RESEARCH PAYOFFS FROM QUALITY IMPROVEMENT: THE CASE OF BACKFAT DEPTH IN PIG CARCASSES

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ABSTRACT

In this paper closed economy models are developed which can be used to measure the economic benefits from a research-caused improvement in quality. Several features of our approach should be emphasised. Each involves the provision of alternative model specifications. First, commodity demand and supply are specified in both linear and non-linear constant elasticity form. Second, the shift in commodity demand due to research can take the form of a parallel shift or a convergent shift. Third, supply of nonfarm inputs and marketing services can be perfectly or imperfectly price elastic. Fourth, the scope for substitution between marketing inputs and farm product by marketing firms is allowed to be zero or non-zero. The models developed are used to estimate the economic benefits from reducing backfat thickness in Australian pork. In the absence of Australian data on consumers' valuation of reduction in the characteristic 'fatness', use has been made of information on US valuation obtained in a hedonic price analysis.

A preliminary finding reported in this paper is that the Australian pig industry is able to obtain gross annual research benefits over 30 years of approximately $66 million in present values for a 10% reduction in backfat depth. The larger share of this gains accrue to producers. An implication of this finding is that it would be possible to spend up to about $2.2 million per year in order to reduce fat depth in pigs by 10% before this matched the aggregate benefits.

There could be additional social gains as a result of health benefits not incorporated in consumers' valuations. This may be most likely to be so when individuals do not bear the full cost of their health care.
Research Payoff from Quality Improvement: The Case of Backfat Depth in Pig Carcasses

Introduction

Substantial effort has been devoted to estimating the economic benefits from cost-reducing research in agriculture. Much of this work has been carried out using partial equilibrium models in which research causes a downward shift in the commodity supply curve in part or all of the industry (see, for example, Edwards and Freebairn 1981, 1982, 1984; Norton et al., 1987). The analysis has covered both traded and non-traded commodities.

In contrast to the sizable body of work on the payoff from cost-reducing research, little work has been reported on the economic benefits from research which improves the quality of the commodities. The study by Unnevehr (1986) is one of the few instances of such research. One reason for the paucity of studies on the welfare effects of quality-improving research is that quality changes by definition alter the nature of the commodity. This raises problems for welfare measurement which are not encountered when research reduces the costs of producing a commodity with unchanged characteristics. Another reason is that general equilibrium considerations will often be more important when research causes an improvement in commodity quality than when it lowers the costs of production. For example, research which improves a quality characteristic of pigmeat, causing the demand curve for pigmeat to rise, may have significant effects on welfare in the markets for chicken and beef by causing downward shifts in the demand for those commodities.

In the present study a model is developed which can be used to measure the economic benefits from a research-caused improvement in quality. The model follows Freebairn, Davis and Edwards (1982) in permitting the identification of research benefits to four groups: commodity producers, input suppliers, marketers, and consumers. The rationale for this is the reality that economic benefits from a rise in demand for the commodity at farm level will be distributed between groups in the chain between input suppliers and final consumers, with the distribution depending on market structure. However, when the simplifying assumptions of perfectly elastic supply of inputs and of marketing services are valid, the benefits from research accrue totally to commodity producers and consumers, making a simpler model specification possible.

Three other features of our approach should be emphasized. Each involves the provision of alternative model specifications. First, commodity demand and supply is specified in both linear and non-linear (constant elasticity) form. Second, the shift in commodity demand due to research can take the form of a parallel shift or a convergent shift. Third, the scope for substitution between marketing inputs and farm product by marketing firms is allowed to be zero (as in Freebairn, Davis and Edwards, 1982) or non-zero (as in Alston and Scobie, 1983 and Freebairn, Davis and Edwards, 1983).

The models developed in this paper are used to estimate the economic benefits from reducing backfat depth in Australian pork. A reduction of backfat thickness in pork causes an upward shift in demand for pork in Australia. In the absence of Australian data on

\[^1\]A hedonic price analysis (e.g. Hayenga et al., 1985) showed a strong upward trend in carcass value as backfat thickness decreases. This points to the fact that consumers have strong preferences for pork with the characteristic 'low fat'. They are willing to pay higher prices for leaner pork than for pork with a higher
consumers' valuations of reductions in the characteristic 'fatness', use has been made of information on US valuations obtained in a hedonic price analysis (Hayenga et al., 1985). This information represents estimates of consumers' own valuations of reductions in backfat. It is possible that there could be additional social gains as a result of health benefits not incorporated in consumers' valuations. This may be most likely to be so when individuals do not bear the full costs of their health care.

The analytical frameworks

In this section, analytical frameworks for estimating the level and the distribution of economic benefits from quality-improving research are developed. Three separate model specifications arise from the different combinations of assumptions made about the nature of supply and demand curves, the elasticity of supply of nonfarm inputs and marketing services, and substitution between the farm product and marketing services. For the first combination of assumptions about these determinants of research benefits, an additional model specification is provided by allowing the shift in commodity demand due to research to take either a parallel or convergent form. For the other two combinations, parallel shift in demand is assumed.

Linear supply and demand; perfectly elastic supply of nonfarm inputs and marketing services; and no substitution between farm product and marketing inputs

In the first part of this section, the assumption of perfectly elastic supply of marketing goods and services is included in the analysis. The analytical framework for measuring research benefits is depicted in Figure 1. The retail demand curve for pork is represented by $D_D$ and the retail level supply curve is $S_S$. Quality improvement in pork causes an upward shift in the retail demand schedule from $D_D D_0$ to $D_1 D_3$ in the case of a parallel shift, and to $D_2 D_0$ in the case of a convergent shift. The initial equilibrium price and quantity are $(P_0)$ and $(Q_0)$ respectively. The equilibrium price and quantity with the demand shift are represented by $(P_1)$ and $(Q_1)$. The vertical shift in demand is represented by $w$ and is measured at the new equilibrium.

2 This assumption, as argued by Freebairn et al. (1982), provides reasonable approximations given the absence of peculiar inputs for the livestock industry since they use a small proportion of the economy's resources and since there is scant evidence of longrun diseconomies of scale. With this assumption the input suppliers and the marketers gain extra sales but no extra surpluses.

3 In this paper we argue that, unlike demand shifts due to income and population growth, the demand shift due to product quality improvement can be non-parallel and convergent. Quality improvement causes some alterations in the characteristics of the product with the result that there could be some degree of structural change. High quality products tend to face less competition, and are less substitutable. In other words there are fewer substitutes for quality.

4 From the hedonic price analysis, $w$ is equivalent to the economic gain per unit of the commodity. This gain can be expressed as:

$$w = P_{PF}(X_{PF} - X_{PF})$$

where $P_{PF}$ is the implicit price of the fat characteristic in pork; $X_{PF}$ is the new value for the fat characteristic in pork obtained from one unit; and $X_{PF}$ is the old value for the characteristic from one unit.
Several formulae have been developed to measure the areas in Figure 1 that represent consumer, producer, and total net economic surpluses resulting from parallel and convergent shifts in consumer demand for pork. For a parallel shift, the change in producer benefits is represented by the area $P_1E'EP_o$ and the change in consumer benefits is represented by the area $(D_1E'HD_0 - P_1HEP_0)$. The net social surplus equals the sum of the changes in producer and consumer surplus, area $(D_1E'HD_0 + HE'E)$. For a convergent shift, the change in producer benefits is given by the area $P_1E'EP_0$ and the change in consumer surplus is area $(D_2E'HD_0 - P_1HEP_0)$. The net social surplus is the sum of the changes in producer and consumer surpluses, area $(D_2E'HD_0 + HE'E)$.

The changes in economic surpluses in the case of a parallel shift are calculated as:

$$TS = \frac{1}{2}kP_0Q_0(2 + eZ),$$

(1)

$$PS = \frac{1}{2}P_0Q_0(2Z + eZ^2),$$

(2)

$$CS = TS - PS.$$  

(3)

In the case of a non-parallel convergent shift, changes in economic surpluses are calculated as:

$$TS = \frac{1}{2}kP_0Q_0\left(\frac{1 + 2\eta - eZ}{\eta - eZ}\right)(1 + eZ) - (eZ),$$

(4)

$$PS = \frac{1}{2}P_0Q_0(2Z + eZ^2),$$

(5)

$$CS = TS - PS,$$

(6)

where $TS$ is the change in total net economic surplus, $PS$ is the change in producer surplus, $CS$ is the change in consumer surplus, $k$ is the proportionate vertical shift $(w/P_0)$ in the demand curve due to quality improvement, $e$ is the supply elasticity at the initial equilibrium point $P_0Q_0$, $\eta$ is the demand elasticity at initial equilibrium point $P_0Q_0$, $\eta_F$ is the demand elasticity at point $F$ $(P_0Q_1)$, and $Z = k\eta/(e + \eta)$. Once the changes in consumer, producer, and total net economic surplus are calculated for each relevant period, the present values of the benefits can be computed.

Linear supply and demand; imperfectly elastic supply of non-farm inputs and marketing services; and no substitution between pigs and marketing services

Now, while retaining the assumptions of linear demand and supply curves, a zero elasticity of substitution between marketing inputs and the farm product, we allow for rising supply curves for non-farm inputs and for marketing services. The shift in demand resulting from research is assumed to be parallel. In this second part, the general competitive model of

\footnote{Note that the change in producer surplus is the same for the convergent as for the parallel shift in demand.}

\footnote{The analysis here is not extended to a convergent shift as in part one because of mathematical and analytical complexity involved in constructing the model.}
Freebairn et al. (1982) is extended for the purpose of our analysis. The modified approach is outlined as follows:

\[ Q = a - \alpha P, \]  
\[ P_m = b + \beta Q, \]  
\[ P = P_f + P_m, \]  
\[ Q = c + \gamma (P_f - P_i), \]  
\[ P_i = d + \theta Q, \]

where \( P \) represents the retail pork price, \( P_m \) is the retail-farm price margin, \( P_f \) is farm price, \( P_i \) is the input price (expressed as the cost of nonfarm inputs per unit of farm output), and \( Q \) is the quantity (in carcass weight). Equation 7 is the retail demand schedule for pork and equation 10 is the farm supply schedule. Note that supply is a function of farm price and input price. A rising supply function for non-farm inputs is specified in equation 11. The retail-farm price margin equation is described in equation 8. Equation 9 is a general form equation which interprets the cost of all marketing services as the difference between the farm price and retail price. Equations 7 to 11 can be solved to determine the equilibrium prices and quantity.

Research which reduces fatness in pigs causes a parallel upward shift in the final consumer demand for pork by an amount \( w \). Consequently, the retail demand schedule becomes:

\[ Q' = a + \alpha w - \alpha P' \]

where \( Q' \) and \( P' \) denote the new equilibrium quantity and price respectively. By solving equations 8-12 simultaneously, the new equilibrium prices and quantity can be obtained.

An upward shift in consumer demand for pork due to meat quality improvement causes an increase in equilibrium quantity as well as in prices at all production levels. These price and quantity changes can be used to measure the welfare effects of quality-improving research. Changes in economic surpluses can be derived using Figure 1 (using the parallel specification). Denoting the changes in consumer, marketer, farmer, input supplier, and aggregate surpluses by \( CS, MS, PS, IS \) and \( TS \) respectively, we get:

\[ CS = 1/2(w + P - P')(Q + Q'), \]
\[ MS = 1/2(P_m' - P_m)(Q + Q'), \]

\[ \text{The model of Freebairn et al. (1982)} \] was originally intended for assessing the distribution of research gains from cost-reducing or yield-raising research in multistage production systems. In this paper, our modified model allows an assessment of research benefits due to an upward shift in the consumer demand for pork in the Australian pig industry.

\[ \text{Also in this model, we assume that the production function is homogenous of degree one (i.e. constant} \] input-output coefficients between nonfarm inputs and farm output).
\[ PS = 1/2(P_i - P'_i + P'_j - P_j)(Q + Q'), \quad (15) \]
\[ IS = 1/2(P'_i - P_i)(Q + Q'), \quad (16) \]
\[ TS = 1/2(w)(Q + Q'), \quad (17) \]

where all terms are defined as above.

By substituting the pre- and post-innovation prices and quantity into equations 13-17, the gains from research can alternatively be specified as:

\[ GS = \gamma Y(TS), \quad (18) \]
\[ MS = \frac{\alpha \beta \gamma}{Y}(TS), \quad (19) \]
\[ PS = \frac{\alpha}{Y}(TS) \quad (20) \]
\[ IS = \frac{\alpha \theta \gamma}{Y}(TS) \quad (21) \]
\[ TS = Qw + \frac{\alpha \gamma w^2}{2Y} \quad (22) \]

where \( Y = (1 + \alpha \beta)\gamma + (1 + \gamma \theta)\alpha \), and other terms are defined above.

Non-linear supply and demand; perfectly elastic supply of nonfarm inputs and of marketing services; and substitution between farm product and marketing services

Now, while retaining the assumption of perfectly elastic supply of marketing services, we allow for non-linear (constant elasticity) demand and supply curves and a non-zero elasticity of substitution between marketing inputs and the raw farm product (i.e. pork). The shift in demand is again assumed to be parallel. Suppose that the retail production of pork (Q) involves 2 inputs: pig carcasses (F) and marketing services (M). The marketing industry’s production function is assumed to yield constant returns to scale. The marketing industry production function is expressed as:

\[ Q_s = f(F, M). \quad (23) \]

The retail demand function for pork is

\[ Q_d = D(P). \quad (24) \]

Note that \( Q_s = Q_d = Q \) at market-clearing equilibrium. The input supply function of M is

\[ P_m = h(M), \quad (25) \]
and the supply function of F (hog production) is

\[ P_F = g(F). \]  \hspace{1cm} (26)

The model is completed by equations representing the markets for M and F. For profit-maximising firms, both factors are paid the value of their marginal products:

\[ P_m = P Q_m, \]  \hspace{1cm} (27)

and

\[ P_F = P Q_f. \]  \hspace{1cm} (28)

This system contains 6 equations in six endogenous variables \((F, M, Q, P_f, P_m, P)\). In our closed economy case, there will be a unique equilibrium for given values of the exogenous variables. At this equilibrium, the values of the six endogenous variables are determined by the simultaneous equation method.

Now consider the displacement from the initial equilibrium resulting from an upward shift in the retail demand curve. Along the retail demand schedule, the relative change in \(Q\), or \(dQ^*\), which is the logarithmic differential of \(Q\), is equal to the elasticity of the retail demand curve, \(\eta\), multiplied by the relative change in price, \(dP^*\). Denoting the vertical upward shift in the retail demand curve by \(\alpha\), the new demand schedule becomes in differential form:

\[ -\frac{1}{\eta} dQ^* + dP^* = \alpha. \]  \hspace{1cm} (29)

Now, equations 23, 25, 26, 27, 28, 29 can be solved for reduced form equations which express the percentage changes in quantities and prices of inputs and outputs due to exogenous shift in the retail demand curve\(^9\). Incorporating changes to Muth's analysis similar to those suggested by Freebairn et al. (1983), the final expressions for consumer and producer surplus gains can be solved by substituting the old and the new equilibrium quantities and prices into the following equations:

\[ CS = 1/2(P - P')(Q + Q'), \]  \hspace{1cm} (30)

and

\[ PS = 1/2(P'_f - P_f)(Q + Q'). \]  \hspace{1cm} (31)

The final algebraic expressions are:

\[ CS = \alpha PQ[-\eta(\sigma + S_m e_f + S_f e_m) - \frac{D}{D} + 1][1 + \frac{1/2\alpha\eta(\sigma(S_f e_f + S_m e_m) + e_f e_m)}{D}] \]  \hspace{1cm} (32)

and

\[ PS = \left(\frac{\alpha F P_f \eta(\sigma + e_m)}{D}\right)[1 + \frac{1/2\alpha e_f \eta(\sigma + e_m)}{D}]. \]  \hspace{1cm} (33)

where \(D = e_f e_m + \sigma(S_f e_f + S_m e_m) - \eta(S_f e_m + S_m e_f) - \sigma\eta\) and where \(\eta\) (taken to be positive) is the partial elasticity of demand for pork; \(e_f\) and \(e_m\) are, respectively, the partial elasticities of supply of the farm product and marketing services; \(\sigma\) is the elasticity of substitution between marketing inputs and the farm product in the production of pork; \(\alpha\) is the shift of

\(^9\)The new equilibrium prices and quantities are derived by setting all shift parameters except \(\alpha\) to zero.
the retail demand curve expressed as a fraction of the initial price \( P \), so the absolute shift is \( aP \); and \( S_f \) and \( S_m \) are, respectively, the shares of the farm product and marketing goods and services in the cost of the retail product \( (S_f + S_m = 1) \). With \( e_m = \infty \), equation 32 and 33 become:

\[
PS = \left[ \frac{\alpha FP_P}{D'} \right] \left[ 1 + \frac{1/2ae_P}{D'} \right],
\]

and

\[
CS = \alpha PQ \left[ -\frac{\eta S_f}{D'} + 1 \right] \left[ 1 + \frac{1/2ae_m(\sigma S_m + e_f)}{D'} \right]
\]

where \( D' = e_f + \sigma S_m - \eta S_f \).

The data

The values of key price and quantity variables required to apply the formulae are listed in Table 1. They refer to average 1988 conditions. Price and quantity variables refer to the retail level equivalents. \( Q \) denotes the annual production of porkers in Australia. Pork prices are taken from the weighted average retail prices of leg and loin chops in major capital cities of Australia.

The retail-level demand elasticity for pork in Australia had been previously estimated to be price elastic. A review of previous studies by Hill (1968), Gruen et al. (1967) and Pender and Erwood (1970) for different time periods suggested that the demand elasticity for pork increased substantially in the sixties due to increases in competitiveness of pork (the presence of a strong substitution effect induced by the growth of the white meat industry). For our empirical analysis, we adopt the most recent estimate reported by Pender and Erwood (1970).

The wholesale-level demand elasticity for pigs is taken to be \(-1.14\), based on the estimate by Hill (1967).

Direct estimates of the price elasticity of supply of pork in Australia are not available. The work by Hill (1968), Gruen et al. (1967) and Richardson and Connor (1978) on the econometric studies of sow inventory response\(^{10}\) suggests that the supply of pigs in Australia is relatively price inelastic. The studies point, however, to some rise in the elasticity of supply in the 1980's relative to that in the 1960's due to the reduced number of small and increased number of large piggeries. The pig industry in Australia has been changed from a sideline activity to a specialised competitive enterprise. For empirical estimation, the short-run supply elasticity of pork is taken to be \(0.8\), based on the estimate by Richardson and Connor (1978).

Although estimates of the pork demand and farm level pig supply price elasticities are available, no estimates were found for the marketing and input supply elasticities. Most

\(^{10}\) The supply of pigmeats has a good proxy in the sow inventory response. Supply of pigmeats is directly related to the number of sows at any one period;

\[
S_t = N_t(LS_t)(WT_t)
\]

where, \( S_t \) is the annual supply of pigmeats, \( N_t \) is the number of sows at year \( t \), \( LS_t \) is the number of pigs sold per sow per year multiplied by the average number of litters per year, and \( WT_t \) is the average slaughter weight of pigs.
available evidence (e.g. Freebairn et al., 1982; Alston and Scobie, 1983) points to a highly elastic long-run supply function. For illustrative purposes, we consider elasticities of 2 or infinity (hence, price flexibilities of 0.5 or 0). To transform the price flexibilities to slopes, we multiplied by the appropriate quantity-to-price ratios.

The implicit price estimates for quality characteristics in pig carcasses were not available in Australia. Estimates of implicit price were therefore obtained from Hayenga et al. (1985) using US data. In that article, the implicit price for fat characteristic in pig carcasses (based on 1981 wholesale price) was estimated to be 1.87 cents/kg for each subsequent reduction of a tenth of an inch backfat relative to the base class. Discrete dummy variables for 6 backfat categories (in tenths of an inch measured at the last rib) were used, ranging from 1.15-1.25 inch (i.e. the base or average backfat thickness in pigs) to 0.55-0.65 inches. Reduction of a tenth of an inch backfat therefore represents an improvement of about 8.3% in carcass leaness. In this paper, the average carcass leaness is assumed to improve by 10%, giving a total benefit, \( w \) (measured as a vertical shift in demand) of 2.253 cents/kg. The target of up to 50% reduction in fatdepth in pigs can be achieved by nutritional and/or hormonal manipulations (PDC, pers comm.) Genetic control is, nevertheless, the most common practice. There has been significant improvement in pig quality (up to 50% reduction in backfat depth in pigs) over the past three due to genetic selection for leaner pigs. The target of 10-50% reduction in backfat depth in pigs is feasible, as in the past, with genetic selection for leaner animals (Australian Pork Corporation, pers comm.). Thus, our assumed 10% reduction in backfat is realistic. The rate at which reduction in fatdepth in pigs may be attained depends to a larger extent, however, on the intensity of research.

It is necessary to derive the value, \( w \), which corresponds to Australia's. To do this, the following procedures are performed. First, the US data are converted to those relevant to Australia using appropriate US and Australian carcass price ratios. Second, the data corresponding to 1981 are converted to those corresponding to 1989, after taking account of inflation. Third, the implicit value at the wholesale level (carcasses) is transformed to the implicit value at the retail level (pork) using the following formula (see Appendix 1 for the derivation)\(^{11}\):

\[
w_P = w_C \left( \frac{P_P}{P_C} \right) \left( \frac{\eta_C}{\eta_P} \right)
\]

where

- \( w_P \) represents the economic gain per unit of pork,
- \( w_C \) represents the economic gain per unit of carcass,
- \( P_P \) is retail price of pork,
- \( P_C \) is the wholesale carcass price,
- \( \eta_C \) denotes the own-price elasticity of demand for pig carcasses, and
- \( \eta_P \) denotes the own-price elasticity of demand for pork.

The transformation of US data to those corresponding to Australia is reasonable because Australian consumers valued fat characteristics in pigmeat in much the same way as their US counterparts (Australian Pork Corporation, pers comm.). Consumers in both countries tend to react against fatness in pork\(^{12}\), and say that fat is a primary reason why they do not

\(^{11}\)The transformation is justified by the fact that pork is considered to be a derived product of carcasses, hence increase in the demand for pig carcasses due to quality improvement results in a proportionate increase in the demand for pork.

\(^{12}\)This implies that consumers derived greater utility from the consumption of leaner and healthier pork.
eat more pork (ACIL, 1985; Hayenga et al., 1985).

Results

Linear supply and demand; perfectly elastic supply of nonfarm inputs and of marketing services; and no substitution between farm product and marketing services

Welfare effects of a 50% reduction of fat depth in pigs due to scientific research are shown in Table 2. With a parallel shift in demand, the gross research benefits over 30 years from a 50% reduction of fatness in pigs amount to $180 million in present values. Approximately 80% of the economic benefits accrue to producers and 20% to consumers. This distribution reflects the high value for the price elasticity of demand relative to that for the elasticity of supply. The aggregate benefits derived using a convergent shift in demand are larger (by 17%) than those for a parallel shift. Consumers' share of benefits is approximately twice as high for a convergent shift as for a parallel shift.

Linear supply and demand; imperfectly elastic supply of nonfarm inputs and marketing services; and no substitution between pigs and marketing services

A parallel shift in demand for pork due to reduced backfat depth is assumed. When the assumption of perfectly elastic supply of non-farm inputs and of marketing services is relaxed, producers' and consumers' benefits from reduction in fat depth in pork are lower (see Table 4). While the aggregate gain is insensitive to assumptions about supply elasticities, some of the benefits from research under those conditions are passed on to marketers and input suppliers. Marketers receive a larger share of research benefit than input suppliers because the marketing services industry is larger.

Non-linear supply and demand; perfectly elastic supply of nonfarm inputs and of marketing services; and substitution between pigs and marketing services

Again, the results reported for this combination of model specifications suppose a parallel shift in demand for pigmeat due to quality-improving research. Aggregate benefits for the linear and non-linear constant elasticity specifications are similar. However, for the limiting case of zero elasticity of substitution between pigs and marketing services, producers' share of research benefits is smaller by about 12 percentage points than with a linear specification of demand and supply, ceteris paribus (see Table 3). With increases in the elasticity of substitution, the producers' share of research benefits decreases and the consumers' share increases substantially. Again, the aggregate benefits are unaffected by changes in the elasticity of substitution.

13Our results are consistent with the finding of Alston and Scobie (1983) that the distribution of research gains in the multistage production system changes with the elasticity of substitution.
Table 1: Values of variables for the Australian pig industry

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>285.40kt</td>
<td>Commercial pork production (carcass weight)(^a)</td>
</tr>
<tr>
<td>F</td>
<td>285.40kt</td>
<td>Commercial pig production (in pig units)(^b)</td>
</tr>
<tr>
<td>M</td>
<td>285.40kt</td>
<td>Supply of marketing good and services (in marketing units)(^b)</td>
</tr>
<tr>
<td>P</td>
<td>$6.05/kg</td>
<td>Retail price of pork(^c)</td>
</tr>
<tr>
<td>P(_r)</td>
<td>$3.23/unit</td>
<td>Net farm value of pork(^d)</td>
</tr>
<tr>
<td>P(_i)</td>
<td>$0.65/kg</td>
<td>Value of nonfarm inputs(^e)</td>
</tr>
<tr>
<td>P(_m)</td>
<td>$2.82/unit</td>
<td>Value of marketing services(^f)</td>
</tr>
<tr>
<td>S(_f)</td>
<td>0.533</td>
<td>Share of farm product in the cost of the retail product(^g)</td>
</tr>
<tr>
<td>S(_m)</td>
<td>0.467</td>
<td>Share of marketing services in the cost of the retail product(^g)</td>
</tr>
<tr>
<td>(\eta)</td>
<td>-3.29</td>
<td>Retail demand elasticity for pork(^h)</td>
</tr>
<tr>
<td>(\eta_f)</td>
<td>-1.14</td>
<td>Wholesale demand elasticity for pork(^i)</td>
</tr>
<tr>
<td>(e_m)</td>
<td>2 or (\infty)</td>
<td>Elasticity of supply of marketing services(^j)</td>
</tr>
<tr>
<td>(e_s)</td>
<td>0.8</td>
<td>Farm supply elasticity for pigmeats(^k)</td>
</tr>
<tr>
<td>(w)</td>
<td>2.25 cents/kg</td>
<td>Elasticity of supply of nonfarm inputs(^l)</td>
</tr>
<tr>
<td>(\alpha)</td>
<td>0.011</td>
<td>Economic gain per unit of pork(^l)</td>
</tr>
<tr>
<td>(\sigma)</td>
<td>0, 0.2, 0.4, 0.6, 08, 1.0</td>
<td>Elasticity of substitution(^n)</td>
</tr>
</tbody>
</table>

\(^a\) From the Commodity Statistical Bulletin, 1988 quarterly publications.

\(^b\) Units of farm product and marketing services defined so all initial quantities are equal.

\(^c\) From Australian Bureau of Statistics (ABS), 1988 quarterly publications, 'Average retail prices of selected items'.

\(^d\) From Freebairn et al. (1982) and ABS.

\(^e\) Using nonfarm inputs as 20% of farm value.

\(^f\) \(P\(_m\) = P - P\(_f\)\).

\(^g\) Set to satisfy zero profit condition \((PQ = P\(_f\)F + P\(_m\)M)\) when initial quantities are all equal, using other appropriate data in the table.

\(^h\) From Pender and Erwood (1970).

\(^i\) From Hill (1967).

\(^j\) See text.

\(^k\) From Richardson and Connor (1978).

\(^l\) \(w = PPF(FPF - FPF)\)

\(^m\) \(\alpha = w/P\).

\(^n\) From Alston and Scobie (1983).
Table 2: Gains to Australian producers and consumers for 10% reduction in fatdepth in pork in the Australian pig industry (PV in millions of dollars summed over 30 years): linear supply and demand, perfectly elastic supply of nonfarm inputs and marketing services and no substitution between pigs and marketing inputs

<table>
<thead>
<tr>
<th>Demand Shift</th>
<th>Industry situation</th>
<th>Recipients of benefits&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Farmers</th>
<th>Consumers</th>
<th>Aggregate</th>
<th>Farmers' share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parallel</td>
<td>$e_i = e_m = \infty$</td>
<td>53.06</td>
<td>13.12</td>
<td>66.18</td>
<td>80.17%</td>
<td></td>
</tr>
<tr>
<td>Convergent</td>
<td>$e_i = e_m = \infty$</td>
<td>53.06</td>
<td>24.40</td>
<td>77.46</td>
<td>68.50%</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Estimation based on formulae 1-6 in text, using a discount rate of 10%.

Table 3: Gains to Australian input suppliers, farmers, marketers and consumers for 10% reduction in fatdepth in pork in the Australian pig industry (PV in millions of dollars summed over 30 years): linear supply and demand, imperfectly elastic supply of pigs and marketing services, and no substitution between pigs and marketing services

<table>
<thead>
<tr>
<th>Industry Situation</th>
<th>Recipients of benefits&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Input Suppliers</th>
<th>Farmers</th>
<th>Marketers</th>
<th>Consumers</th>
<th>Aggregate</th>
<th>Farmers' Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e_i = e_m = \infty$</td>
<td>0</td>
<td>53.06</td>
<td>0</td>
<td>13.12</td>
<td>66.18</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>$e_i = 2, e_m = \infty$</td>
<td>2.21</td>
<td>51.41</td>
<td>0</td>
<td>12.50</td>
<td>66.12</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>$e_i = \infty, e_m = 2$</td>
<td>0</td>
<td>46.11</td>
<td>8.59</td>
<td>1.25</td>
<td>65.92</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>$e_i = e_m = 2$</td>
<td>1.93</td>
<td>44.73</td>
<td>8.34</td>
<td>10.87</td>
<td>65.86</td>
<td>67</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Estimation based on formulae 18 to 22 in text, using a discount rate of 10%.

Summary and Implications

For a parallel shift in demand, all model specifications and parameter values indicate aggregate benefits of around $66 million over 30 years, or 2.2 million a year, from a 10% reduction in backfat depth. Pig producers receive 60% to 80% of these benefits. Benefits to producers and consumers are both reduced slightly if inputs are assumed to be in imperfectly elastic supply. The reductions in benefits to both groups are larger, but not substantial, under conditions of a rising supply price for marketing services. Allowing substitution to occur between pork and marketing services causes a moderate reallocation of research benefits from pig producers to consumers. The main implication of the analysis is for investment in reducing backfat depth in pork. Our results show that it is possible to invest up to $2.2 million per year in order to reduce fatdepth in pigs by 10% before this matched the aggregate benefits. With around 60% to 80% of benefits estimated to accrue to pork producers, it could be profitable for them to generate annual research and other expenditures up to about $1.5 million to obtain the reduction in backfat depth. It is recognised that the pig industry could sensibly spend less than $2.2 million a year if there is a lag between spending the money and achieving the fat reduction.

It is possible that there would be benefits additional to those considered in our analysis from a reduction in backfat depth in pork. These could arise from at least two sources. First, individuals might underestimate the benefits to their health from reducing their intake of fat. Admittedly, overestimation of these private benefits from reduced backfat is also possible.
Table 4: Gains to Australian pig producers and consumers for 10% reduction in fat depth in pork in the Australian pig industry (PV in millions of dollars summed over 30 years): non-linear supply and demand, perfectly elastic supply of nonfarm inputs and marketing services, and substitution between pigs and marketing services

<table>
<thead>
<tr>
<th>Assumed value for $\sigma$</th>
<th>Farmers</th>
<th>Consumers</th>
<th>Aggregate</th>
<th>Farmers' share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>45.62</td>
<td>20.78</td>
<td>66.40</td>
<td>68.70</td>
</tr>
<tr>
<td>0.2</td>
<td>44.00</td>
<td>22.39</td>
<td>66.39</td>
<td>66.28</td>
</tr>
<tr>
<td>0.4</td>
<td>42.50</td>
<td>23.89</td>
<td>66.39</td>
<td>64.02</td>
</tr>
<tr>
<td>0.6</td>
<td>41.09</td>
<td>25.31</td>
<td>67.80</td>
<td>61.60</td>
</tr>
<tr>
<td>0.8</td>
<td>39.77</td>
<td>27.86</td>
<td>67.63</td>
<td>59.80</td>
</tr>
<tr>
<td>1.0</td>
<td>38.53</td>
<td>27.86</td>
<td>66.39</td>
<td>58.04</td>
</tr>
</tbody>
</table>

* Estimation based on formulae 34 and 35 in text, using a discount rate of 10%.

Second, even if individuals are well informed of the health consequences of a change in the fat content of pork, the social benefits from reduced backfat may exceed the private benefits because of subsidies on health and medical services (Clements, 1983).

Being partial equilibrium in nature, our analysis has disregarded welfare effects in markets related to the pork market. Some general statements can, however, be made about the implications of a research-induced rise in the demand for pork for other markets. Downward shifts in the demand curves for international-traded meats which compete with pork have no effect on market prices or producer welfare under ‘small country’, free market conditions. However, lower demand curves for meats which substitute for pork involve reductions in consumer surplus in the markets for those commodities experiencing a downward shift in demand as a result of an improvement in pork quality, there would be welfare losses for both consumers and producers. While general equilibrium welfare effects in related markets may be considered relevant by governments in making decisions on demand-shifting research, they may be considered irrelevant by pig producers in allocating their own resources to research and to promotion.
References

ACIL (1985). 'A study of pig marketing in Australia'. ACIL Australia Pty. Ltd..


Appendix

Given that an increase in demand for carcasses at wholesale causes a proportionate increase in demand for pork at retail, thus:

\[
\frac{dQ_P}{Q_P} = \frac{dQ_C}{Q_C}.
\]

From Ladd and Suvannunt (1976), increase in consumption relative to quality improvement is calculated as follow:

\[
\frac{dQ_C}{dX_{CF}} = \left[\frac{-1}{du/dE}(du/dX_{CF})\right](dQ_C/dP_C)
\]

where \(\frac{dQ_C}{dP_C}\) is income compensated own-price substitution effect. Ladd and Suvannunt (1976) showed that \(-P_{CF}\) can be substituted for the term in brackets, thus:

\[
dQ_C = (-P_{CF})(dQ_C/dP_C)dX_{CF}.
\]

If both sides of the equation are multiplied by \(P_C/Q_C\), then:

\[
dQ_C = (-P_{CF} \cdot dX_{CF} \cdot \eta_C)Q_C/P_C
\]

where \(\eta_C\) is the income compensated own-price elasticity of demand for carcasses. Substituting this equation into the first equation, we have:

\[
\frac{dQ_P}{Q_P} = \frac{-P_{CF} \cdot dX_{CF} \cdot \eta_C}{P_C}
\]

From demand elasticity equation for pork, we have:

\[
\frac{dQ_P}{Q_P} = \eta P \frac{dP_P}{P_P}
\]

Equating this equation with the previous equation, we get:

\[
dP_P = \frac{-P_{CF} \cdot dX_{CF} \cdot \eta_C)P_P}{P_C \eta_P}
\]

Given that \(-P_{CF} \cdot dX_{CF}\) is \(w_c\) and letting \(dP_P\) be \(w_P\), we have:

\[
w_P = w_c\left(\frac{P_P}{P_C}\right)(\frac{\eta_C}{\eta_P})
\]
Figure 1. PARALLEL AND CONVERGENT SHIFT IN DEMAND DUE TO QUALITY IMPROVEMENT