A TWO SECTOR SUBSTITUTION MODEL FOR EVALUATING PIG INDUSTRY RESEARCH AND DEVELOPMENT AND PROMOTION

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Introduction

The Pig Research Council (PRC) (now the Pig Research and Development Corporation) spent $1.6 million in 1986/7 on a range of research and development activities in the pork and bacon industries. The objectives of the Council were to fund research and development (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 were financed by a producer levy on pigs slaughtered for human consumption and a matching 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 objective is to analyse and compare the returns to pig producers from different R&D and promotion strategies within a consistent framework, using 1987 data as a base.

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 per cent reduction in the cost of producing wool than from a one per cent 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, the different structure of the pig industry gives rise to some interesting questions.

The pig industry has two separate sectors - producing fresh pork and processed pigmeat or bacon. We refer to these two sectors as the pork and bacon sectors. There are opportunities for consumers and producers to switch between these two products in response to price changes. The extent of substitution is expected to have a large influence on how the producers and consumers of pork and bacon benefit from different types of R&D and promotion. Such a range of substitution opportunities has not been fully examined in past studies of this nature.

The Australian Pig Industry

As mentioned the Australian pig industry has two distinct sectors producing pork and bacon. These two sectors are linked by substitution in consumption and jointness in farm production.

The manufacturing or processing sector is thought of as two separate sectors for the pork and bacon industries, and uses manufacturing inputs and suitable pigs to produce pork and bacon. The production functions can be written as (definitions of symbols are given in Table 1):

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

2. $Q_b = f_b(X_b, X_m)$

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

4. $C_b = Q_b.H_b(W_b, W_m)$

Based on these production and cost functions the system of equations describing the pork and bacon industries can be written as:

5. $Q_p = Q_p(P_p, P_b, N_p)$

6. $Q_b = Q_b(P_p, P_b, N_b)$

7. $P_p = H_p(W_p, W_{mp})$

8. $P_b = H_b(W_p, W_{mb})$

9. $X_p = Q_p.h_p(W_p, W_{mp})$

10. $X_b = Q_b.h_b(W_p, W_{mb})$

11. $X_{mp} = Q_p.h_p(W_p, W_{mp})$

12. $X_{mb} = Q_b.h_b(W_p, W_{mb})$

13. $W_{mp} = W_{mp}(X_{mp}, T_{mp})$

14. $W_{mb} = W_{mb}(X_{mb}, T_{mb})$

15. $X_p + X_b = X_t(W_p, T_p)$

16. $W_b = X_b(W_p, T_p, T_b)$

Equations 5 and 6 represent the retail demand for pork and bacon 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, 11 and 12 are output constrained input demand functions. The demand for manufacturing inputs is calculated separately for the pork and bacon sectors in equations 11 and 12.

Equations 13 and 14 show the supply of manufacturing inputs to the two pig industries in price dependent form. Equations 15 and 16 represent the supply of pigs at the farm level. New technology that reduces the cost of growing porkers and baconers is represented by T_p and T_b. In the long run pig producers can switch between the production of porkers and baconers. Hence farm prices of these pig types are expected to be closely related (equation 16) and the total supply of pigs at the farm level, X_t, responds to either W_p directly (equation 15) or to W_b indirectly through equation 16. Hence the supply of 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.

However this specification does not constrain porkers and baconers to be perfect substitutes in the production of pork and bacon products. The specification is consistent with Gardner's (1979) more general model of supply in interdependent markets with the exception of the assumption that feed and young pigs are used in fixed proportions in producing porkers, X_p and baconers, X_b. The rationale for our approach is that when we aggregate production data for empirical estimation of pig supply response, this assumption of fixed input proportions is generally made implicitly and hence equation 15 is more consistent with empirical practice. The consequence of our approach is that supply response is biased towards zero with the degree of bias depending on how similar are the prices of porkers and baconers and on the extent of input substitution possibilities at this level.

Note that we have a system of twelve equations and twelve 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 - 16 and converting them to elasticity form to give equations 17-28.

17. $EQ_p = \eta_{pp}EP_p + \eta_{pb}EP_b + EN_p$

18. $EQ_b = \eta_{bp}EP_p + \eta_{bb}EP_b + EN_b$

19. $EP_p = K_pEW_p + K_mEW_{mp}$

20. $EP_b = G_bEW_b + G_mEW_{mb}$

21. $EX_p = -K_m\sigma EW_p + K_m\sigma EW_{mp} + EQ_p$

22. $EX_b = -G_a \tau EW_b + G_a \tau EW_{ab} + EQ_b$

23. $EX_{ap} = K_p \sigma EW_p - K_p \sigma EW_{ap} + EQ_p$

24. $EX_{ab} = G_b \tau EW_b - G_b \tau EW_a + EQ_b$

25. $EW_{ap} = S_{ap} EX_{ap} + ET_{ap}$

26. $EW_{ab} = S_{ab} EX_{ab} + ET_{ab}$

27. $Z_p EX_p + Z_b EX_b = \varepsilon (EW_p - ET_p)$

28. $EW_b = ET_b + \theta (EW_p - ET_p)$,

where E indicates relative change (for example $EX_p = \Delta X_p / X_p$). The input demand equations are based on the assumptions that they are homogenous of degree zero in prices, 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 or a demand shift. The estimated changes in prices and quantities are used to calculate changes in the economic surplus to the consumers of pork and bacon, the producers of porkers and baconers, and the suppliers of processing inputs.

We have followed Rose (1980) in assuming that research-induced supply shifts are parallel in the price direction and we also assume demand shifts are parallel. The formulae which we use 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: Definition of Symbols

Q_p	Quantity of pork consumed
Q_b	Quantity of bacon consumed
P_p	Price of pork at retail
P_b	Price of bacon at retail
X_p	Quantity of porkers
X_b	Quantity of baconers
X_{mp}	Quantity of manufacturing inputs in pork industry
X_{mb}	Quantity of manufacturing inputs in bacon industry
W_p	Price of porkers
W_b	Price of baconers
W_{mp}	Price of manufacturing inputs in the pork industry
W_{mb}	Price of manufacturing inputs in the bacon industry
N_p	Demand shifter for pork consumption
N_b	Demand shifter for bacon consumption
T_p	Supply shifter for porkers
T_b	Supply shifter for baconers
T_{mp}	Supply shifter for manufacturing inputs in porker industry
T_{mb}	Supply shifter for manufacturing inputs in baconer industry
η_{ij}	Elasticity of demand for product i with respect to a change in price of product j where i and j are pork and bacon
K_i	Share in the total cost of pork production of input i where i is either the porker input, or manufacturing inputs used in processing pork
G_i	Share in the total cost of bacon production of input i where i is either the baconer input, or manufacturing inputs used in processing bacon
σ	Allen elasticity of substitution between porkers and manufacturing inputs in the manufacture of pork
τ	Allen elasticity of substitution between baconers and manufacturing inputs in the manufacture of bacon
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 porkers
Z_i	Share of total pigmeat production of porkers and baconers
Θ	Elasticity of price transmission between the farm prices of porkers and baconers
μ_i	Share of total retail revenue from pigmeat to the pork and bacon industries

Parameter Values

Gains from R&D and promotion depend on the parameter values which we have selected after reviewing econometric studies, and on the basis of economic theory.

Price and Quantity Values

The comparison of technologies and promotion was based on production levels and average prices in the pork and bacon industries in 1987. The quantities of pork and bacon consumed and produced were expressed in retail carcase equivalent terms. The quantity of pork produced was 113 595 tonnes and the quantity of bacon was 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 following Griffith, Strong, Green and Freshwater (1990). In 1987 farm prices averaged $1.72 per kilogram for pork and $1.73 per kilogram for bacon (MIA, 1988). The retail prices for pig products are weighted average prices of retail cuts and averaged $4.11 per kilogram for pork (Griffith et al, 1990) and $7.20 per kilogram for bacon (ABS, 1988).

Retail Revenue Shares

The retail revenue from pork was calculated by multiplying consumption of pork, 113 595 tonnes, by price of pork, $4.11 per kilogram, giving $467 million. Similarly the retail revenue from bacon was calculated as 161 252 tonnes by $7.20 per kilogram giving $1 161 million. The total retail revenue from pig products in 1987 was $1 628 million. The share of total retail revenue to the pork industry, μ_p, was 0.29 ($467m/$1628m). Hence the share of total retail revenue to the bacon industry μ_b, was 0.71 ($1161m/$1628m).

Because we have assumed constant returns to scale, total cost equals total revenue at the manufacturing level. Hence, the share for porkers in the total cost of producing pork, K_p, was 0.42 in 1987 and was estimated by dividing the price per kilogram of porkers, $1.72, by retail price of fresh pork $4.11. This leaves the share of manufacturing inputs used in the processing of pork K_m as 0.58.

The estimated value for cost shares in the production of bacon was calculated in the same way. The average annual auction price for baconers in 1987 was $1.73 per kilogram. This was divided by the retail price of bacon, $7.20 per kilogram giving a value of 0.24 as the producer share G_b and thus the share of manufacturing inputs G_m was 0.76.

Physical Shares

The physical share of porkers in total pig production was calculated by dividing the quantity of pork produced by the total amount of pig products giving Z_p as 0.41. This left the physical share of baconers Z_b 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 pork range from -0.78 to -3.29 (Griffith and Burgess (1983), and Pender and Erwood (1970)). Estimates of the own price elasticity for bacon 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 pork with respect to the price of bacon is available in Griffith (1985) and this is 0.35. Four estimates are available for the elasticity of demand for bacon with respect to the price of 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 pork and bacon products, we used the averages of the ranges of the published estimates, -2.0 and -1.6 respectively.

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

$$z_b(\eta_{bb} + \eta_{bp}) + z_p(\eta_{pb} + \eta_{pp}) = -0.8.$$

Symmetry implies that $\eta_{pb} = \mu_b/\mu_p * \eta_{bp}$

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

Substituting the symmetry relation for η_{pb} and the values for η_{bb}, η_{pp}, z_p and z_b into the equation above yields $\eta_{bp} = 0.6$. Hence by the symmetry relation $\eta_{pb} = 1.47$. In comparing these values with the empirical estimates discussed earlier it can be seen that apart from the value for η_{pb} (for which there is only one value) these elasticities 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 pork and bacon. 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 than this because supply increases arise from an increase in total production and by switching from one pig type to another in response to relative price changes.

Elasticity of Price Transmission

The farm prices of pigs for the pork and bacon 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 pork industry equals the marginal profit from producing pigs for the bacon industry. The price relationship is expected to be influenced by differences in feeding costs and by price differentials for quality and could be econometrically estimated using a specification of this nature.

Alternatively if we assume that the supply of processing inputs is perfectly elastic, the elasticity of price transmission, Θ, can be approximated as the ratio of the value of a porker to the value of a baconer, which for average prices and weights in 1987 was 0.76.

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 pork or bacon. 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 pork, σ, is small and we have used a value of 0.1. In the case of bacon the elasticity of substitution, τ, is also expected to be small, although more elastic than for 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 to both industries at 20, consequently the inverse of the supply elasticities of manufacturing inputs, S_{mp} and S_{mb} is 0.05.

Table 2: Summary of Parameter Values

Own price elasticity of demand for pork	η_{pp}	-2.00
Own price elasticity of demand for bacon	η_{bb}	-1.60
Elasticity of demand for pork wrt price of bacon	η_{pb}	1.47
Elasticity of demand for bacon wrt price of pork	η_{bp}	0.60
Own price elasticity of supply of pigs	ε	1.50
Inverse of elasticity of supply of manuf inputs for pork	S_{mp}	0.05
Inverse of elasticity of supply of manuf inputs for bacon	S_{mb}	0.05
Elast of price transmission between farm prices of pigs	Θ	0.76
Elast of substn between pigs and manuf inputs in pork	σ	0.10
Elast of substn between pigs and manuf inputs in pork	τ	0.20
Share of pigs in cost of producing pork	K_p	0.42
Share of manufacturing inputs in cost of producing pork	K_m	0.58
Share of pigs in cost of producing bacon	G_b	0.24
Share of manufacturing inputs in cost of producing bacon	G_m	0.76
Share of porkers in total pigmeat production	Z_p	0.41
Share of baconers in total pigmeat production	Z_b	0.59

Extent of Exogenous Demand and Supply Shifts

We are interested in examining how industry participants are affected by six different types of technology or demand shifts. These comprise new technology in the production of porkers and baconers (ET_p and ET_b), new technology for the processing of porkers and baconers (ET_{mp} and ET_{mb}) and promotion of pork and bacon (EN_p and EN_b). In order to compare the impact of these different scenarios we need to establish the size of the demand and supply shifts. One possible approach which has been used in previous studies of this nature, for establishing values for these shifts, has been to set all the changes to one per cent.

However, starting with the pork industry, our approach has been to compare shifts in derived demand for porkers from promotion and new processing technology with a shift in farm supply from new production technology, that would result in a five cent shift in farm price at the initial equilibrium. Hence we are comparing supply and demand shifts that change farm price by five cents at the initial equilibrium before industry can adjust to the new technologies either through input substitution or through induced supply and demand responses in the bacon industry. We need to estimate the extent of changes in the exogenous demand and supply shifters that will allow this comparison.

The five cent shift in the farm price for pigs needs to be calculated as a percentage in order to estimate the extent of changes in the exogenous demand and supply shifters that will allow the comparison of these three shifts. The farm price of porkers was 172.2 cents per kilogram in 1987. A five cent reduction in price is equivalent to a reduction in ET_p of 2.90 per cent. ET_p assists in determining the values for the other two shifts, EN_p and ET_{mp}.

The relative change in retail price that will give a five cent change in price at the initial equilibrium is given by:

$$EP_p = ET_p * K_p \qquad \text{(Since } K_p = W_p/P_p\text{)}$$

This price change is converted into a relative change in quantity demanded at retail, EN_p, by multiplying by η_{pp}, the own price elasticity of demand for pork.

$$EN_p = \eta_{pp} * ET_p * K_p$$

$$= -2.4 \text{ per cent}$$

Now we want to determine the value for the processing shift in the porker industry, ET_{mp}. The relative change in the price of processing inputs that results in a five cent change in the price of these inputs at the initial equilibrium is given by:

$$ET_{mp} = ET_p * K_p/K_m$$

$$= -2.1 \text{ per cent}$$

By a procedure similar to that used for the pork industry we are also able to derive values for exogenous shifts in demand and supply for the bacon industry as a result of new technology or promotion.

A five cent reduction in the farm price of baconers from 172.6 cents is also equivalent to a relative price change of -2.9 per cent. From this start we determine the other shifts for the baconer industry resulting from new technology in the processing of baconers, ET_{mb} and promotion of bacon products, EN_b. The equivalent changes in prices at the retail and farm levels are given by the following formulas:

$$EN_b = ET_b * G_b * \eta_{bb}$$

$$= 1.1 \text{ per cent}$$

$$ET_{mb} = ET_b * G_b/G_m$$

$$= -0.9 \text{ per cent}$$

Estimating Changes in Economic Surplus

General Approach

The estimation of changes in economic surplus is complex because there are linkages in supply and demand between the two separate industries - porkers and baconers. For example the farm supply of porkers shifts out to the right directly as a result of new porker production technology and indirectly as baconer producers switch to porker production. There is also a corresponding shift inwards in the supply of baconers. Linkages in demand between the two industries mean that consumers switch between consumption of the two products according to their relative prices.

Because of these complex interrelationships we have not attempted to disaggregate the welfare changes to pork and bacon producers, but rather we estimate welfare changes to all pig producers. Likewise the welfare changes to pork and bacon consumers are not disaggregated. However we calculate the welfare changes to suppliers of manufacturing inputs for the porker and baconer industries separately.

Surplus to Pig Producers

We have chosen to estimate the impact of new technology on pig producers as the change in producer surplus under the aggregate supply function (equation 15). The formula for new technology in the production of porkers is:

$$29.\quad PS_p = (W_p*X_p+W_b*X_b)*(EW_p-ET_p/100)*(1+0.5*(Z_p*EX_p+Z_b*EX_b))$$

The first term in this equation is the total farm value of pigs in both sectors. The last term is the change in quantity produced of porkers and baconers weighted by their share of total production. As explained earlier we model aggregate supply as responding to either a change in the price of porkers or a change in the price of baconers, which is reflected in the middle price term. In the case of new technology in the bacon industry the price term is $(EW_b-ET_b/100)/\Theta$.

Surplus to Processors

The surplus to pork and bacon processors is measured in the two markets for these processing inputs. We can do this because new technology in production or promotion does not cause supply shifts in the processing sector. Supply of processing inputs only shifts as a result of new processing technology. The formulae are as follows:

$$30.\quad MS_p = W_{mp}*X_{mp}*(EW_{mp}-ET_{mp}/100)*(1+0.5*EX_{mp})$$

$$31.\quad MS_b = W_{mb}*X_{mb}*(EW_{mb}-ET_{mb}/100)*(1+0.5*EX_{mb})$$

The values for ET_{mp} and ET_{mb} will be zero for shifts other than those related to new processing technology. The total change in surplus to processors is the addition of MS_p and MS_b.

Surplus to Consumers and Processors

The change in surplus to all consumers and processors in both the pork and bacon industries as a result of new technology in the pork industry can be measured as the change in consumer surplus under the derived demand for porkers. Similarly for new technology in the bacon industry the change in surplus to all consumers and processors is the change in surplus under the derived demand for baconers (Just, Heuth and Schmitz, 1982).
The general formula to calculate these changes is:

$$32.\quad CSMS_i = -W_iX_i*(EW_i-EH_i/100)*(1+0.5*EX_i) \qquad \text{Where } i = p \text{ or } b$$

Because of supply and demand interrelationships between the pork and bacon industries, there is a shift in the derived demand curve for pigs for all types of technology and demand shifts. The EH_i term measures this vertical shift in derived demand and the procedure we used to estimate EH_i is discussed below.

Surplus to Consumers

The change in consumer surplus is the surplus to consumers and processors, $CSMS_i$, less the total change in surplus to processors, MS_i.

Estimation of Derived Demand Shift

To estimate the change in surplus to consumers and processors from new technology in the pork industry we need to know not only the change in the price of porkers, EW_p, but also the vertical shift in the derived demand curve EH_p. This shift in the derived demand curve is not an exogenous shift that we impose on the model as for ET_p, ET_{xp} and EN_p, for example, but arises from these exogenous shifts through demand and supply interrelationships.

The value of EH_p is different for each type of technology. The vertical shift in derived demand, EH_p, is estimated by making the supply of pigs perfectly inelastic and estimating the changes in the farm price of porkers that result from new production and processing technologies and retail demand shifts in the pork industry. In practical terms this means eliminating equation 15, the total supply of pigs, and making the quantity of porkers an exogenous variable. EH_p is estimated as EW_p from successive solutions of the reduced form model when ET_p, ET_{xp} and EN_p take values as described above.

The appropriate value for EH_p is then used in equation 32 (for $CSMS_i$) for price and quantity changes estimated from the full model. EH_b is estimated for shifts in the bacon industry and used in a similar way to calculate $CSMS_b$.

The following are the values for the derived demand shifts for each of the six different industry shifts that we consider:

EHT_p= 1.16, EHT_{xp}= 3.56, EHN_p= 3.83, EHT_b= 4.04, EHT_{xb}= 4.17 and EHN_b= 4.93

For example EHT_p is the value for the derived demand shift when we consider new technology that reduces the cost of producing porkers by five cents at the initial equilibrium.

Results of Base Run

We have examined the impact of new technologies that reduce the cost of growing porkers and reduce the cost of processing inputs in the porker industry and compared these two scenarios with promotion in the porker industry which increases the price of pork at the retail level. These comparisons are made for five cent price changes at the initial equilibrium. The percentage changes in prices and quantities resulting from these supply and demand shifts, as well as the economic surplus enjoyed by the consumers, pig producers and manufacturing inputs producers, are detailed in Table 3. Similar values are detailed in Table 4 for the bacon industry base run.

New Technology for Production of Porkers

As a result of production research in the pork industry the supply curve for porkers shifts out to the right as producers supply more porkers at the lower cost. The increase in production lowers the price of porkers as well as lowering the price of pork on the retail market, leading to increased consumption. Because of linkages between the two industries in production and consumption, new technology in the production of porkers also causes a shift in the demand for bacon products and in the supply of baconers. On the demand side, the lower price for pork at the retail market causes the demand curve for bacon, a substitute, to shift to the left leading to a decrease in both the amount of bacon consumed and its price.

On the supply side, the production of porkers has become more profitable, hence some producers of baconers have switched to producing for the pork market which shifts the supply curve for baconers to the left. This decreases the quantity supplied and increases the price of baconers which feeds through to the retail market as a decrease in the amount of bacon on the market and an increase in the retail price. Note that the demand and supply effects have opposing influences on the retail prices of bacon products. In this case the supply side effects are greater as we observe a rise in the price of bacon at

Table 3: Price, Quantity & Surplus Changes from Shifts in Porker Industry

		PORKERS	
	Production	Processing	Promotion
Q pork consumed	2.09	2.12	2.02
Q bacon consumed	-0.67	-0.66	0.01
P pork at retail	-1.02	-1.04	0.28
P bacon at retail	0.04	0.02	0.10
Q porkers	2.25	1.99	1.99
Q baconers	-0.71	-0.70	-0.05
Q manuf inputs for pork	1.98	2.21	2.04
Q manuf inputs for bacon	-0.66	-0.65	0.03
P porkers	-2.57	0.27	0.53
P baconers	0.25	0.20	0.40
P manuf inputs for pork	0.10	-1.99	0.10
P manuf inputs for bacon	-0.03	-0.03	0.002
Consumer surplus	7 393 387	6 494 800	6 241 564
% Consumer surplus	82.5%	83.4%	69.1%
Producer surplus	1 585 796	1 272 375	2 503 766
% Producer surplus	17.7%	16.3%	27.7%
Manuf producer surplus	-17 686	16 021	292 566
% Manuf producer surplus	-0.2%	0.2%	3.2%
Total surplus	8 961 496	7 783 196	9 037 896
Total value of industry	1627890000	1627890000	1627890000
% Surplus of industry	0.6%	0.5%	0.6%

the retail market.

The increase in the size of the pork industry leads to a shift to the right in the demand for manufacturing inputs used by the pork industry. Conversely there has been a decrease in the size of the bacon industry which has led to a shift inwards in the demand for manufacturing inputs for the bacon industry.

Under these circumstances porker and baconer producers gain a surplus of $1 585 796 per annum. Consumers of pork and bacon products gain $7 393 387 in total consumer surplus per annum. However note that because there has been an increase in price and reduction in quantity consumed of bacon, consumers of bacon products are less well off. The suppliers of manufacturing inputs actually experience a loss in surplus of $17 686 per annum, as the loss of demand from the bacon industry is not offset by the increase in the size of the pork industry.

The total surplus accruing to the whole pig industry, including producers of pigs, producers of manufacturing inputs used in processing of pigs, and the final consumers of the pig products is $8 961 496 per annum which is about 0.6 per cent of the total value of the industry.

New Processing Technology in the Porker Industry

New processing technology shifts the supply curve for manufacturing inputs to the right as producers are willing to supply more manufacturing inputs at the lower cost. The initial effect of lower manufacturing costs is to increase the demand for porkers at the farm level, as processors are willing to process extra porkers due to the lowering in the price of processing inputs. Thus there is an increase in quantity of porkers used which increases the farm price of porkers. Even though the price of porkers has increased at the farm level, there is still a decrease in the price of pork at the retail level due to the decrease in the cost of processing pork. The lower price for pork is an incentive for consumers to substitute bacon for pork products.

Concentrating now on the effect on the baconer industry of new processing technology for porkers, we see a decrease in the quantity of bacon consumed due to the lowering of the price of pork. The shift inwards in the demand for bacon also increases the price of bacon slightly. The lower demand for bacon flows through the system to a shift inwards also in the farm demand for baconers, leading to a fall in the price of baconers. The other influence on the baconer market is the higher price paid for porkers which results in a contraction in the supply of baconers as baconer producers switch to producing the more profitable porkers. The shift inwards in both the demand for bacon and the supply of baconers create opposing forces on the prices of bacon, but as can be seen the supply side forces override as there are slight increases in the price of bacon and baconers. The supply and demand forces however both contribute towards reduction in the quantity of baconers on the market and so it follows that there is a reduction in the demand for and the price of manufacturing inputs used in the processing of bacon.

The suppliers of manufacturing inputs gain an increase in their surplus of $16 021 from new technology in their industry, producers and consumers gain $1 272 375 and $6 494 800 respectively.

Promotion in the Porker Industry

The third type of shock imposed on the industry is an effective promotional campaign. The first result of successful promotion in the pork industry is an expansion in the retail demand for pork as consumers are encouraged to purchase more pork due to the advertising. The shift in demand is also evident in the farm schedule for pork. The consequence of the demand shifts is an increase in the quantity of pork consumed and porkers used for processing, and increases in the price of porker pigs and their products. Following the shift in demand for pork there is also an expansion in the demand for manufacturing inputs used in the processing of porkers, which increases the price and quantity used of these manufacturing inputs.

Examining now the effect of pork promotion on the bacon industry, on the supply side, there is a contraction in the supply of baconers. This is due to the higher price being paid for porkers, and producers see that porkers are a more profitable production alternative. This shift reduces the supply of

baconers on the market and also increases the price paid for baconers due to the lower level of supply. On the demand side, following the promotion of pork it would be expected that there would be a shift to the left in the demand for bacon as consumers substitute the more popular pork for bacon. However due to the cross price elasticities the increase in the price of pork has led to a shift out in the demand for bacon, and a slight increase in the quantity of bacon consumed. Here we have the demand and supply effects contributing to a rise in the price of bacon at retail. Even though there is a lower throughput of baconers in the processing sector there has been a slight increase in the amount of manufacturing inputs used. This situation has arisen due to the substitution of manufacturing inputs for baconers as there has been a substantial rise in the price of baconers.

The resultant changes in surplus for the industry are an increase in consumer surplus of $6 241 564 per annum, an increase in producer surplus of $2 503 766 per annum, and producers of manufacturing inputs also have an increase in their surplus of $292 566 per annum. The total surplus to the industry is calculated as $9 037 896 per annum.

New Technology for Production of Baconers

Introduction of new production technology in the bacon industry lowers the cost of supplying pigs for bacon so there is a shift outwards in the supply curve for these pigs, a decrease in the retail price of bacon, and a rise in the consumption of bacon. Due to substitution in consumption the lower price of bacon causes a shift inwards in the demand for pork. Producers of porkers switch to producing baconers because of improved profitability from the new technology. This causes an inward shift of the supply curve for pork which results in increases in the price of porkers and the price of pork at the retail level, again opposing the retail demand shift.

New technology for the production of baconers causes a shift to the right in the demand schedule for manufacturing inputs used in processing bacon but the lower production of porkers leads to a shift inwards in the demand for pork manufacturing inputs. The net effect of the changes in both the quantity and price of manufacturing inputs is a gain in surplus of $256 234 per annum for the suppliers of manufacturing inputs.

Producers of pigs increase their surplus by $1 291 275 per annum. Again the loss in surplus to consumers of pork from the rise in price of these products is more than offset by the gain in surplus to consumers of bacon products as there is a total gain in consumer surplus of $18 610 000 per annum.

New Processing Technology in the Baconer Industry

The initial effect of a new innovation in the processing of baconers is to shift the supply curve for manufacturing inputs out to the right, with more inputs being made available at a lower price. There is a shift out in the demand for baconer pigs due to the lower cost of processing which has a slight upwards effect on the price of baconers. Even though a higher price is being paid for baconers they are able to be processed at a lower price than previously due to the new technology, which results in bacon being less expensive when offered on the retail market. Consumers are willing to purchase more bacon at the lower price and thus lowering their consumption of pork due to the substitution effect.

Following the lower consumption of pork on the retail market, there is also a shift to the left in the demand for porkers at the farm level. These demand shifts cause downward pressure on both the price of bacon and the price of baconers. Porker producers are encouraged to switch production to baconers because of the higher price being paid for baconers due to the new processing technology. So in the bacon market we see a contraction in demand and also a contraction in supply. The supply shift is seen to have the most influence due to the price rise in bacon at the farm and retail level. The lower level of throughput of baconers yields an inward shift in the demand for manufacturing inputs used for the processing of bacon, resulting in a decrease in the quantity and price of these inputs.

Following the changes in prices and quantities of variables in the pigmeat industry, emanating from new processing technology for the baconer industry, all producers and consumers enjoy an increase in their surplus. Producers of

Table 4: Price, Quantity and Surplus Changes from Shifts in Baconer Industry

		BACONERS	
	Production	Processing	Promotion
Q pork consumed	-1.07	-0.96	-0.14
Q bacon consumed	1.03	1.03	1.03
P pork at retail	0.08	0.008	0.14
P bacon at retail	-0.61	-0.64	0.10
Q porkers	-1.09	-0.96	-0.16
Q baconers	1.45	0.89	1.00
Q manuf inputs for pork	-1.05	-0.95	-0.12
Q manuf inputs for bacon	0.90	1.07	1.04
P porkers	0.27	0.09	0.35
P baconers	-2.69	0.06	0.27
P manuf inputs for pork	-0.05	-0.05	-0.006
P manuf inputs for bacon	0.04	-0.86	0.05
Consumer surplus	18 610 000	11 125 000	12 589 800
% Consumer surplus	92.3%	93.7%	85.6%
Producer surplus	1 291 275	405 143	1 668 818
% Producer surplus	6.4%	3.4%	11.3%
Manuf producer surplus	256 234	347 708	446 865
% Manuf producer surplus	1.3%	2.9%	3.0%
Total surplus	20 157 600	11 877 800	14 705 500
Total value of industry	1627890000	1627890000	1627890000
% Surplus of industry	1.2%	0.7%	0.9%

manufacturing inputs receive an increase in their surplus of $347 708 per annum, while pig producers receive a small $405 143 per annum increase in their surplus and consumers again receive the largest amount of surplus increase of $11 125 000 per annum.

Promotion in the Baconer Industry

The final scenario that we have considered in the base run is a successful promotional campaign aimed at the consumers of bacon. Changes in prices and quantities for the pigmeat industry are smaller for this shift than for any of the other shifts already considered. The promotion shifts out the demand curve for bacon and subsequently for baconers at the farm level to keep up with retail demand for the product. The demand shifts lead to increases in the consumption of bacon and use of baconers as well as increases in the prices of these two products. The quantity and price of manufacturing inputs used in the processing of bacon is increased as there is also an outwards demand shift for these inputs as the number of baconers processed increases.

In the pork industry there is a shift to the left in the supply of porkers as pig producers switch to the production of baconers. The contraction in supply of porkers pushes the price of porkers up. On the demand side there is a shift to the left in the demand for pork as consumers switch their preferences to the consumption of bacon due to the promotion. The demand shift for pork would suggest that the price of pork at the retail level would decrease. However we can see that there has in fact been an increase in the price of pork, showing that the contraction in the supply of porkers lifts up the price of porkers at the farm level and flows through to an increase in the price of pork at the retail level. Due to the reduced throughput of porkers there is an inwards shift in the demand for manufacturing inputs used for pork, which decreases the quantity of manufacturing inputs used and the price of these inputs.

In terms of increases in surplus due to promotion of bacon, the consumers gain the most with a value of $12 589 800 per annum. Gain in surplus to producers of pigs is $1 668 818 per annum and to producers of manufacturing inputs is $446 865 per annum.

Comparing Results of Shifts in the Pork Industry

Comparing the three shifts in the pork industry, the shift due to promotion results in the largest total surplus to the pig industry of $9 million. Production technology gives the next largest total surplus to the industry followed by processing technology. In all three cases the largest proportion of total surplus, 69% to 83%, is gained by the consumers of pig products. Producers of pigs receive the next largest proportion of surplus from the shifts receiving between 16% and 28%, and producers of manufacturing inputs receive a minimal amount of the change in surplus, and even lose surplus from new porker production technology.

In total dollar amounts the producers of pigs receive the largest increase in their surplus, $2.5 million from promotion of porkers. In terms of proportion of total surplus, pig producers also are better off from promotion in the porker industry as they receive over a quarter of the total surplus.

Comparing Results of Shifts in the Bacon Industry

The differences in total surplus between the three shifts is greater for the bacon industry as total surplus ranges from $12 million to $20 million. This time production technology gives the greatest increase in total surplus followed by promotion and then processing. Consumers receive the bulk of the surplus with pig producers receiving the next largest share followed again by producers of manufacturing inputs who only receive a small amount of the change in surplus.

In total dollar amounts producers again receive the greatest amount and percentage of total surplus from promotion receiving an increase in their surplus of $1.7 million. Production research returns $1.3 million but producers only receive a small increase in their surplus from processing research.

Concluding Comments

In this paper we have reported our method of modelling the impact of new technology and promotion on the Australian pig industry. The industry has been disaggregated into the fresh and processed sectors where substitution in consumption and jointness in production has been allowed. We have compared the changes in returns to participants in the Australian pig industry from supply and demand shifts due to new technology in production and processing and the promotion of pig products. 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.

The changes in surplus to the industry as a result of the demand and supply shifts show some similarities for the two sectors of the industry. In both cases a demand shift from promotion results in the highest increase in surplus to the pig producers. However in terms of total surplus to the industry promotion in the pork industry gives the highest rise in surplus, but in the bacon industry a supply shift resulting from new production technology for baconers results in the highest increase in total surplus to the industry.

The magnitudes of change in total surplus to the pig industry are much larger in the bacon sector, for example $9 milllion for a supply shift resulting from new production technology in the porker sector compared to $20 million for new production technology in the bacon sector. A general result for both sectors is that the majority of the total increase in surplus is received by the consumers of the retail pig products, pig producers receive the next largest share and the share received by the suppliers of manufacturing inputs is minimal and in one case they actually lost surplus.

As yet we have not performed any sensitivity tests on the model for the elasticities that we have used. However their influence is particularly evident in the case of promotion in the pork industry where the bacon industry does not experience a decrease in demand due to the rise in price of pork. Also in this case the elasticity of substitution is influential as although there was a lower throughput of baconers there was an increase in the amount of manufacturing inputs used due to processors substituting other inputs for the highly priced baconers.

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