EVALUATING RESEARCH AND DEVELOPMENT ACTIVITIES IN THE AUSTRALIAN PIG INDUSTRY

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INTRODUCTION

The Pig Research Council (PRC) spent $1.6 million in 1986/7 on a range of research and development activities in the fresh and processed pigmeat industries. The objectives of the Council are to fund R&D in the pig industry "with a view to increasing the commercial returns to members of the pig industry and to the community in general" (PRC, 1987). The PRC are financed by a producer levy on pigs slaughtered for human consumption and a contribution from the Commonwealth government. The Australian Pork Corporation (responsible for pigmeat advertising) spent an additional $4.3 million on promotion in 1986/7 (Ball and Dewbre, 1989), and they are also funded by producer levies at the point of slaughter. Our final objective is to analyse and compare the returns to pig producers from different R&D and promotion strategies within a consistent framework. In this paper we report our progress in modelling the impact of new technology on the Australian pig industry and indicate the future direction of this project.

Mullen, Alston and Wohlgenant (1989) have completed a similar study of how Australian woolgrowers benefit from on and off farm R&D activities. They found that the Australian wool industry is likely to gain more from a one percent reduction in the cost of producing wool than from a one percent reduction in the cost of processing wool. An important aspect of their study was an examination of how substitution in wool processing inputs influenced the distribution of returns from wool production and processing technologies.While in the pig industry we are looking at the same general questions as in the wool project, there are a number of differences in this present study.

The different structure of the pig industry gives rise to some interesting aspects. The pig industry has two separate sectors - fresh and processed, and there are opportunities for consumers and producers to switch between these products in response to price changes. The extent of substitution is expected to have a large influence on how the producers and consumers of fresh and processed pig products benefit from different types of R&D. Such a range of substitution opportunities has not been fully examined in past studies of this nature.

The Australian Pig Industry

The following simple model assumes that the fresh and processed pigmeat industries are not characterised by jointness in the processing of fresh and processed pigmeat products. The industries are linked however by substitution in consumption and jointness in farm production.

The manufacturing or processing sector, which can be thought of as separate sectors for fresh and processed pigmeat, uses manufacturing inputs and suitable pigs to produce these fresh and processed products. The production functions can be written as (definitions of symbols are given in Table 1):

1. $Q_f = f_f(X_f, X_m)$

2. $Q_p = f_p(X_p, X_m)$

If we assume that both these sectors are characterised by constant returns to scale then the cost functions related to these production functions are:

3. $C_f = Q_f . H_f(W_f, W_m)$

4. $C_p = Q_p . H_p(W_p, W_m)$

Based on these production and cost functions the system of equations describing the fresh and processed pigmeat industries can be written as:

5. $Q_f = Q_f(P_f, P_p, N_f)$

6. $Q_p = Q_p(P_f, P_p, N_p)$

7. $P_f = H_f(W_f, W_m)$

8. $P_p = H_p(W_p, W_m)$

9. $X_f = Q_f . h_f(W_f, W_m)$

10. $X_p = Q_p . h_p(W_p, W_m)$

11. $X_m = Q_f . h_f(W_f, W_m) + Q_p . h_p(W_p, W_m)$

12. $W_m = W_m(X_m, T_m)$

13. $X_f + X_p = X_t(W_f, T_f)$

14. $W_p = X_p(W_f, T_f, T_p)$

Equations 5 and 6 represent the retail demand for fresh and processed pigmeat and allow substitution in consumption. The N_i terms are exogenous demand shifters such as promotion, changes in the price of other meats, population changes etc.

Equations 7 and 8 are the equilibrium conditions that product price equals marginal cost which equals minimum average total cost when the industry is in equilibrium. Their form reflects our assumption of constant returns to scale.

Equations 9, 10, and 11 are output constrained input demand functions. The demand for manufacturing inputs, equation 11, is the sum of the demand for these inputs in the fresh and processed pigmeat sectors.

Equation 12 is the supply of processing inputs in price dependent form.

Equations 13 and 14 represent the supply of pigs at the farm level. In the long run pig producers can switch between the production of fresh and processing pigs quite readily and hence farm prices of these pig types are expected to be closely related as in equation 14. In this situation the supply of total pigmeat at the farm level, X_t, responds to either W_f or W_p as in equation 13. The separate supply schedules for the different pig types can be derived as excess supply schedules by deducting, for example, the demand for fresh pigs from the supply of total pigmeat at each price to give the excess supply of pigs for processing. The supply schedule for each type of pig is more elastic than the supply of all pigs because each industry can expand production by bidding pigs away from the other as well as through increasing the total number of pigs produced.

The T_i terms are exogenous supply shifters encompassing new technology in the production and processing of pigmeat. As the model is presently defined, we can distinguish new technology in the production of pigs for the fresh and processed sectors but new technology in processing applies to both sectors. This assumption will be relaxed at a later stage. Note that we have a system of ten equations in ten unknowns.

When the adoption of new technology causes a small shift from an initial industry equilibrium, changes in prices and quantities can be approximated linearly by totally differentiating equations 5 - 14 and converting them to elasticity form to give equations 15 - 24.

15. $EQ_f = \eta_{ff}EP_f + \eta_{fp}EP_p + EN_f$

16. $EQ_p = \eta_{pf}EP_f + \eta_{pp}EP_p + EN_p$

17. $EP_f = k_fEW_f + k_mEW_m$

18. $EP_p = g_pEW_p + g_mEW_m$

19. $EX_f = -k_m\sigma EW_f + k_m\sigma EW_m + EQ_f$

20. $EX_p = -g_m\tau EW_p + g_m\tau EW_m + EQ_p$

21. $EX_m = k_f\sigma EW_f - k_f\sigma EW_m + EQ_f + g_p\tau EW_p - g_p\tau EW_m + EQ_p$

22. $EW_m = s_mEX_m + ET_m$

23. $z_fEX_f + z_pEX_p = \varepsilon(EW_f - ET_f)$

24. $EW_p = ET_p + \theta(EW_f - ET_f),$

where E indicates relative change (for example $EX_f = \Delta X_f/X_f$). The input demand equations are based on the assumptions that prices are homogenous of degree zero, both processing industries are characterised by constant returns to scale, and the underlying cost functions are symmetric. For small changes from an initial equilibrium, market parameters are assumed to be constant and no presumption is made about the functional form taken by these equations.

If the market parameters are known, the system of equations above can be solved for the changes in prices and quantities caused by the impact of new farm or manufacturing technology. The estimated changes in prices and quantities are used to calculate changes in the economic surplus to the consumers of fresh and processed pigmeat products, CS_i, the producers of pigs for the fresh and processing industries, PS_f and Ps_p, and the suppliers of processing inputs, PS_m, using the following formulae:

25. $CS_i = Y_i.P_i(EN_i - EP_i)(1 + 0.5.EY_i)$

26. $PS_i = X_i.W_i(EW_i - ET_i)(1 + 0.5.EX_i)$.

We have followed Rose (1980) in assuming that research-induced supply shifts are parallel in the price direction. These formulae are exactly correct for parallel shifts of linear supply or demand curves but are only approximate for other functional forms. The approximation errors are small for the small shifts considered here.

Table 1: <u>Definition of Symbols</u>

Q_f	Quantity of fresh pork consumed
Q_p	Quantity of processed pigmeat consumed
P_f	Price of fresh pork at retail
P_p	Price of processed pigmeat at retail
X_f	Quantity of pigs for fresh pork
X_p	Quantity of pigs for processed pigmeat
X_m	Quantity of manufacturing inputs in the fresh and processed industries
W_f	Price of pigs for fresh pork
W_p	Price of pigs for processed pigmeat
W_m	Price of manufacturing inputs
N_f	Demand shifter for fresh pork consumption
N_p	Demand shifter for processed pigmeat consumption
T_f	Supply shifter for pigs for fresh pork
T_p	Supply shifter for pigs for processed pigmeat
T_m	Supply shifter for manufacturing inputs
η_{ij}	Elasticity of demand for product i with respect to a change in price
of	product j where i and j are fresh pork and processed pigmeat
k_i	Share of the total cost of producing fresh pork of input i where i is pigs for fresh pork and manufacturing inputs used in processing fresh pork
g_i	Share of the total cost of producing processed pigmeat of input i where i is pigs for processed pigmeat and manufacturing inputs used in the manufacture of processed pigmeat
σ	Allen elasticity of substitution between pigs and manufacturing inputs in the manufacture of fresh pork
τ	Allen elasticity of substitution between pigs and manufacturing inputs in the manufacture of processed pigmeat
S_m	Inverse of the elasticity of supply of manufacturing inputs
ε	Elasticity of supply of total pigmeat with respect to a change in the farm price of pigs for fresh pork
z_i	Share of total pigmeat production of pigs for the fresh and processing industries
θ	Elasticity of price transmission between the farm prices of pigs for the fresh and processed industries
μ_i	Share of total retail revenue from pigmeat to the fresh and processing industries

Parameter Values

Gains from R&D depend on the parameter values which were selected after reviewing econometric studies, and on the basis of economic theory. At a later stage in the project we intend to econometrically estimate some of these parameters.

Price and Quantity Values

The following price and quantity values for the fresh and processed pigmeat industries are for 1987 and were used as the equilibrium values in the model and to derive the shares below. The quantities of fresh and processed pigmeat consumed and produced were set at the same levels and are in retail carcase equivalent terms. The quantity of fresh pork used is 113 595 tonnes and the quantity of processed pigmeat is 161 253 tonnes (Ribic, McGrath, Strong and Griffith, 1990). The farm prices of pigs are dressed carcase prices at auction adjusted to retail equivalent weights using price spread calculation procedures (Strong, Griffith, Green and Freshwater, 1988) and averaged $1.72 per kilogram for fresh pork and $1.73 per kilogram for processed pigmeat (MIA, 1988). The retail prices for pig products are weighted average prices of retail cuts and averaged $4.11 per kilogram for fresh pork (Strong et al, 1988) and $7.20 per kilogram for processed pigmeat (ABS, 1988).

Retail Revenue Shares

The retail revenue from fresh pork was calculated by multiplying consumption of fresh pork, 113 595 tonnes, by price of fresh pork, $4.11 per kilogram, giving $467 million. Similarly the retail revenue from processed pigmeat was calculated as 161 252 tonnes by $7.20 per kilogram giving $1 161 million. The addition of these two retail revenues gave the total retail revenue from pig products in 1987 as $1 628 million. The share of retail revenue to the fresh pork industry was then calculated by dividing retail revenue from fresh pork by total retail revenue giving $\mu_f = 0.29$. The same procedure was applied to obtain the value of $\mu_p = 0.71$ as the share of retail revenue to processed pigmeat.

Input Cost Shares

Initially we have assumed constant returns to scale in the model, total cost being equal to total revenue at the manufacturing level. The share of pigs for fresh pork in the total cost of producing fresh pork k_f in 1987 was 0.42 and was estimated by dividing the price per kilogram of fresh pork type pigs $1.72, by retail price of fresh pork $4.11. This leaves the share of manufacturing inputs used in the processing of fresh pork k_m as 0.58.

The estimated value for cost shares in the production of processed pigmeat was calculated in the same way. The average annual auction price for baconer type pigs in 1987 was $1.73 cents per kilogram, this was divided by the retail price of bacon, $7.20 cents per kilogram giving a value of 0.24 as the producer share g_p and thus the share of manufacturing inputs g_m was 0.76.

Physical Shares

The physical share of pigs for fresh pork in total pig production was calculated by dividing the quantity of fresh pork produced by the total amount of pig products giving z_f as 0.41. This left the physical share of processing pigs z_p as 0.59.

Demand Elasticities

Past econometric estimates of demand elasticities in the pig industry were generally made using single equation rather than systems approaches and this is perhaps why we have found it difficult to arrive at a set of demand elasticities that are consistent with each other and with published estimates. Estimates of the own price elasticity for fresh pork range from -0.78 to -3.29 (Griffith and Burgess (1983), and Pender and Erwood (1970)). Estimates of the own price elasticity for processed pigmeat have been made by Griffith (1985), Griffith and Burgess (1983) and Hill (1968) and the long run elasticities range from -1.98 to -1.22. Only one value for the elasticity of demand for fresh pork with respect to the price of processed pigmeat is available in Griffith (1985) and this is 0.35. Four estimates are available for the elasticity of demand for processed pigmeat with respect to the price of fresh pork (Griffith, 1985) ranging from 0.32 to 2.86.

Using these empirical estimates as a starting point we have attempted to derive a set of demand elasticities that are theoretically consistent with each other. For the own price elasticities of demand for fresh and processed products, we used the averages of the ranges of the published estimates, -2.0 and -1.6 respectively.

If we suppose that the aggregate retail demand elasticity for all pigmeat is -0.8 then

$$z_p(\eta_{pp} + \eta_{pf}) + z_f(\eta_{fp} + \eta_{ff}) = -0.8.$$

Symmetry implies that $\eta_{fp} = \mu_p/\mu_f * \eta_{pf}$

$$= 0.71/0.29 * \eta_{pf}$$

Substituting for η_{fp} and the values for η_{pp}, η_{ff}, z_f and z_p above yields

$\eta_{pf} = 0.6$ and by the symmetry relation above, $\eta_{fp} \approx 1.47$.In comparing these values with the empirical estimates discussed earlier it can be seen that apart from our value for η_{fp} (for which we had only one value) our estimates are within the ranges of the empirical estimates.

Supply Elasticities

There are only a few studies that have looked at supply elasticities in the pig market and there are no separate supply elasticities available for fresh and processed pigmeat. Griffith and Gellatly (1982), Griffith and Burgess (1983) and Griffith (1985) provided estimates for elasticity of supply of pigs ranging from 0.36 to 1.38. We have assumed that in the long run the elasticity of supply of pigs in aggregate is 1.5. The two pig types are more elastic in supply as supply increases both by increasing total production and by switching from one pig type to another.

Elasticity of Price Transmission

The farm prices of pigs for the fresh and processed industries are expected to be closely related as producers switch between industries in such a way that the marginal profit from producing pigs for the fresh industry equals the marginal profit from producing pigs for the processing industry. The price relationship is expected to be influenced by differences in feeding costs and by price differentials for quality. We have assumed that in the long run the elasticity of price transmission, v, is 1.0.

Elasticities of Input Substitution

We do not have estimated values for the two Allen elasticities of substitution between pigs and manufacturing inputs in the production of either fresh pork or processed pigmeat. Commonly it is assumed that in processing the farm input and the manufacturing inputs are used in fixed proportions. But it is possible for there to be input substitution in cases where there is a choice between production technologies which use inputs in different proportions. Mullen, Wohlgenant and Farris (1988) in their study of the US beef industry showed that even a limited degree of substitution between cattle and marketing inputs had a significant impact on the distribution of surplus gains between producers and consumers. It is expected that the elasticity of substitution between inputs for fresh pork, σ is small and we have used a value of 0.1. In the case of processed pigmeat the elasticity of substitution, τ is also expected to be small, although more elastic than for fresh pork, as there is more flexibility in the inputs used to produce the various outputs such as bacon or ham. A slightly higher value of 0.2 has been used.

Elasticity of supply of manufacturing inputs

We have assumed a highly elastic supply of manufacturing inputs at 20, consequently the inverse of supply of manufacturing inputs, s_m is 0.05.

Summary of Parameter Values

Own price elasticity of demand for fresh pork	$\eta_{ff} = -2.00$
Own price elasticity of demand for processed pigmeat	$\eta_{pp} = -1.60$
Elast of demand for fresh pork wrt price of proc pigmeat	$\eta_{fp} = 1.47$
Elast of demand for proc pigmeat wrt price of fresh pork	$\eta_{pf} = 0.60$
Own price elasticity of supply of pigs	$\varepsilon = 1.50$
Inverse of elasticity of supply of manufacturing inputs	$s_m = 0.05$
Elast of price transmission between farm prices of pigs	$\theta = 1.00$
Elast of substn between pigs and manuf inputs in fresh pork	$\sigma = 0.10$
Elast of substn between pigs and manuf inputs in proc pigmeat	$\tau = 0.20$
Share of pigs in cost of producing fresh pork	$k_f = 0.42$
Share of manuf inputs in cost of producing fresh pork	$k_m = 0.58$
Share of pigs in cost of producing proc pigmeat	$g_p = 0.24$
Share of manuf inputs in cost of producing proc pigmeat	$g_m = 0.76$
Share of pigs for fresh pork in total pigmeat prodn	$z_f = 0.41$
Share of pigs for proc pigmeat in total pigmeat prodn	$z_p = 0.59$

Base Run

We have examined the impact of new technologies that reduce the cost of growing pigs for the fresh pork or processing industries by one percent and compared these two scenarios with one in which the price of the bundle of processing inputs is also reduced by one percent. The changes in prices and quantities arising and in the economic surplus enjoyed by the producers, processors and consumers of fresh and processed pig products from these changes in technology are detailed in Table 2.

New Technology for Production of Fresh Pork Pigs

As a result of production research in the fresh pork industry the supply curve for pigs for fresh pork shifts out to the right as producers are able to supply more pigs for fresh pork at a lower price. This decreases the price of fresh pork on the retail market and leads to increased consumption. Because of linkages between the two industries in production and consumption, new technology in the production of pigs for fresh pork also causes a shift in the demand for processed pig products and in the supply of pigs for processing. On the demand side, the lower price for fresh pork at the retail market causes the demand curve for processed pigmeat, a substitute, to shift to the left leading to a decrease in both the amount of processed pigmeat consumed and its price.

On the supply side, the production of pigs for fresh pork has become more profitable, hence some producers of pigs for processed pigmeat have switched to producing for the fresh pork market which shifts the supply curve for pigs for processed pigmeat to the left. This decreases the quantity supplied and increases the price of pigs for processed pigmeat which feeds through to the retail market as a decrease in the amount of

Table 2: Changes in prices, quantities and surpluses

	New Technology for Production of Pigs for Fresh Pork $ET_f = -1$	New Technology for Production of Pigs for Processed Pigmeat $ET_p = -1$	New Technology for Production of Manufacturing Inputs $ET_m = -1$
		Percentage Changes	
Quantity fresh pork consumed	0.78	-0.40	-0.06
Quantity processed pigmeat consumed	-0.29	0.37	0.80
Price of fresh pork at retail	-0.36	0.04	-0.47
Price of processed pigmeat at retail	0.04	-0.22	-0.68
Quantity of pigs for fresh pork	0.84	-0.40	-0.13
Quantity of pigs for processed pigmeat	-0.30	0.51	0.63
Quantity of manufacturing inputs	0.46	-0.06	0.85
Price of pigs for fresh pork	-0.89	0.09	0.21
Price of pigs for processed pigmeat	0.11	-0.91	0.21
Price of manufacturing inputs	0.02	-0.003	-0.96
	$	$	$
Fresh pork consumer surplus	1687163	-170531	2179389
Processed pigmeat consumer surplus	-513009	2563860	7894598
Fresh pork producer surplus	217876	178476	411903
Processed pigmeat producer surplus	308244	255106	588283
Manufacturing inputs producer surplus	268116	-35772	490271

processed pigmeat on the market and an increase in the price. Note that the demand and supply effects have opposing influences on the retail prices of processed pigmeat products. In this case the supply side effects are greater as we observe a rise in the price of processed pigmeat at the retail market.

The increase in the size of the fresh pork industry more than offsets the decrease in the size of the processed industry and hence there is an increase in the demand for processing inputs and also in their price.

Under these circumstances fresh pork producers gain a surplus of $218 000 and processed pigmeat producers gain $308 000. The producers of manufacturing inputs enjoy a surplus gain of $268 000. Consumers of fresh and processed pork products gain $1 174 000 in total consumer surplus but note that because there has been an increase in price and reduction in quantity consumed, consumers of processed pork products are less well off.

Note that in calculating changes in economic surplus, ET_f has been set to a negative one percent and all other exogeonous shifters have been set to zero in equations 25 and 26. A similar procedure has been adopted in modelling the impact of the other two types of technology. There is some uncertainty as to whether this is the correct approach when the products are closely linked in production and consumption.

New Technology for Production of Processed Pigmeat Pigs

Introduction of new production technology in the processed pigmeat industry lowers the cost of supplying pigs for processed pigmeat so there is a shift outwards in the supply curve for these pigs. The increased supply of pigs lowers their price and decreases the price of processed pigmeat at the retail level, leading to a rise in the consumption of processed pigmeat. Due to substitution in consumption the lower price of processed pigmeat causes a shift inwards in the demand for fresh pork. It would be expected that this would lower the price of fresh pork but this is not the case as the supply side effect is greater. Producers of pigs for fresh pork switch to producing pigs for processed pigmeat because of improved profitability from the new technology. This causes a shift inwards of the supply curve for fresh pork which results in increases in the price of pigs for fresh pork and the price of fresh pork at the retail level.

The net effect on manufacturing inputs of new technology in production of pigs for processing is that both the quantity demanded and the price of manufacturing inputs decreases because the size of the total industry has contracted. This result is different from that for new technology in the fresh pork industry and is explained by a number of factors including a smaller input cost share and retail elasticity of demand for processed pork and a larger elasticity of substitution between processing pigs and manufacturing inputs. The decrease in both the quantity and price of manufacturing inputs leads to a loss in surplus of $36 000 for the suppliers of manufacturing inputs. Producers of pigs for processed pigmeat increase their surplus by $255 000 and fresh pork producers have an increase of $178 000. Again the loss in surplus to consumers of fresh pork products from the increase in price of these products is more than offset by the gain in surplus to consumers of processed pork products for a total gain in consumer surplus of $2 393 000.

New Technology in the Manufacture of Fresh and Processed Pig Products

New manufacturing technology shifts the supply curve of manufacturing inputs to the right as producers are willing to supply more manufacturing inputs. The initial effects of lower manufacturing costs would be to increase the demand for both types of pigs at the farm level and to lower the retail prices of both products. Because the demand for processed pork products is more inelastic than the demand for fresh pork, there is a larger fall in the price of processed pork and an incentive for consumers to substitute processed for fresh pork products. This seems to be the main factor explaining the reduction in the size of the fresh pork industry, outweighing an opposite influence from the supply side.

The suppliers of manufacturing inputs gain an increase in their surplus of $490 000 from new technology in their industry, processed pigmeat producers and consumers gain $588 000 and $7 895 000. Fresh pork producers and consumers experience an increase in their surplus of $412 000 and $2 179 000 but this seems doubtful since their industry has contracted in size and is the cause of our concern about the way in which economic surplus is presently being estimated.

Because manufacturing inputs account for the largest share of costs in both sectors a reduction in the price of these inputs has the largest impact on the total industry.

Concluding Comments

In this paper we have reported our progress to date in modelling the impact of new technology in the Australian pig industry. The industry has been disaggregated into fresh and processed sectors but substitution in consumption and jointness in production has been allowed. We have looked at a long run situation in which both total industry supply response and the ability to switch production between sectors is quite large. In later work we intend to look at a short run situation in which this ability is more restricted.

Similarly allowing substitution in consumption has had an important influence on our results as is evidenced by the contraction in the fresh sector in response to new manufacturing technology. There are few estimates of cross price demand parameters for the pig industry and estimating as a system the demand for the products of the pig industry is another avenue for further work.

So far we have restricted our attention to examining the impact of new technology in the production of pigs and manufacture of pig products but as mentioned at the start of this paper, we hope to be able to model the impact of demand shifts from promotion within this framework and hence to be able to compare the returns to Australian pig producers from specified gains in efficiency in the production, processing and promotion of pig products.

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