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PESTICIDE REGULATIONS - MEASURING WELFARE COSTS WITH MARGINAL ANALYSIS

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Abstract:

Agricultural chemicals are an integral component of agricultural production in Australia and many other parts of the world. However, community attitudes are changing and concerns are being raised about the use of chemicals generally and the use of chemicals in the production of foodstuffs in particular.

Most agricultural chemical regulation in Australia goes on without any economic analysis. This project was started with a view to developing or adapting a methodology that would allow an easy assessment of the efficiency and equity effects of a change in the regulation provisions for an agricultural chemical.

The methodology that has been adopted is the marginal analysis approach expounded by Muth and used by Lichtenburg, Parker and Zilberman in similar studies in California. The methodology has been applied to two case studies to date - the effect of lowering the levels of cadmium in pig meat by banning the use of rock phosphate as a component of feed mixes and the impact of banning hormone growth promotants in the beef industry. The results of the cadmium study are reported in this paper. The study showed, as would be expected, that prohibiting the use of rock phosphate in pig diets in Victoria would cause only a very small increase in the price of pig meat. The more interesting question relates to the distribution of net social welfare between users, non-users and consumers; in this case consumers would bear most of the social cost of a change in policy.

1. INTRODUCTION

Agricultural chemicals are an integral component of agricultural production in Australia, although their usage is not usually as intensive as it is in many other parts of the developed world.

However, community attitudes are changing world-wide and concerns are being raised about chemicals use generally, and the use of chemicals in the production of foodstuffs specifically. Some of these concerns are founded on health grounds. In addition, as technology improves to enable the detection of smaller traces of chemicals people are becoming more aware of their presence and the impacts of agricultural chemicals on human and animal health, and the environment, are being revised. Concern is also generated by health and environmental lobby groups who, although they have genuine concerns, do not usually have any scientific evidence to support them. Other concerns about agricultural chemicals are political; with the move to lower tariffs and abolish quotas in the international trade in agricultural products some countries are in the process of imposing non-tariff trade barriers in the form of bans on various chemicals in imported foodstuff. For example, the EC recently banned the import of beef produced with the assistance of growth promotion hormones.

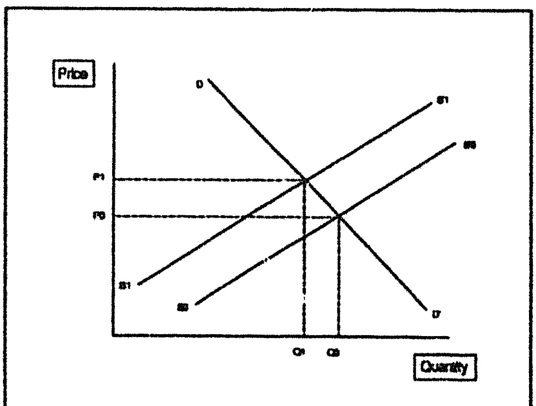

Figure 1: Effect of Increased Costs of Production.

A change in the use of chemicals for the production of an agricultural good will, with existing technology, cause a shift in the supply curve of the good. Assuming that producers are profit maximisers, then any change in their mix of inputs such as a restriction on the use of a particular chemical, will cause a contraction in supply due to increased production costs. In a market-clearing situation there will an increased price and reduced demand for the product. (Refer Figure 1).

The United States Federal Food, Drug and Cosmetic Act stipulates that tolerances for pesticide residues on raw commodities are "to be set at levels deemed necessary to protect public health, while taking into account the need for an adequate, wholesome and <u>economical</u>[1] food supply" (National Academy of Sciences, 1987, p.1). Thus, their act explicitly recognises that the use of agricultural chemicals imposes both benefits and risks and both should be taken into account in setting tolerance levels.

In Australia the emphasis appears to be placed on toxicity and efficacy rather than considering the benefits that might be derived from allowing specified uses of a particular chemical; benefits that may outweigh the risks in some circumstances.

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[1] Authors emphasis.

The objective of this project was to develop and/or adopt a methodological approach for determining the costs and benefits to Victoria and Australia of restricting agricultural chemicals. It was developed in response to the Governments "Economic Strategy for Agriculture" (Victorian Govt. 1988) in which one of the major strategies was Cleaner Agriculture:

> "The continuing concern about chemical resolves in food warrants special attention. It is essential that public health problems are not created through residues in food. In addition, valuable export markets for Australian products would be a risk if more stringent controls were imposed by overseas countries on food and fibre that contain residues" (p.39).

The output from this project should go some way toward providing a balance to this approach by allowing an assessment of the costs of restricting the use of an agricultural chemical and providing an estimate of the distribution of these costs between different groups of producers and between producers and consumers.

The methodology adopted here has been applied to the problems of cadmium levels in pig meat and concerns over the use of hormone growth promotants in the beef industry. This paper contains a summary of the cadmium study in section 4 following section 3's outline of the approach.

2. BACKGROUND

A number of different methods have been used to estimate the benefits and costs to society of regulating the use of specific chemicals in agriculture. These methods range from simple budgeting approaches to complex econometric and mathematical modelling.

The most popular method is the partial budgeting approach (e.g. Krystynak,1983; Dunnett,1983). The budgeting process involves the evaluation of expected inputs, outputs, costs and revenues resulting from the banning of a pesticide. This simple approach clearly indicates how the results are obtained, which is an advantage if the results need to be explained to and understood by decision makers who are not familiar with economic analysis techniques. The method is also suggested to provide a guide for collecting, organising and analysing data. While this approach is commonly used when making individual farm management decisions it has some limitations when aggregated to a national level in that it can not be used to predict changes in:

- planting decisions;
- pesticide prices; or
- commodity prices.

The mathematical programming approach is very appealing because it is possible to make the objective function either the minimisation of the social cost of using a chemical or the maximisation of consumers' and producers' surplus. The more sophisticated of these models cover the whole of the agricultural sector and are capable of analysing national and regional economic consequences of restrictions on chemical usage (e.g., Burton and Martin, 1987).

An interesting alternative approach, which is based on the use of an econometric model and marginal cost analysis, estimates net social welfare costs and their distribution using only information on price, quantities, elasticities of supply and demand, and estimates of cost and/or yield effects of the policy initiative (Lichtenberg, et al., 1988).

Risk-benefit analysis has also been used by some researchers. However, as risk-benefit analysis is a descriptive rather than a formal economic analytical method, it does not provide a quantitative answer on the effects of a regulation, though it could logically provide a framework within which relevant data (concerning a request to deregister a particular pesticide) could be organised and analysed, for example by including a formal analytical method such as an econometric model or a partial budgeting analysis.

3. A MARGINAL ANALYSIS APPROACH[2]

The marginal analysis approach was chosen for this study because it can still allow the estimation of disaggregated welfare effects if applied to data on supply and demand elasticities, price, quantities, and the estimated costs and yield effects of the policy.

The procedure proposed by Lichtenberg *et al* has three components:

(i) estimate changes in the equilibrium price and quantities produced in each region using the method of Muth (1964). (This gives a good approximation for small changes.)

(ii) estimate the change in consumers' and in producers' surplus for producers indirectly affected by the policy (i.e. current non-users of the chemical in question) assuming that the demand and supply curve of these agents are linear. (Again, this method given a good approximation for small changes.)

(iii) estimate the changes in producers' surplus for those producers directly affected by the policy (i.e. those producers currently using the chemical in question), under the additional assumption that the policy induces parallel shifts in their supply curves.

The method can be expressed as follows:

- Assume (i) K groups of producer
  (ii) K_1 groups directly affected by a policy change, leaving $K-K_1$ groups unaffected

[2] This section draws heavily on Lichtenberg *et al* (1988).

(iii) 2 groups of consumers (domestic and foreign) for the sake of simplicity but with no loss of generality.

- Neo-classical theory suggests that all producers will adjust output to equate marginal cost and price. That is, producers are profit maximisers and will produce until the marginal cost of each unit equals the price received.

- Market clearing implies that supply and demand equate.

Thus:

$$
\begin{aligned}
MC^k(Q_k,a_k) &= P \quad k = 1 \ldots K_i \\
MC^k(Q_k) &= P \quad k = K_i+1 \ldots K \\
D^d(Q_d) &= P \\
D^e(Q_e) &= P \\
Q_1 + \ldots + Q_k &= Q_d + Q_e
\end{aligned}
\tag{1}
$$

where
- MC^k = marginal cost function
  = inverse supply function
  = $S^{-1}(q) = P$
- Q_k = output of group k
- D^d = inverse domestic demand
  $[Q_d = D(P_d)$ so $P = D^{-1}Q(_d)]$
- Q_d = domestic consumption
- D^e = inverse export demand
- Q_e = export volume
- a_k = shifter expressing impact of proposed policy on MC function of group k

Totally differentiating this set of equations, and using the fact that the marginal cost function is the inverse supply function, gives the impact of the proposed policy change on price and output. Thus:

$$
\begin{aligned}
(1/e_k)(P/Q_k)dQ_k - dP &= MC^k_a da_k \quad k = 1 \ldots K_i \\
(1/e_k)(P/Q_k)dQ_k - dP &= 0 \quad k = K_i+1 \ldots K \\
(1/e_d)(P/Q_d)dQ_d - dP &= 0 \\
(1/e_e)(P/Q_e)dQ_e - dP &= 0 \\
dQ_1 + \ldots + dQ_k - dQ_d - dQ_e &= 0
\end{aligned}
\tag{2}
$$

where
- e_k = supply elasticity of group k
- e_d = elasticity of domestic demand
- e_e = elasticity of export demand

If we can obtain estimations of the impacts of the proposed changes on the marginal costs of producer group K ($MC^K_a da_k$), then this second system of equations can be solved to obtain estimates of the impacts on:

- price (dP)
- output of different producing groups (dQ_k);
- foreign and domestic consumption (dQ_e dQ_d); and thus
- post policy change equilibrium price and output levels.

The impacts of the policy change on the welfare costs of different groups can then be estimated.

The effect on current non-users and consumers' welfare can be estimated under the assumption that supply and demand are approximately linear around the pre-policy change equilibrium.

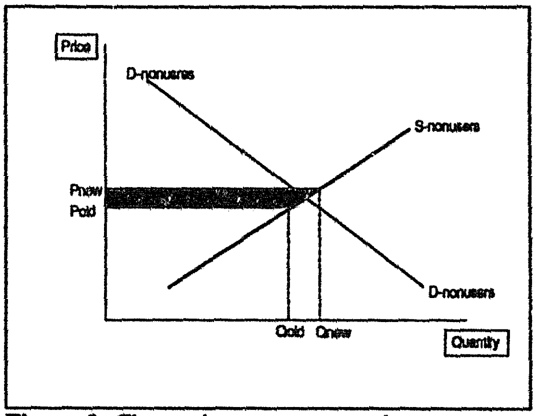

Figure 2: Change in non-users surplus

Change in non-users surplus

$$= dP(2Q_k + dQ_k)/2 \quad (3)$$

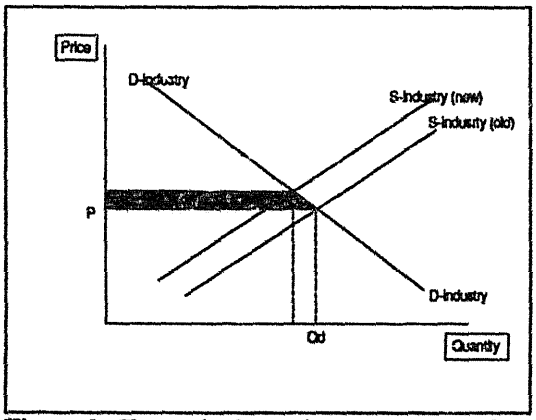

Figure 3: Change in domestic consumers surplus

Change in domestic consumers surplus

$$= -dP(2Q_d - dQ_d)/2 \quad (4)$$

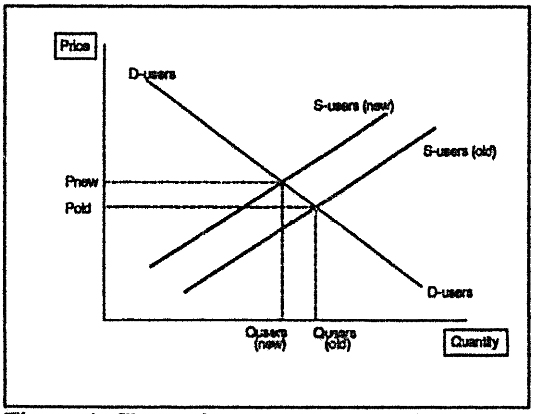

Figure 4: Change in current users surplus

Change in current users surplus

= (change in revenue)

- (change in chemical use costs)

+ (cost savings due to decreased output)

$$= (P+dP)(Q_k+dQ_k) - PQ_k - dC_k(Q_k+dQ_k)/Y_k + PdQ_k \qquad (5)$$

under the implicit assumption that the policy change causes a parallel shift in the current-users' supply curves.

The net change in domestic welfare is the sum of the change in producers' and consumers' surplus. The change in export revenues is the difference between the new revenue and the old revenue:

$$(P + dP)(Q_c + dQ_c) - PQ_c$$

If the policy change only affects costs, then the change in marginal cost in the kth region can be estimated as the change in cost per ha divided by the yield per ha:

$$MC^k{}_a da_k = dC_k / Y_k$$

However, if the policy change affects both yield and price then the marginal cost change in the kth region becomes:

$$MC^k{}_a da_k = [P(dY_k/Y_k) - dC/Y_k] / [1 - dY_k/Y_k]$$

The implementation of this model into an easy to solve spreadsheet is described in the next section.

3.1 The Spreadsheet Model

Modem spreadsheet packages have a number of matrix manipulation features that make the solution of simultaneous equations relatively straight forward. The particular spreadsheet used for this project was Quattro® Pro from Borland.

First, the set of simultaneous equations (2) can be represented in matrices format as follows:

$$A_{ii} * X = A_{ij}X$$

$$\begin{bmatrix} (1/e_u)(P/Q_u) & 0 & 0 & 0 & -1 \\ 0 & (1/e_n)(P/Q_n) & 0 & 0 & -1 \\ 0 & 0 & (1/e_d)(P/Q_d) & 0 & -1 \\ 0 & 0 & 0 & (1/e_e)(P/Q_e) & -1 \\ 1 & 1 & -1 & -1 & 0 \end{bmatrix} * \begin{bmatrix} dQ_u \\ dQ_n \\ dQ_d \\ dQ_e \\ dP \end{bmatrix} = \begin{bmatrix} -MC_u \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

To solve the **X** matrix, which gives the changes that will occur in the quantities demanded and supplied and the change in price paid for the product, the inverse of the A_{ij} matrix is multiplied by the $A_{ij}X$ matrix. In matrix notation:

$$A_{ij} * X = A_{ij}X$$
$$\Rightarrow \quad A_{ij}^{-1} * A_{ij} * X = A_{ij}^{-1} * A_{ij}X$$
$$\Rightarrow \quad X = A_{ij}^{-1} * A_{ij}X$$

The elements of the **X** matrix can then be substituted in the equations for producers' and consumers' surplus (equations (3),(4) and (5)).

The use of spreadsheets for the manipulation of this matrix formulation of the simultaneous equations was validated by comparing the spreadsheet formulation estimates with estimates from a number of problems investigated by Lichtenberg *et al* (1897, 1988).

Lichtenberg *et al* (1988) estimated the welfare costs of cancelling parathion on three different tree crops grown in California and the spreadsheet model described above was tested against their reported results.

The first crop was plums, and almost the entire US plum crop is grown in California and consumed domestically so that they only needed to consider three groups of economic agents (domestic consumers, current parathion users, and those producers not currently using parathion). The second crop was almonds and, like plums, the entire crop is grown in California. However, its consumption differs in that almost 80% of the crop is exported. The third crop considered by Lichtenberg *et al* was prunes with nearly 90% grown in California but significant amounts produced in other states.

Using Lichtenberg's data we were able to reproduce his results almost identically for the plum and almond crops and within ten percent for the prune crop[3].

4. RESTRICTING THE USE OF CADMIUM CONTAINING ROCK PHOSPHATE IN PIG DIET FORMULATIONS - A CASE STUDY

In this case-study the economic impact of restricting the exploitation of rock phosphate (containing cadmium) additions to pig diets as a mineral supplement, is examined.

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[3] Lichtenberg has advised us of one error in the reported data for the prune crop and there may be others.

4.1 Cadmium

Cadmium was discovered in 1817 and has since become important because of the range of applications of its metal products. As a metallic element, cadmium occurs in trace concentrations in most soils. Application of phosphate fertilisers may increase the concentration of cadmium in soil (Cook and Freney, 1988). Cadmium concentrations in food products can be related to the amounts of cadmium taken up by plants from soil (Tiller, 1988), by grazing animals via plants or soils, and via feed ingredients (e.g. rock phosphate) forming minerals supplements in the intensive livestock industry. Animals protect themselves against cadmium intoxication by forming complexes between cadmium and the metal-binding protein, metallothionein (Langlands, 1988). These complexes are accumulated in the liver and kidney, and cadmium is only slowly excreted. As a result the cadmium burden is accumulated throughout life, so its concentration in the liver and kidney is generally greater in older animals. The National Residue Survey found the highest values of cadmium in sheep liver in Western Australia and South Australia where a relatively high proportion of aged females were among sheep slaughtered for export (Tweddle, 1989).

Health authorities in many parts of the world are becoming increasingly concerned about the effects of cadmium on human health. Cadmium is toxic to virtually every system in the human body. When absorbed into human bodies it accumulates, mainly in the liver and kidneys, and is excreted only slowly. Consequently, if it is absorbed over a sufficiently long time, even in small quantities, cadmium concentration in the body can build up to toxic levels. Humans ingest cadmium with food and inhale it with tobacco smoke. In some countries contaminated air and drinking water near industries processing materials containing cadmium may be additional sources of cadmium.

From experiments with animals and clinical studies on human beings it is concluded that diseases in which cadmium is the causal or contributing factor are renal diseases, osteoporosis, "Tai-tai" disease (Japan), and possibly cancer of the prostate (Black, 1988).

Since the 1970's developed countries have attempted to control the dispersal of cadmium in order to reduce human exposure to it. For example the European Community has set limits for cadmium in foodstuffs. The USA, Canada, and some other countries prefer to regulate contaminating releases of cadmium; they possibly regard cadmium in food limits as impracticable (Walker, 1988).

The Department of Primary Industries and Energy has monitored harmful residues in agricultural commodities since the 1960's as part of its export inspection procedures, and since 1985 for the domestic market. Monitoring of cadmium in meat was added to the National Residue Survey in the late 1970's. Monitoring has been against stringent standards (maximum permissible concentrations) set on advice of the National Health and Medical Research Council.

The National Residue Survey (NRS) in 1981 and 1988 (Table A1) showed significant proportions of meat products, some grains, and some vegetables exceeding the maximum permissible concentrations (MPC) for cadmium (Morgan, 1989). Differences were observed between regions and class of animals and types of grain and vegetables. In March 1988 the National Symposium on Cadmium Accumulations in Australian Agriculture in Canberra (Simpson & Curnow, 1988) gave serious consideration to the causes of cadmium accumulations. Participants noted that little systematic research had been done on cadmium in agriculture.

Given that much of Australian's agricultural production is exported, if other countries impose stringent limits on the cadmium content in foodstuffs, then there could be difficulties created for some of Australian exports. Thus, Australia might need to introduce stricter monitoring and control of cadmium contents in agricultural exports in the future.

4.2 Pig Industry

A. Production

The Victorian pig industry produces pig meat primarily for domestic consumption. In 1987/89 there were 938.2 million pigs slaughtered in Victoria, or 19% of the national total.

The Victorian Department of Agriculture estimates that about 35% of these pigs were transported from New South Wales and South Australia for slaughter in Victoria. Victoria is the third largest pig-producing State (Table A2). In 1987/88 a total of 54,327 tonnes carcass weight were produced, representing 18% of the national total.

B. Consumption

Per capita consumption of pig-meat reached the highest level ever at 17.1 kg in 1987/88 (Table A3). Consumption of pig-meat has been expanding slowly over the last five to six years. This expansion is partly explained by the relative price of pig-meat in comparison to the prices of other meats (beef and lamb) which increased sharply in 1983 and 1984 and then again in 1987.

Consumption of pig-meat has also been influenced by the intensive promotional efforts of the Pigmeat Promotion Committee and by the development of more consumer-oriented cuts of pork. Normally, less than 3% of pig-meat is exported annually.

C. Victorian Industry Structure and Location

About 65% of the State's pigs are located in the Loddon-Campaspe and Goulburn statistical divisions, where the biggest pig farms are located.
The heavy concentration of pigs in the central northern region is related to access to feed grains and water, and availability of large tracts of open land suitable for disposal of pig effluent.

The industry's trend in development is towards concentration and intensification. The number of pig establishments declined from 2,239 to 947, or by 58% in the ten-year period ending 1988. During the same period total number of pigs increased by 30%, from 331,489 to 437,167 and the average herd size increased from 150 to 461 pigs. Since the mid-1960s the pig industry has become increasingly capital intensive.

In the ten-year period ending 1988, there was an evident Victorian trend toward increasing the number and size of "corporate integrated piggeries" and falling number of non-commercial holdings.

4.3 Empirical Analysis

Rock phosphate is a common additive in the formulation of pig diets as a source of calcium and phosphate. The marginal analysis model was used in this study to evaluate the welfare costs of prohibiting the use of rock phosphate as a component of pig diet. The inclusion rate of rock phosphate in pig diets is limited to 1% for grower pigs, and 0.5% for breeding stock because of high fluorine levels. There is evidence (Denis Tracey, personal communication) that rock phosphate sources low in cadmium are high in fluorine content (3.5-4% fluorine compared to around 1.8% in rock phosphates with high level of cadmium). For animal health reasons, the maximum inclusion rate of fluorine in pig diets is 220mg per kg of feed. (Note that a 1% inclusion rate of rock phosphate sample of 3.5% fluorine will give a fluorine content in the diet of 350mg/kg).

There are alternatives to rock phosphate as calcium and phosphate supplements - examples are bone char and dicalcium phosphate. The least cost pig diet (Table A4) for each category was formulated by DARA officers in the Bendigo office on the basis of the availability of feed ingredients for pigs on the market.

In the first column of Table A4 the restrictions which were stated are :

- rock phosphates and bone char inclusions in the diets to be less than 1 per cent per tonne of the pig diet.

In the second column of the table the restrictions are:

- 0.5 per cent for rock phosphates,
- 1.0 per cent for bone char.

In the third column the rock phosphates are restricted to zero, and bone char to 1 per cent.

Replacing rock phosphate with bone char will increase the cost of the diet by about 1 percent. The difference in costs between restricted (zero per cent) and unrestricted (1 per cent) rock phosphates (Tables A4 and A5) in pig diets are \$226.54 - \$224.23 = \$2.31 per tonne of food in average of pigmeat production. But bone char is not included in any type of the diet for "starters" since it is too expensive (\$350/tonne). At 1989 prices if the price of bone char was less than \$310.19/t, it would be included in the diet of the "starter". Availability of bone char on the market is another problem. Even at a price of \$350/t bone char availability on the market in September 1989 was scarce. However, bone char's availability at only \$200/t was good in 1984. The price of bone char (\$350/t) is too high even for the diet of "growers" if rock phosphates are unrestricted (first column Table A4) In the diets of other categories the inclusion of bone char depends on the prior restrictions on the use of rock phosphates.

Dicalcium phosphate as a substitute for rock phosphate is excluded from pig diets in each category because of its price ($650/ton in 1989).

The calculation of average feed costs of the pig diets is provided in Table A5. The average costs of pig diet with unrestricted rock phosphates are $224.23; with partially restricted rock phosphates the average costs of pig diets are $225.22; and with total restriction of rock phosphates the average costs are $226.54.

Generally, rock phosphates are used in the production of (about) 80% of whole pigmeat production (54,327t in 1987/88). The coefficient of 4.5 is used to calculate the cost of meat from the cost of feed (see Tables A5 and 1). Cancelling rock phosphate as an ingredient in pig diets would increase the production costs of pigmeat by $10.39 per tonne in Victoria.

For this study the elasticity of supply and elasticity of demand for pigmeat in Victoria (Australia) were taken as E_s=5.0 (Wilcox 1985) or E_s=0.5 (West 1980 and Griffith & Gellatly 1982) and E_d=-1.5 (Cashin 1989).

Table 1. Cadmium in Pigmeat - Parameters for Marginal Analysis Model

Variable	
Total production of pigmeat (tonnes)	54,327.00
Pigmeat quantity produced by users of rock phosphates (tonnes)	43,462.60
Pigmeat quantity produced by non-users of rock phosphates (tonnes)	10,865.40
Share of production by users	0.80
Price of pigmeat ($/kg)	1.92
Elasticity of domestic demand	-1.50
Elasticity of demand for export	0.00
Elasticity of supply:	
Run 1.	5.00
Run 2.	0.50

4.4 Results from the Cadmium Study

The results from the estimation are as follows:

Firstly, the impact of cancelling rock phosphate in pig diets would increase the saleyard price of meat by 0.64 cents per kg, decrease annual consumption of pig meat by 271.4 tonnes, increase production of pig meat by non-users of rock phosphate by 181.0 tonnes but decrease production by users of rock phosphate by 452.3 tonnes. It may be said that the effect of cancelling of rock phosphate is very small, since production by non-users would increase only by 1.8 percent, production by users would decrease by 1.5 percent and consumption would decrease by 0.5 percent.

Table 2. Welfare Costs of Cancelling Rock Phosphates

Variable	Model - supply elasticity	
	equal to 5.0	equal to 0.5
Market impact		
Change in marginal cost ($/tonne)	10.39	10.39
Change in price (c/kg)	0.639	0.208
Change in users (of rock phosphates) output (tonnes)	-452.3	-94.2
Change in non-users output(tonnes)	180.9	5.9
Change in consumption (tonnes)	-271.4	-88.3
Impact on current users		
Change in revenue ($)	-590.000	-91.000
Change in costs of calcium and phosphorus supplements($)	+447.000	+451.000
Change in other costs($)	-870.000	-180.000
Change in producers' surplus($)	-167.000	-360.000
Impact on current nonusers		
Change in producers' surplus($)	+70.100	+22.600
Impact on domestic consumers		
Change in consumers' surplus($)	-350.000	-110.000
Net welfare impacts		
Change in domestic surplus($)	-450.000	-450.000
Change in world surplus($)	-450.000	-450.000

Secondly, the policy effect on the marginal cost of production estimated as dC_ux4.5 (change in food cost per tonne times coefficient (4.5) - feed used per meat production), was estimated at $10.39 per tonne of pig meat.

Thirdly, the effects on the welfare of current non-users and domestic consumers was estimated under the assumption that supply and demand are linear around the equilibrium point. (Figure 1 and 2)

The change in non-users' producer surplus is estimated as:

$$dP(2Q_{onu}+dQ_{nu})/2 = \$70,100 \text{ per year.}$$

where $dQ_{nu} = Q_{1nu} - Q_{onu}$

The change in domestic demand surplus is estimated as:

$$- dP\ (2Q_{od} - dQ_{d})/2 = -\$350,000 \text{ per year.}$$

The change in current producers surplus is estimated as the sum of the change in revenue, the change in feed costs, and the cost savings due to the reduction in output:

$(P_o+dP)\ (Q_{ou} + dQ_u) - P_oQ_{ou}$	= -\$590,000
$-dC_u\ (Q_{ou} + dQ_u)$	= -\$447,000
$-P_o * dQ_u$	= +\$870,000
Equals	= -\$167,000

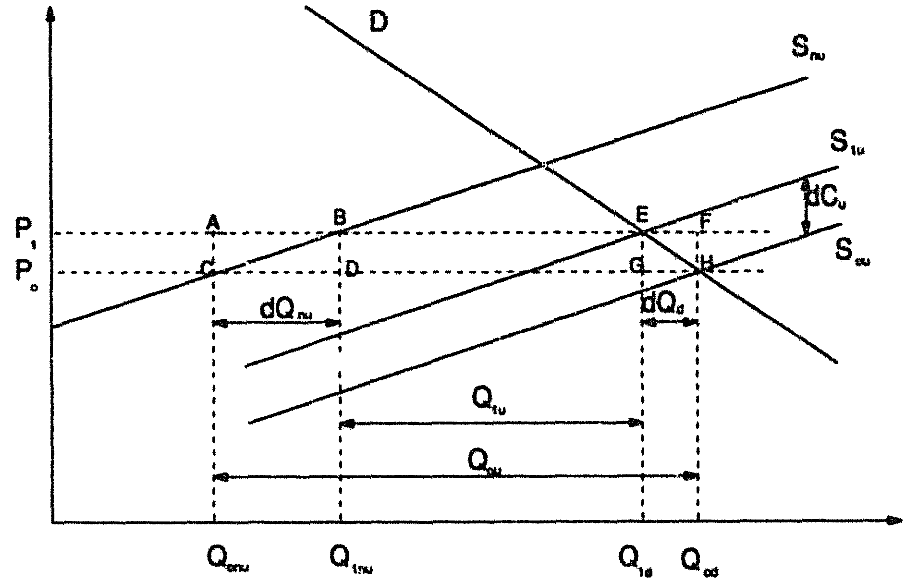

Figure 4: The effect of cadmium exclusion from pig diets on consumer and producer surplus

In Figure 5 the supply curve S_{nu} describes the supply of pigmeat by rock-phosphate non-users. The supply curve S_{ou} describes the total supply of pigmeat before the prohibition of rock phosphates; the supply curve S_{1u} describes the total supply of pigmeat after the prohibition of rock phosphates in pig diets. The supply of pigmeat by rock phosphates users is described by the differences between S_{ou} (S_{1u}) and S_{nu}, then $[S_{ou}$ (or S_{1u}) $- S_{nu}] = S_{users}$.

Before the prohibition of rock phosphates in pig diet the total supply of pigmeat is depicted by the supply curve S_{ou}. The demand is described by the demand curve D, and the total consumption is Q_{od} at the price P_o. The supply of pigmeat by non-users of rock phosphates is depicted by the supply curve S_{nu}. S_{nu} describes the supply of pigmeat by non-users before and after prohibition of rock phosphates. Before the prohibition of rock phosphates in pig diet the quantity of supply by non-users is Q_{onu} at the price P_o and the quantity of pigmeat supply by users of rock phosphates is $Q_{ou} = Q_{od} - Q_{onu}$.

If rock phosphates are prohibited in pig diet the costs of production for users of rock phosphates would increase by dC_u and the total supply curve is shifted to S_{1u}. The total consumption of pigmeat after prohibition is decreased to Q_{1d} at the price P_1. The supply of pigmeat by non-users of rock phosphates is increased to Q_{1nu} at the price P_1; and the supply of pigmeat by users of rock phosphates is decreased to $Q_{1u} = Q_{1d} - Q_{1nu}$.

The loss in social surplus is $450,000 per year if rock phosphates are prohibited for use in pig diet for meat production. Consumer's loss is $350,000, which in Figure 5 is depicted by the rectangle $P_1EHP_o = -dP\ (2Q_{od} - dQ_d)/2$. Non-users of rock phosphates gain $70,000 per year after prohibition. The gain is depicted in Figure 5. by $P_1ACP_o + ABC = dP\ (2Q_{onu} + dQ_{nu})/2$.

Producers, who are users of rock phosphates will suffer losses of $167,000. The loss is calculated as change in revenue, change in the cost of calcium and phosphorus supplements and the change in other costs.

The change in revenue is calculated as $(P_o + dP)(Q_{ou} + dQ_u) - P_oQ_{ou} = Q_{1nu}BEQ_{1d} - Q_{onu}CHQ_{od}$ in Figure 5, where $dQ_u = dQ_d - dQ_{nu}$. The loss in revenue is $590,000 for users of rock phosphates as producers of pigmeat.

The costs of the replacement of inputs (rock phosphates) as supplements of calcium and phosphorus is increased by $447,000 for producers (users). The cost is depicted in Figure 4 as:
$dC_u(Q_{1d} - Q_{1nu}) = -dC_u\ (Q_{ou} + dQ_u)$.

The change in other costs $(-P_o * dQ_u)$ = $870,000 is the costs which producers (users of rock phosphates) do not bear because the quantity of their production decreased by $dQ_u = dQ_d + dQ_{nu}$. In the Figure 4 the other costs to users are depicted as $(Q_{onu}CDQ_{1nu} + Q_{1d}GHQ_{od}) = Q_{ou} - Q_{1u}$.

The total loss in social surplus does not change if the elasticity of supply for pigmeat has changed from E_s=5.00 to E_s=0.50 (Table 2). However, the income among different social groups (producers and consumers) is changed.

The total loss in social surplus is $450,000 in each model, but consumers are losing only $110,000 in the model with E_s=0.50. The consumers loss makes sense since the retail price of pigmeat is increased only by 0.21 c/kg in the model with E_s=0.50 in comparison to 0.64 c/kg in the model with E_s=5.00.

The social loss of producers (users of rock phosphates) is \$360,000 if supply elasticity E_s=0.50. The decrease in revenue ($Q_{1mu}BEQ_{1d}$ - $Q_{omu}CHQ_{od}$) = \$91,000, and the decrease in the other costs ($Q_{omu}CDQ_{1mu}$ + $Q_{1d}GHQ_{od}$) = \$180,000 is much lower than in the previous model (E_s=5.00). On the other hand, the increase in the cost of calcium and phosphorus supplement does not make the real difference between the models (\$4,000).

The reason for such small difference is:

1. the marginal costs of the change of inputs in pig diet is the same (\$1,039 per kg) in both models,
2. the change in the quantity of pigmeat supply is very small as the proportion of total quantity of pigmeat supply (0.9 per cent in the model with E_s=5.00, and 0.2 per cent in the model with E_s=0.50).

These results suggest that a major impact of environmental policies affecting agriculture may well be the redistribution of income among different groups of the community. A corollary is that consumers may bear most of the social cost of these policies. In this case study consumers pay about 78% of the loss in net social surplus. Analysis of comparison of two models with different elasticities of supply (5.0 and 0.5) for pig meat shows that consumers' losses increases if supply becomes more elastic. (In the case of E_s=0.5 the consumers' loss is only 24% of net social surplus). Moreover, consumers bear 0.64 c/kg of the increase in costs of pigmeat production (1.039 c/kg) in the model with supply elasticity equal 5.0; but, they bear only 0.21 c/kg of the increase in costs of pigmeat production in the model with supply elasticity equal 0.5.

The extent to which users lose and nonusers gain from prohibiting rock phosphate usage depends on the elasticities of supply and demand. In this case with a high elasticity of supply (5.0) the ratios of non-users' gain to users' loss is 0.42 and with a low elasticity of supply (0.5) the ratio is 0.06. The result is similar to Lichtenberg et al's (1988) finding in that the ratio of non-users' gains to users' losses is monotonically increasing with respect to elasticity of supply.

Furthermore, the results show that with the change of elasticity of supply the cost of pigfeed changes very little, but the change in revenue and in cost saving due to decreased production is very large.

4.5 The Welfare Effect - An Alternative View

Generally, the cost-benefit analysis points out gainers and losers in the community who are affected by a recommended policy change. In the case of chemicals as dangerous goods the impact of the change in policy (regulation of rock phosphates application in pig diets) on the welfare of the community might be in the opposite direction than it would seem from the result of the study.

Consider, that consumers accepting chemically treated foods are always under the risk of damaging their health. In that case they pay less for foods now (if food grown with chemicals is less expensive than otherwise), but in the future private and public costs may be incurred for medical treatment and/or disabilities. Thus one may argue that the community subsidised consumers allowing them to consume commodities containing chemicals (dangerous goods).

Subsidies distort a market. In this case it is its supply side which is distorted through production which uses cheaper inputs (rock phosphates). Production costs are lower if producers are using rock phosphates, but because of that the distortion exists in the market of inputs in pig diets. Thus, if the community allows the application of rock phosphates in pig diets in fact they are subsidising producers of those inputs and consequently users of rock phosphates in pig diets. In such a case the losers are non-users of rock phosphates, though before the recommended policy change (prohibition of rock phosphates) they should be compensated. Therefore, if rock phosphate application in pig diets is prohibited, non-users would be compensated because they will get their share on the market. Compensation of producers (users of rock phosphates) and consumers should not be approved because in the case of rock phosphates, before the policy change (prohibition of rock phosphates), they were subsidised and a loser was the whole community.

Asserting that one may derive similar policy to chemicals control as Reichelderfer (1990), senior fellow at Resources for the Future's (RFF) National Center for Food and Agricultural Policy. She argues that market incentives might possibly achieve better risk reduction at lower cost than regulations, explaining:

> "For example, quotas for maximum level of pesticide risk could be allocated to users who could choose to employ or sell their rights to pesticide use. Or, manufacturers could be taxed on the basis of quantity of risk their products pose, with rebates offered for those who develop less risky substitutes."

In our opinion such a source of public revenue should be used to support the research and development of new technologies, innovation and invention to slow the environmental or health damage.

4.6 Implications and Conclusions

Four general conclusions can be drawn from this analysis. First, the case study demonstrates the use of Lichtenberg et al methodology for estimating the welfare costs of environmental policies affecting agriculture. Second, consumers' share in bearing the social cost may reach 75-90% when supply elasticity is very high and demand is quite inelastic. Third, the ratio of non-users' gains to users' loss is increasing with respect to elasticity of supply. Finally, the users' cost of calcium and phosphorus supplements change very little with higher elasticity. However, the change in users' revenue (a decrease) and saving cost on pigfeed (an increase) due to production is very large.

5. CONCLUSIONS

An attempt was made to develop or adopt a methodology for assessment of the efficiency and equity effects after a change in government regulations aimed at achieving environmental and social goals. The initial step was to define the problem to be investigated using methodology of marginal analysis developed by Muth and applied by Lichtenberg, Parker and Zilberman.

The marginal analysis approach has been applied to two case studies - the effect of banning the use of rock phosphate, containing cadmium in pig diets (reported in this paper), and the effect of banning hormonal growth promotants as sources of human health risk and the adverse health side-effects of animals.

This study showed, that prohibiting the use of rock phosphate in pig diets in Victoria would cause only a small increase in price of meat (0.64 cents per kg) and decrease consumption by 0.5 per cent (271.4 tonnes). The effect of prohibiting the use of rock phosphate is very small on production as well; non-users would increase their production by 1.8 per cent (121.0 tonnes), users would decrease their production by 1.5 per cent (452.3 tonnes).

The preliminary study of hormonal growth promotants (HGP's) shows, that the effect of prohibiting hormones in production of beef meat in Australia depends on the length of the period estimated. Generally, the effect is higher in longer terms; e.g. an increase in price of 20 cents per kg in the long term (10 years) and practically no change in the short term (1 year). However, the main reason behind the HGP's study is to estimate the effect of a ban on Australian exports of beef meat as a result of Australian use of these chemicals. The study shows, that the effect of banning HGP's would be minimal (about $7 million in the long term). However, of more importance is the estimate of the effect of an HGP's ban in the medium term (5 years) which shows that Australian exports of beef meat would not be affected by the ban; export would increase by $0.5 million to about $1.8 billion of total beef meat exports.

The results of both studies suggest that a major impact of environmental policies affecting agriculture will be the redistribution of income among different groups of the community. The main losers would be consumers who may bear most of social cost (70 - 90 per cent) of the loss in net social surplus.

The marginal analysis approach described in this paper provide an easy method to estimate disaggregated welfare effects of changes in regulations affecting agricultural production with a minimum of data collected without regards to economic needs.

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7. APPENDICES

APPENDIX A

Table A1. Pilot Survey 1988/89

Commodity	No Tested	50-100%MPC of Cadmium	Over MPC of Cadmium
Meat:			
- Beef Kidneys	104	3%	2%
- Sheep Kidneys	109	6%	3%
- Pig Kidneys	158	8%	2%
Grains:			
- Wheat	86	24%	0
- Barley	35	34%	0
- Oats	27	22%	15%
- Oilseeds	2	10%	5%
Vegetables:			
- Tomatoes	18	17%	0
- Potatoes	32	34%	28%
- Carrots	31	52%	10%
- Onions	16	31%	19%
- Sweet Potato	32	34%	28%

MPC = Maximum Permissible Concentration

Table A2. Number of Pigs Slaughtered and Pig Meat Produced 1987/88

	NSW	VIC	QLD	SA	WA	TAS	AUST
Number of pigs slaughtered (millions)	1,596.0	938.2	1,113.5	602.2	507.6	97.5	4,923.3
Red meat produced (ton.)	96,894	54,327	69,454	36,671	29,393	5,973	296,769

Source: ABS Cat. No. 7215.0 - Livestock Products, Australia - July 1989

Table A3. Australian Retail Prices (Nominal) and per Capita Meat Consumption

YEAR	BEEF		LAMB & MUTTON		PORK		CHICKEN	
	kg	c/kg	kg	c/kg	kg	c/kg	kg	c/kg
1980	45.1	431.6	20.0	343.5	15.5	415.2	21.0	201.8
1981	47.9	429.7	19.0	345.7	15.3	427.4	19.3	230.2
1982	49.7	431.2	21.2	345.7	14.8	474.0	19.5	244.7
1983	42.5	489.7	20.5	367.9	15.9	488.7	19.5	257.4
1984	42.5	517.3	22.1	381.3	16.3	490.7	20.2	256.3
1985	41.5	533.9	24.7	379.3	16.6	519.7	23.0	265.8
1986	41.3	561.9	22.7	414.7	16.8	538.1	22.8	272.3
1987	39.4	592.2	23.3	461.3	17.1	566.3	24.1	286.9
1988[e]	38.1	650.0	21.4	483.0	16.9	606.0	24.2	295.0

[e] - estimated by ABARE

Source: Commodity Statistical Bulletin, December 1988 (ABARE)
Australian Bureau of Statistics, Livestock Products, Australia, Cat. No. 7215.0

Table A4. Cost of Pigdiet for Different Categories

	Pig diet with		
CATEGORY	Unrestricted[a] R.Ph. ≤ 1% B.Ch. ≤ 1%	Partial Restr. R.Ph. ≤ 0.5% B.Ch. ≤ 1%	Total Restr. R.Ph. = 0 B.Ch. ≤ 1%
Starter Bone char excluded from diet until its price equals $310.19.	$304.91	$305.85	$306.78
Grower	$234.56 Bone char excluded	$235.39 Bone char = 0.49%	$236.39 Bone char = 1%
Finisher	$209.92 Bone char = 0.03%	$210.84 Bone char = 0.60%	$212.09 Bone char = 1%
Dry Sow	$175.00 Bone char = 0.61%	$176.31 Bone char = 1%	$178.43 Bone char = 1%
Lactating Sow	$192.52 Bone char = 0.60%	$193.91 Bone char = 1%	$196.36 Bone char = 1%

a = Unrestricted - 1 per cent level of rock phosphates generally accepted in pig diets
Restricted - hypothetical 0.5 per cent or zero level of rock phosphates
R.Ph. = Rock Phosphates
B.Ch. = Bone Char

Table A5. Calculation of the Feed Cost in the Pig Industry

		Pig Diet with		
Category	Proportion in Total Food Expenditure	Unrestricted R.Ph. ≤ 1% B.Ch. ≤ 1%	Partial Restr. R.Ph. ≤ 0.5% B.Ch. ≤ 1%	Total Restr. R.Ph. = 0 B.Ch. = 1%
Starter	15%	45.74	45.88	46.02
Grower	25%	58.64	58.85	59.10
Finisher	40%	83.97	84.34	84.84
Dry Sow	15%	26.25	26.45	26.76
Lactating Sow	5%	9.63	9.70	9.82
		224.23 x 4.5[a]	225.22 x 4.5	226.54 x 4.5
Price of Meat		$1009.04 $/tonne of meat	1013.49 $/tonne of meat	1019.43 $/tonne of meat

a = 4.5 is the coefficient which is generally accepted for calculation of the costs of 1 kg of pigmeat from the costs of food in pig diets

R.Ph. = Rock Phosphates

B.Ch. = Bone Char