under consideration. However, if such information was to be provided, the strength of assumptions regarding market adoption of R&D outcomes and the magnitude of gains realised would still need to be tested by decision makers.

One of the greatest benefits from ex-post project evaluation is that they *provide(s) evidence on the validity and appropriateness of assumptions, forecasts and analyses used in decision making* (Department of Finance 1992). Therefore, to bridge the gap between ex-post and ex-ante project evaluation, it would be desirable to ensure that ex-post evaluations provide adequate explanation of assumptions made and methods used. However, the trade off between cost, accuracy and relevance of an ex-post evaluation is not obvious, and the lack of this information was the driving force behind this paper.

In this paper two ex-post evaluations are carried out on research projects carried out within IAPP. The two project evaluations considered in this paper are the SIROLAYER and AUSPIG technologies developed by CSIRO during the 1980's. In the following section these two projects are described and the economic pay off from past R&D (measured by the net present value) is the estimated. The sensitivity of the likely pay off from the R&D under different assumptions is then tested. These results are then used as a basis for examining the value of allocating effort to different parts of an evaluation.

## Evaluation case studies

### *(1) AUSPIG*

"AUSPIG" is a computer decision support system designed to increase the profitability of pig production. The system is comprised of the "AUSPIG" growth and production simulation module, the "FEEDMANIA" diet formulation system and the enterprise optimisation model "PIGMAX". The "AUSPIG" growth model was described in Black et al (1986) and Standing Committee on Agriculture (SCA (1987)).

The "AUSPIG" growth module *simulates energy and amino acid utilisation for pigs of varying genotype from birth to maturity. The model predicts feed intake, changes in body weight, feed conversion efficiency, body composition, back fat thickness and value of finishing carcasses given the age and sex of pigs in the enterprise, diet and feeding method and the physical environment* (CSIRO 1990, p.1). FEEDMANIA is a least cost diet formulation system. The AUSPIG model specifies pig requirements for dietary protein and energy levels that are tailored to the strain, sex, level of feeding and climatic environment of the pigs, (CSIRO 1990). FEEDMANIA then formulates the most profitable ration by employing linear programming to generate the least cost diet from a wide range of available ingredients.

AUSPIG and FEEDMANIA outputs are incorporated into the PIGMAX module which utilises linear programming to maximise the resources employed in the piggery given prevailing production and marketing conditions. *The profit maximising strategy specifies the best weight and market outlet for male and female pigs, optimum size of breeding herd, whether to purchase or home grow replacements and labour requirements. The resources allocated by optimum strategy are capital, pen space, different classes of accommodation, breeding sows, farrowing pens, dry sow stalls and permanent labour* (CSIRO 1990, p.6). Output from within the AUSPIG system is processed by an expert system to provide recommendations in a readily understandable form to the user. The expert system analyses and interprets model output and transforms the data into reports and graphs.

The AUSPIG system was designed to consider a greater range of parameters influencing pig productivity when compared to other simulation models (Black et al 1986). The system draws together the many interacting and dynamic parameters affecting pig production and can be used, with a high degree of precision, to determine the appropriate mix of inputs that will maximise profits in any given piggery. In this evaluation the model's capacity to generate a more profitable feeding strategy is analysed.

*The national pig industry*

The pig industry was worth $600 million at the farm gate in 1990/91 (Australian Pork Corporation (APC) 1991). The consumption of pig meat has been increasing in Australia, from an estimated 14.8 kg per capita annual consumption in 1982 to 18.3 kg in 1990. Pork and pork-based product represented 42% of pig meat purchases whilst ham and bacon consumption represented the remaining 58% in 1990 (APC 1991). Australian pig meat production is primarily consumed on the domestic market, however, there has been an increasing focus on export markets with sales increasing from 4,000 tonnes in the mid 1980's to greater than 10,000 tonnes by 1990/91 (APC 1991).

The production of pig meat has changed from being a sideline enterprise run in conjunction with dairying to a sophisticated capital intensive industry exhibiting a relatively high degree of vertical integration (Strong and Griffith 1992). The size of the Australian herd has also increased over the last decade. Sow numbers have increased from 301 thousand in 1978 to 363 thousand in 1990, an increase of 20% (APC 1991). Fresh pork production has risen 63% over the last decade, from 83 thousand tonnes in 1980 to 135 thousand tonnes in 1990. The increase in productivity is derived from the trend toward increased slaughter weight of pigs and productivity improvement within the herd.

The number of pig slaughterings rose from 4.1 million in 1980/81 to 5.1 million in 1989/90 whilst the average carcass weight rose from 55.6 kg to 60.7 kg (APC 1991). The increased carcass weight has largely resulted from the introduction of the heavier "super porker" carcass category into the industry. Previously pigs were slaughtered into the pork trade light weight carcass specification of 40-55 kg or the heavier baconer or cured meat trade carcass specification of 65-75 kg (Shorthose 1991). Over the past decade fresh pork pigs have been sold at an increased weight into the super porker class which is of similar weight to that of the baconer (60-70 kg). The new fashion pork cuts are derived from this carcass specification. The super porker is a more profitable animal to produce as more saleable product per unit of breeding stock is utilised in the growing of heavier pigs relative to traditional porker weight (Shorthose 1991).

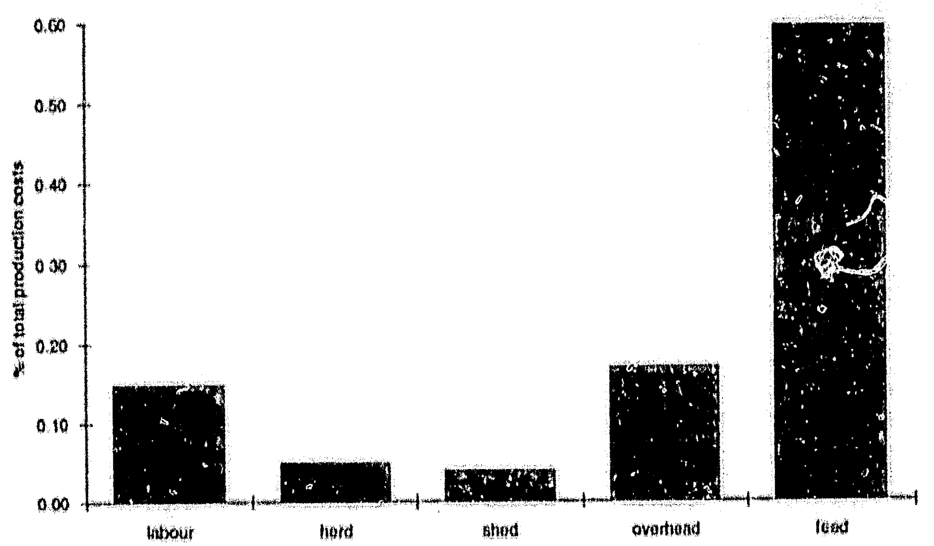
Reduced prices for back fat thickness have arisen from consumer preference for leaner retail cuts of pig meat. The development of farmgate pricing using estimated lean meat yield is currently being developed to further the orientation of the industry towards lean meat production (Whan 1991). The refining of ration formulation to reduce the laying down of back fat and increased lean meat growth increases the profitability of pig production. The ability of the AUSPIG system to formulate dietary specifications for differing genotypes and improve profitability is investigated in more detail later in this case study.

Improved management and genetics in the industry have also led to greater herd productivity. The profitability of a piggery is largely determined by the number of market pigs sold per sow annually and the growth rate of those pigs, (APC 1991). The number of pigs produced per sow in a 12 month period depends on how many litters are produced and the average size of the litter. The average number of litters produced by sows in NSW and Victoria in 1989 was 2.14 and the average litter size of pigs born alive was 10.1 (APC 1991).

Average breeding herd performance outlined in APC (1991) under estimates the performance of herds on many of the commercial piggeries. Averages reported by APC (1991) incorporate sideline enterprises and the consequent productivity estimates are less than that on enterprises where pigs are the major enterprise. A more representative estimate of productivity in main line commercial piggeries is outlined in Pork Research Council (PRC) (1990). The average number of litters per sow in these units was 2.24 in 1989/90, with an average litter size of 10.53 and 18.77 pigs marketed per sow.

Profitability is also governed by the pig's potential for growth. Considerable genetic progress has been made through breeding pigs to exhibit low feed conversion, high growth rates and reduced back fat thickness. Improved diet formulation and feeding methods reduce the cost of pig production and improve the pig meat quality. Feed costs represent the highest variable cost to pig producers and account for 60-70% of total variable cost expenditure. A breakdown of the costs of pig production taken from PRC (1990) is presented in Figure 1 below.

Figure 1: The costs of pig production.




Herd costs include the costs associated with health, herd performance recording, livestock requisites and stock mortalities. Shed costs include power and gas, overhead costs comprise administrative charges, rates, depreciation, insurance and miscellaneous expenses, labour costs include owner, permanent and casual labour and feed costs represent the sum of ingredients used. Typically, pig rations are comprised of 85% grains high in crude protein such as wheat. Protein meals constitute approximately 10% of the ration. Meat and bone, skim milk powder, fishmeal and soybean meals are typically used. The remainder of the ration is comprised of vitamin and mineral premix, salt and synthetic amino acids (PRC

1990).

The use of the AUSPIG model to define dietary specification for differing genotypes is examined in this study. The importance of tailoring the energy and protein intake in the diet for specific genotypes was shown earlier in this section. With feed representing such a substantial cost to pig producers, the value of improved ration formulation is likely to be of significant value to the national industry.

*Key assumptions used in the study*

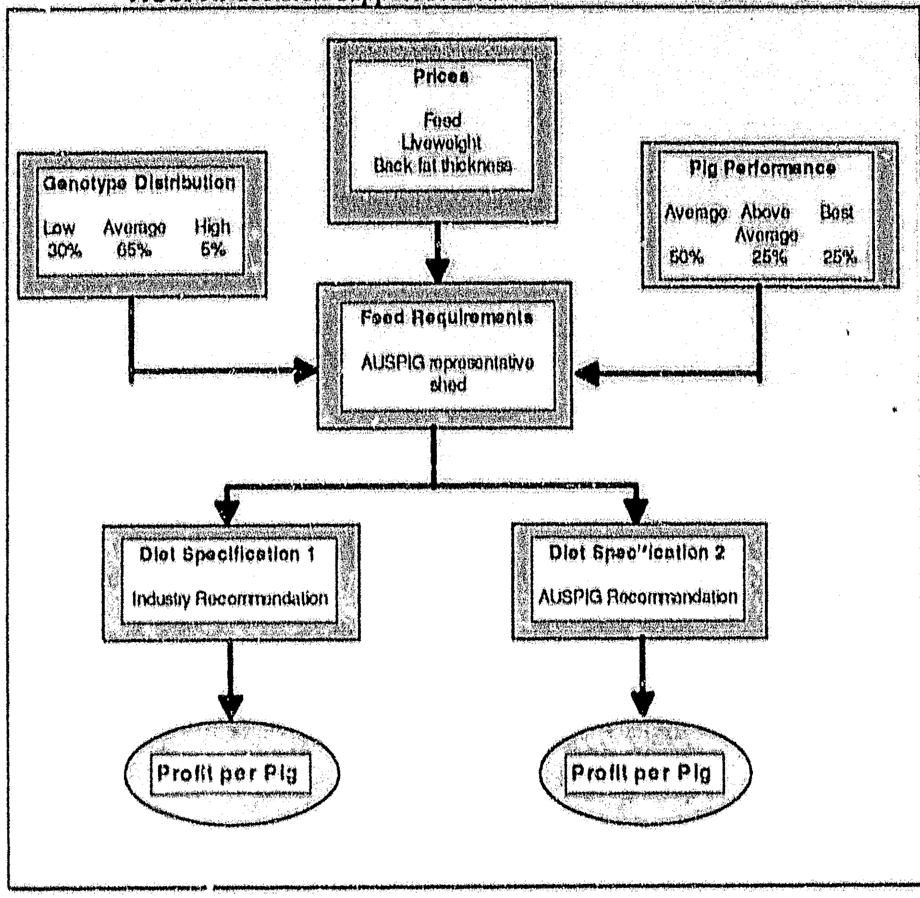
*(a) Derivation of on-farm benefits*

The main project benefit considered was the use of the AUSPIG model throughout the industry to better formulate feed rations so as to optimise pig growth. The magnitude of the on farm profitability the adoption of AUSPIG generates for the pig producer significantly determines industry benefits from development of the software. The estimation of on farm profitability constituted the major effort in the evaluation. Benefits from use of the model in commercial piggeries to improve other husbandry practices (for example the environmental conditions in a shed) were ignored because of the difficulty if accurately specifying a typical practise across the industry. In Figure 2 the steps involved in deriving the net benefit per pig as a result of better formulated feed rations are summarised.

To determine the benefits accruing to the use of the AUSPIG model as a result of improved ration formulation the pig herd was divided into high, average and low performing genotypes, as derived by Bradley (1992). High performing genotypes display high growth rates, efficient feed conversion and a low propensity to deposit backfat. The Australian herd was assumed to contain 5% high, 65% average and 30% low performance genotypes. The genetic background of the pig largely determines the partitioning of protein and energy. The ability of each genotype to portion feed into lean tissue growth was specified in the AUSPIG simulation by Bradley (1992).

Variation in the ability of pigs to partition nutrients into lean growth is also found in each of the three genotypes described. CSIRO (1992) used a normal distribution to describe this variation in the ability of individual pigs within each genotype to partition nutrients. The variability within each genotype was aggregated into average, above average and high performing individuals.

Figure 2 : Steps involved in the estimation of net benefits per pig using the AUSPIG decision-support software




AUSPIG (1992) recommended that above average and high performing pigs within each genotype should be provided with sufficient nutrients to satisfy their growth potential. Prior to this recommendation pig rations for each genotype were formulated to only satisfy the growth potential of the average pig in the genotype and better performing pigs did not attain growth potential. To determine the benefit from specifying rations aimed at the above average pigs in each genotype, it was assumed that commonly used rations and AUSPIG dietary recommendations would be fed to high, low and average genotype populations. The AUSPIG simulation model generated the productivity of the pigs on each ration and NSW Agriculture and Fisheries (1992) April feed ingredient prices were used to cost rations. The profitability of AUSPIG recommendations compared to commonly used ration formulations are outlined in Table 1 for each genotype and type of pig within each genotype.

Table 1: The profitability of pigs using different diet specifications.

| | Individuals | | | |
|---|---|---|---|---|
| Genotype | Average | Above av | Best | Weighted [a] |
| Low | 0.9 | 1.18 | 3.71 | 1.67 |
| Average | 0.23 | 1.43 | 2.51 | 1.1 |
| High | 0.33 | 0.9 | 1.51 | 0.77 |
| Industry | | | | 1.26 |

(a) In each genotype average performers represents 50% of the population, whilst above average represent 25% and best 25%. The weighted genotype profit increase is derived by applying these proportions to each of the differences. Industry profitability is derived by assuming 65% of the herd is average, 35% low and 5% high performing genotypes, each of the genotypes and performance categories were weighted to generate the industry average of $1.26 profitability increase per marketed pig using AUSPIG.

The feeding of AUSPIG recommendations generates the greatest profitability in best performing low genotype pigs, as profit increases by $3.71. The industry weighted profit increase is $1.26. The magnitude of industry benefits arising from the development of the AUSPIG software is also largely governed by the adoption of the technology. In the next section the determination of likely adoption scenario is detailed. The determination of potential adoption consumed a substantial amount of time due to the influence of this parameter on industry benefit.

*(b) Adoption*

The profitability of adopting the AUSPIG system is estimated from the perspective of the average national farm described in APC (1991) with 45 breeding sows, main line commercial production unit of 200 sows, and corporate production unit with 5000 sows to determine the segments of the pig industry most likely to adopt the AUSPIG system.

In the evaluation AUSPIG is assumed only to affect performance of the marketed pig and all other facets of the production process are assumed to be similar regardless of adoption of the AUSPIG system. The potential of the AUSPIG system to optimise other husbandry practices and improve profitability in addition to that generated from improved ration formulation is likely to occur. Benefits described in this analysis are likely to be a conservative estimate of the value of the AUSPIG model. The AUSPIG current single user price is $9000 and it is assumed sideline and mainline producers would only purchase a single license. The corporate entity would most likely purchase two licenses for use across the estimated 5000 sow breeding herd.

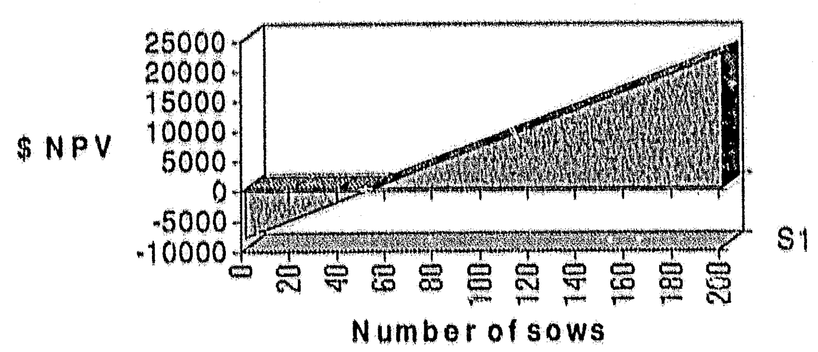
In 1990 it was estimated that there were 8,000 pig farms in Australia (APC 1991). Given that the total number of breeding sows in Australia was 363 thousand in 1989/90 the average farm maintained approximately 45 breeding sows. This estimate of average farm size was representative of a sideline pig production enterprise. PRC (1990) gained a sample breeding sow per farm mean of 370 in a survey of 23 pig producers in 1989. Whan (1992) indicated that at least 150 sows must be maintained and 50 pigs marketed weekly for profitable mainline pig production. To accommodate the variation in operating size, the net present value of farmer investment in AUSPIG was viewed from the perspective of the sideline (45 sows), commercial (200 sows) and corporate producer (5000 sows). This approach was pursued so potential segments likely to adopt AUSPIG could be identified.

APC (1991) estimated each sow has approximately 2.14 litters annually with an average litter size of 10.1 piglets born alive. In 1989/90 the average number of pigs sold per sow annually was 14.45 when mortalities prior to marketing were incorporated (APC 1991). The number of sows required to generate a positive net present value on the license to use AUSPIG is presented in Figure 3. The profit per pig marketed used was $1.26, cost of the single user license is $9000 and the breeding herd productivity described above was evident on the farm. The benefit stream was projected forward 10 years and subject to a discount rate of 10%. It is evident that 50 to 60 breeding sows are required for the investment in AUSPIG to generate a positive return. Most of the sideline enterprises generally have less or similar sows than this number. The large number of producers operating piggeries to supplem. .I other enterprise income would not be likely to purchase the AUSPIG software.

The estimate of return presented in figure 3 was based on a turn-off of 14.45 pigs per sow annually. This estimate of turn-off was unlikely to be observed on mainline commercial and corporate piggeries during 1989/90. Full time pig producers manage the breeding herd to obtain higher turn-off of pigs per sow annually. A PRC (1990) survey of 23 piggeries in 1989/90 gained a sample mean of 18.64 pigs turned off per sow.

The sensitivity of net present value of the AUSPIG investment over a 10 year period at 10% discount to the number of pigs turned off per sow is depicted in Figure 4. The investment is displayed for the sideline and mainline producer. At all levels of turn-off the investment in AUSPIG was not profitable for the 45 sow or sideline farm. Again, it is unlikely that sideline piggeries would adopt the AUSPIG system. Conversely the AUSPIG investment by mainline commercial producers with 200 sows is profitable for all levels of turn-off per sow. It could be expected that a number of producers in this segment would adopt the software.

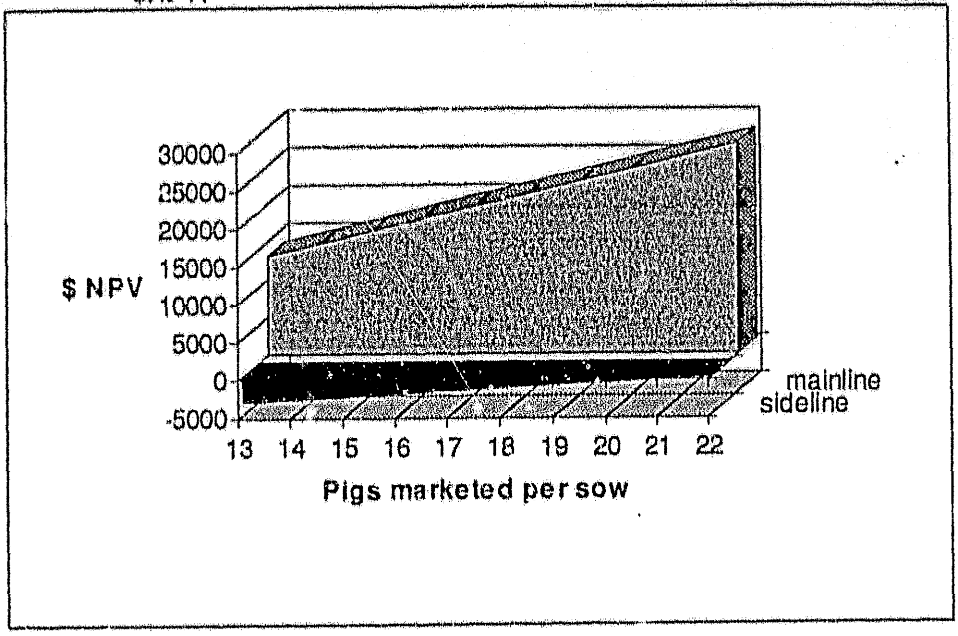
Figure 3: Returns on AUSPIG investment by the number of breeding sows carried : $npv.




The corporate producer not presented in Figure 4 would gain a positive net present value of $530 thousand at a 13 pig annual turn-off per sow, and $899 at an annual turn-off of 22 pigs per sow. The net present value was estimated using a discount rate of 10% and benefits projected over a 10 year period. It was assumed that the corporate producer would purchase two AUSPIG user licenses. The substantial returns on the investment by corporate producer suggest a high adoption of AUSPIG by this segment of the industry.

The Australian pig meat industry is characterised by a relatively high degree of concentration and vertical integration. In 1990 approximately 30% of the industry production of pig meat was derived from a few very large and sophisticated units (APC 1991). The growth in the corporate pig production sub-sector has been relatively rapid as only 18% of the pig industry was corporate owned in 1985. The large turn-off of pigs and technical expertise of staff employed in these units would facilitate profitable purchase of the AUSPIG system. The remaining 70% of the industry can be divided into commercial and sideline enterprises. As the size of pig production enterprise diminishes the return on the investment in the AUSPIG model decreases and adoption is assumed to be low by smaller producers. Adoption of the model would also be constrained by the level of technical expertise and management skills required to operate the system efficiently.

Figure 4 Sensitivity of AUSPIG investment to pigs marketed per sow annually : $NPV.




In the evaluation a base adoption was developed which had a ceiling of 30% and accounted for the majority of corporate piggeries and a portion of commercial enterprises who could adopt the AUSPIG model. A second scenario not outlined in this paper utilised a ceiling of 60% and incorporated pig producers who could indirectly benefit from AUSPIG recommendations through consultant advice and extension programmes. Maximum adoption was assumed to be reached after 3 years from the commercial availability of the software.

*(c) Distribution of benefits*

Although pigmeat production is largely geared for the domestic market, an Edwards and Freebairn (1982) analysis of the distribution of productivity gains between producers and consumers was carried out. Only a minimal level of effort was required to include the distribution of gains between consumers and producers as a result of gains generated from the use of the AUSPIG software. Estimates of demand and supply elasticities were derived from Griffith et al (1991) and Morrris et al (1991) respectively.

## *(2) SIROLAYERS*

The SIRO CT and CB layers are a genetic subline of hens derived from selection within the CSIRO Eggatron research project. The Eggatron research project was established in 1959 with the aims of increasing egg production beyond the conventional barrier of one ovulation per 24 to 25 hours, to investigate relevant genetic correlations with other production traits and to further the understanding of physiological and endocrinological parameters governing selection responses (Sheldon 1989).

In 1980 a collaborative research and development project was begun with Australian Poultry Ltd predecessors (Sheldon 1989). At this time, the SIRO CT and CB sublines which had been developed under the Eggatron project were further improved so that they would be commercially viable. With the exception of 1984, industry field trials of various genetic lines available to commercial egg producers showed that the SIRO CT and CB layers had improved feed efficiency, increased egg production and decreased average egg weight when compared to genetic lines which were available at that time.

Australian egg production was estimated at 195 million dozen for 1989/90 with a corresponding farmgate value of $260 million (Australian Council of Egg Producers ACEP, 1991). The majority of eggs are produced for the fresh shell market, with surplus production being processed into egg product. NSW is the largest state producer of eggs accounting for 70% of Australian production, followed next by Victoria which accounts for around 20% of annual production. Production areas are typically in close proximity to cities where the availability of water, electricity and markets facilitate viable production (ACEP 1991).

The White Leghorn and Australorp crossbreeds are the two most popular egg-producing breeds in Australia. Intensive cage systems account for 95% of total egg production and are characterised by a high degree of capitalisation. Laying hens, purchased as one day old chicks or 18 week old pullets, produce on average 21-22 dozen eggs across a period of 12-14 months after which time they are sold to poultry abattoirs and processed into poultry by-products. Throughout the production life of hens they are fed specially formulated diets which are high in crude protein and trace elements, subjected to standardised day length using artificial light and controlled temperature so as to maximise egg production. Eggs are priced according to their size (grade), and the major variable costs of production which are incurred by farmers are the purchase of feed and replacement stock.

The egg industry had quota arrangements in place from 1948 to 1989 in order to increase producer returns, improve market efficiency and ensure market stability (BAE 1983). The NSW egg industry was deregulated in 1989 and other states have been moving in that direction. The imposition of quotas on production restricts the extent to which industry gains from the adoption of cost-reducing technologies can be realised and modifies the distribution of welfare gains between consumers and producers that would otherwise occur in an unregulated environment.

***Key assumptions used in the study***

*(a) Derivation of on farm benefits*

Egg production by hens has improved over the last 30-40 years through improved management and careful breeding programmes. The selection of hens for improved performance in a particular environment becomes more difficult as time passes and variability in the flock diminishes. A breeder is thought to have reached a selection plateau when production gains as a result of selection become marginal (CSIRO 1980).

Poultry breeders have increased hen production to 150-250 eggs in the first year of lay, but have failed to breed birds capable of producing more than one egg in a day. The Eggatron project was set up to break through the physiological barrier of one egg per 24 hours and thereby improve the production efficiency of hens. The ovulatory cycle is significantly controlled by day length and CSIRO scientists were able to manipulate the light environment in conjunction with other novel environmental modification methods to identify poultry with a genetic tendency for higher production otherwise masked in a normal environment. White Leghorn and Australorp lines with an observed shorter mean interval between eggs laid in a clutch were used as the basis for the environmental modification experiments (CSIRO 1980)

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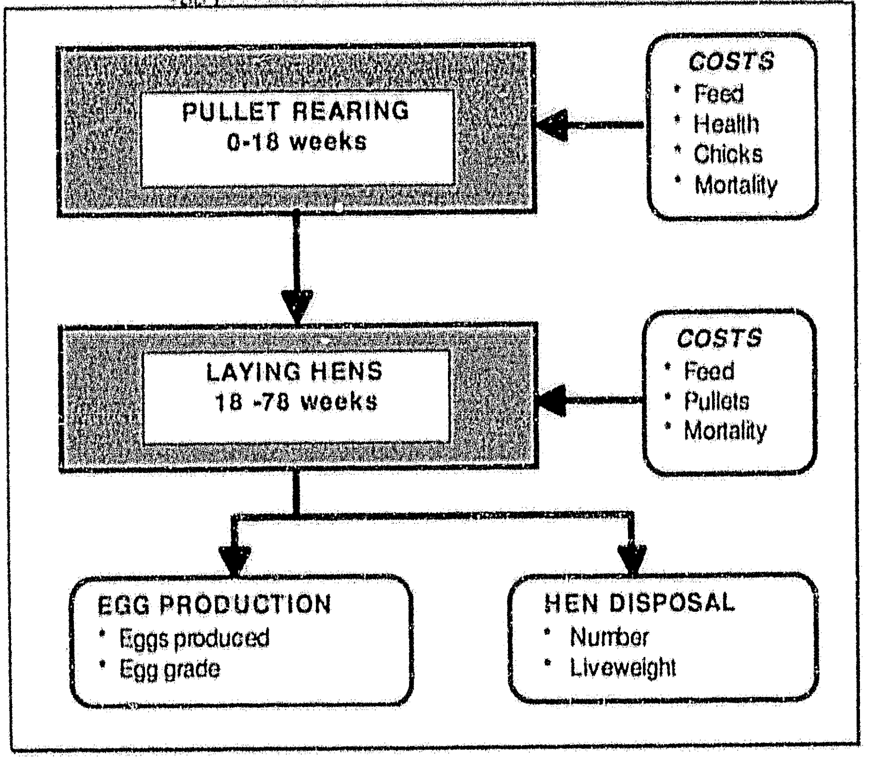
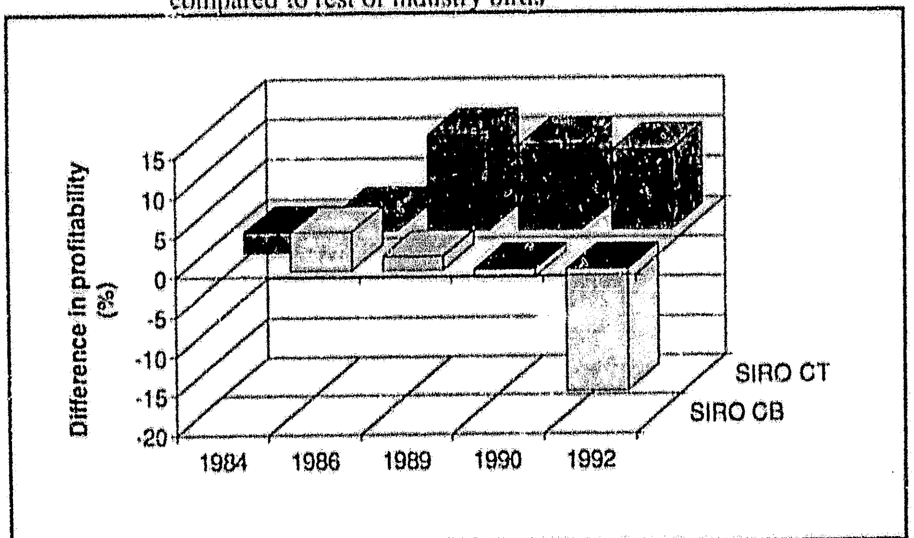
Figure 5 : Major components determining farm level profitability of egg production




The major components given in Figure 5 were estimated to the level indicated, and farm level profitability of the SIROLAYERS is given in Figure 6. The determinants of profitability used in the analysis were rearing costs, layer feed costs, egg production, value of eggs produced and the return on the sale of spent hens. Gross margins were calculated for SIRO layers and the for the rest of the industry. The performance of different birds was derived from NSW Agriculture Random Layer Trials across the period 1984 to 1989. To determine industry the profitability of SIROLAYERS to that of industry in 1992 and into the future, prices were taken from NSW Agriculture (1992) and production indices from the 1990 Random Layer Trial.

Figure 6 shows that the SIRO CT and CB layers were more profitable egg producing strains than the industry average before 1990 with the exception of the first year of release of the CT line. The performance of the CB layers in the NSW Agriculture 1990 layer trial combined with the cost of feed and egg prices resulted in CB layers being less profitable than the rest of the industry in 1992. It must be noted that since the deregulation of the NSW egg market the gross margin for egg producers has diminished dramatically (Horn 1991). The 15% reduction in profitability associated with the SIRO CT layer only represents, however, a 48c per bird reduction in gross margin. The reduced profitability of the CB layer was attributed to reduced egg price and poorer feed conversion efficiency. SIRO CT layers have shown increased profitability over the rest of the industry in the range of 2% to 14 %.

Figure 6: Overall difference in farm profitability of CSIRO birds as compared to rest of industry birds



*(b) Adoption*

The SIRO CT and CB layer sublines were sold to Australian Poultry Ltd predecessors and use of the sublines throughout the industry was estimated at 20% of national egg producers. Adoption was assumed to have increased at a linear rate of 5% since the initial commercial availability of the sublines in 1984. Because the profitability of the sublines varied from year to year depending on prevailing feed costs and egg prices, it was further assumed that egg producers would use the strain which maximised egg production profitability in that year. Producers are able to respond quickly to changing economic conditions because of the short life cycle of a layer. From 1992 onwards it was assumed that the profitability of each subline would be maintained.

*(c) Distribution of benefits*

Because of the egg industry regulation which existed in 1984, and through to 1992 in some states, it was necessary to construct both a regulated industry model and a competitive industry model. The regulated industry model was derived from studies by Alston (1986), Edwards and Freebairn (1982) and Strong et al (1990) and the competitive model based on the framework developed by Edwards and Freebairn (1982). In the regulated model, as it was assumed that industry supply was perfectly elastic, productivity gains would be captured by producers in the form of quota rents.

***Case study results summary***

Evaluation results for each of the case studies considered in this paper are reported in Table 2 below. For the AUSPIG decision support software the net present value of research and development expenditures was estimated at $9m, compared to $42m for the SIROLAYER technology. In both evaluations the quantification of benefits per head of stock required the greatest effort, accounting for over 75% of the time allocated to the evaluation.

Table 2 : Evaluation results : $m

| Result | AUSPIG | SIROLAYER |
|---|---|---|
| Present value of benefits | 11 | 43 |
| Present value of costs | 2 | 1 |
| Net present value | 9 | 42 |

Note : A discount rate of 5% was used for the estimation of present values.

## Sensitivity of estimated pay off to changes in key assumptions.

In the previous section the economic pay off from the research and development of AUSPIG decision support software and SIROLAYER technology were estimated. These results were used as a base from which changes in key assumption were examined. The value of undertaking such a sensitivity analysis is that it provides an indication as to where effort should be directed when undertaking project evaluations. However, given the differences which exist across ex-post project assessments, only broad generalisations are possible here. In Table 3 the impact on estimated net present values of increasing the value of key variables by 10% is reported. The key variables considered include project benefits, adoption levels and rate and the distribution of gains across producers and consumers.

In Table 3 the sensitivity of evaluation results to changes in key assumptions is tested. For the AUSPIG case study evaluation both changes in the distribution of genotypes and pig performance were examined. The sensitivity analysis involved assessing the impact of a 10% shift of genotypes out of the middle group to the lower end of the distribution and a 10% shift from the middle group to the higher end. The profit per pig (see Table 1) was changed in line with the different distributions considered. Likewise, the proportion of average, above average and best performing pigs in a herd was changed and the project NPV recalculated. In all cases, the impact of the 10% change on the estimated project NPV was minimal.

Table 2 : Impact on estimated net present values of a 10% increase in the value of key variables : % deviation from base value.

| AUSPIG | | SIROLAYERS | |
|---|---|---|---|
| Key assumption | NPV | Key assumption | NPV |
| Base | $9m | Base | $42m |
| *Benefits* | | *Benefits* | |
| Genotype distribution | | | |
| . middle to low | 4 | Pullet rearing cost | -62 |
| . middle to high | -2 | Laying hen cost | -90 |
| Performance | | | |
| . above average to average | -2 | Egg return | 410 |
| . above average to best | 4 | Spent hen return | 5 |
| *Net benefit* | 12 | *Net benefit* | 10 |
| *Adoption* | | *Adoption* | |
| Rate | 2 | | 1 |
| Maximum level | 12 | | 15 |
| *Distribution* [a] | | *Distribution* [a] | |
| Elasticity of demand | 18 | Elasticity of demand | 1 |
| Elasticity of supply | -20 | Elasticity of supply | -1 |
| Producer benefits only [b] | -89 | Producer benefits only [b] | -48 |

(a) For the purpose of this study, only producer benefits are considered. In this situation the base NPV is estimated at $1m for the AUSPIG technology and $22m for the SIROLAYER technology

(b) The difference between gains accruing only to producers compared to the base level gains estimated for the entire industry.

The sensitivity of on farm benefits was also tested for the SIROLAYER technology. For each of the major component (see Figure 4) a 10% increase in value was considered. The estimated project NPV was found to be highly sensitive to changes in pullet rearing cost, laying hen cost and egg returns. In the case study evaluation it was found that feed cost was the main expense in pullet rearing and laying hens, and hence these costs have a major impact on the accuracy of the evaluation.

A sensitivity analysis was also carried out on the derived on farm benefit. For the AUSPIG case study, a 10% increase in estimated non farm benefits resulted in an increase in the estimated NPV. A similar result was obtained for the SIROLAYER project. The value of testing the sensitivity of NPV's from changes in aggregated on farm benefits is of little value because such analyses fail to indicate the underlying variation which can possibly result from small changes in the various components of on farm benefits. Further, in such simple sensitivity analyses the direction of variation and magnitude can be easily assessed before hand from an examination of the relative size of project benefits and costs.

For both the case study evaluations, information on the component parts of on farm benefits was readily accessible by decision makers (in this case researchers) themselves. Because the objective of the analysis was solely to assess whether or not the return on R&D was worthwhile, in hindsight, there was little need for an evaluation to be carried out by the evaluation team. However, it was felt that a secondary objective of the evaluation was met, that being to provide information on what market information is relevant in an evaluation. Such information would assist researchers and decision makers carrying out their own evaluations of projects in the future, especially in prioritising the work required in estimating project benefits.

Sensitivity analysis was also carried out on the level and rate of uptake of the technologies. As shown in Table 3 and as expected, the assumed maximum level of adoption has a major impact on estimated performance measures (NPV). The time required to derive adoption figures for the SIROLAYER project was minimal as market information already existed. However, a simplifying assumption was made that the use of the SIROLAYER birds by industry past 1992 would be maintained at the 1992 levels. It was decided that the effort needed to firm adoption estimates further was not justified. In contrast, there was no market information available on the adoption, and likely adoption through time of the AUSPIG software technology. To derive an estimate of maximum adoption considerable time was spent on examining the profitability of the technology across different types of piggery operations. Although realistic bounds could be placed on the adoption parameters, it was felt that considerable uncertainty still existed and that the scope for error was still quite large.

The final area of uncertainty that was tested was the distributional impacts following adoption of the technologies by industry. For most agricultural commodities there exists a substantial volume of literature from which information on the distributional consequences of productivity improvements can be assessed. This information can be easily incorporated into project evaluations with the use of simple spreadsheet models. As shown in Table 2, substantial errors can be introduced if stakeholders in the project being evaluated form only one part of the industry (for example producers in an industry or Australians as a whole when commodities which are largely exported are considered). It was found that distributional considerations could be brought into the evaluations with minimal effort.

## Conclusions

An attempt has been made in this paper to evaluate some ex-post evaluations carried out in CSIRO's Institute of Animal Production and Processing. If the sole objective of these evaluations was to demonstrate whether or not the research investment had been worthwhile, then it is likely that these evaluations were over resourced. On the other hand, given that the objective was also to demonstrate the methods used in project evaluation and to provide information for future evaluations in this area, then these evaluation may have in part met these goals. In carrying out the evaluations it was found that the estimation of on farm benefits required the greatest effort, and that substantial trade offs between effort and accuracy could be made. However, without such effort the direction and magnitude of such errors would remain unknown.

Three major parts of an ex-post (or for that matter an ex-ante) evaluation were identified. These were the estimation of on-farm (unit level) benefits, adoption level and rate through time and the distribution of benefits across different industry groups. The derivation of on-farm benefits attributable to R&D will continue to remain the key part of project evaluation, and the use of evaluators with considerable background knowledge of the industry being considered is really a prerequisite. Because of the considerable market knowledge usually held by the researchers and developers of the technologies being evaluated, they are in a prime position to undertake the evaluations themselves. Exposure to methods of assessment will increase their capability to carry out project evaluation on a routine basis, or as part of their ongoing project management responsibilities.

Adoption levels and rates used in ex-post evaluations are major determinants of project pay off. In cases where little market information exists on uptake of technologies by industry, a considerable amount of effort is required to derive meaningful boundary estimates. Substantial more work in the area of technology adoption is needed to assist in project evaluation. Because of the case specific nature of project evaluation this work would need to focus on the major product attributes sought by different groups of potential adopters of different technologies.

The final area requiring some effort in the conduct of ex-post evaluations was the estimation of the distribution of benefits between different groups in an industry. Such effort is only required in cases where project stakeholders form only one part of the industry. However, given the volume of information which exists on the distributional consequences of productivity improvements in Australian agricultural industries, the effort required to incorporate distributional consequences is a relatively trivial exercise.

It has been the aim of this paper to look closely at methods of ex-post project evaluation and see what lessons can be learnt from them. It is our believe that project evaluation can be undertaken to a greater extent by researchers and decision makers themselves, and that the gains from internalising project evaluations will deliver substantial improvements in future project selection. The more critical and widespread evaluation of ex-post evaluations will increase the benefits that researchers and decision makers gain from such evaluations.

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