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# ESTIMATION OF WELFARE GAINS FROM THE PARASITE CONTROL PROGRAM 'WORMKILL'

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*WORMKILL is a program for parasite control in sheep. It was introduced in 1986 and adopted in certain regions of Australia. The adoption of WORMKILL is used as a case study to estimate the likely changes in economic welfare, measured in terms of producer and consumer surplus. A simple model of demand for and supply of sheep-based commodities was used in the analysis. Producers adopting WORMKILL earned (mainly in the form of lower costs) gains estimated at nearly $55m in 1988-89. Producers as a whole gained only about $42m due to lower prices as a result of the adoption of WORMKILL. Consumers gained from the reduction in prices by almost $13m in 1988-89. Because the Australian wool industry is heavily export oriented, overseas consumers enjoyed nearly $11m of this gain. The Edwards and Freebairn model is a useful tool for those allocating limited research funds amongst projects with the aim of generating the greatest net gain to producers and to Australia as a whole.*

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## Introduction

Given the size of the Australian sheep industry and the severity of parasite infestation, gains from research aimed at improving parasite control can be substantial. In 1988-89 sheep numbers were estimated at 163 million with a corresponding gross value of production of $6.5b. Wool alone accounted for nearly $5.9b (ABARE 1989). The average farm level gross return from wool and sheep sales was $67 792 in 1984-85 (BAE 1987). At the farm level the cost incurred from internal parasites in 1985 was estimated at $4695 per farm on average (Beck, Moir and Meppem 1985). This figure includes estimated prevention and treatment expenses for 1985 control programs and the associated production losses due to infestation levels.

Farmers will adopt parasite control programs if the likely gain from the program is greater than the program's cost. The decision to fund research for the development of such programs is not as straightforward, as many more factors need to be considered. Estimates of cost savings alone are a poor basis for assessing the ongoing commitment of funds for research. Funding decisions should be based on the net gains which accrue through time. Such gains depend upon factors such as the relevance of research findings to an industry, the extent of adoption and price effects. Estimates of gains based solely on projected cost savings and adoption rates, for example, can be misleading as commodity price changes following changes in the aggregate level of production are ignored.

Previous studies have highlighted the inadequacies of research evaluations undertaken without the use of economic models which include relevant price responses and distributional effects (Greig 1981; Lindner and Jarrett 1978). Depending on market supply and demand for sheep products, the distribution of gains from control programs are distributed amongst consumers, producers adopting the program and those producers for whom the program is not appropriate. In certain cases the producer gains are small relative to the gains captured by consumers. Further, the net gain to Australia may be considerably less than the total gain generated. Because of the export orientation of the Australian sheep industry, overseas consumers may appropriate a large portion of the generated benefits.

In this paper the likely change in economic welfare, measured in terms of producer and consumer surplus, from the introduction of a sheep parasite control program is estimated and the distribution of gains amongst different producers and domestic and overseas consumers examined. The parasite control program WORMKILL, which was introduced in 1986 and adopted in certain regions of Australia is used as a case study. A simple model of the demand for and supply of sheep based commodities is used for the analysis. The results and their sensitivity to different price responses are also discussed and the net gains generated over a five-year period are estimated. The paper concludes with some implications of the results for the research funding of parasite control programs in general. As background, a description of the WORMKILL program is provided in the following section.

## Overview of WORMKILL

Internal parasites are a major source of production loss in the sheep industry. These parasites include tapeworms, liverfluke and gastro-intestinal nematodes. The effect of internal parasites varies with species of parasite, severity and length of infection. Other factors include the host sheep's level of resistance, nutrition status and physiological state (for example pregnancy and lactation) (Hart 1984). Symptoms of infection include anaemia, poor appetite and reduced nutrient absorption. For infested sheep this leads to lower liveweight gains and reduced production and quality of wool. Also, mortality rates are significantly higher (Beck et al. 1985).

The WORMKILL program was a cooperative effort between the CSIRO Division of Animal Health, New South Wales Agriculture and Fisheries and the Pastures Protection Board of New South Wales. It is a strategic drenching program aimed at controlling barber's pole worm. WORMKILL is targeted for areas where barber's pole worm is endemic, principally the New South Wales Northern Tablelands. The program has also been extended to the Northern Slopes and Upper Hunter regions of New South Wales and is being used in south-east Queensland where it is known as 'Worm Buster'.

Producer awareness is essential for any program like WORMKILL to be effective. For this reason the technical program has been accompanied by an extension campaign using electronic and print media, workshops, field days and farmer meetings. As a result there has been a high adoption rate with around 90 per cent of sheep producers in the New England area of New South Wales adopting WORMKILL (NSW Agriculture and Fisheries 1988).

The strategic aspect of the drenching program involves the use of a parasite specific drench chemical (Sepnova) in place of the currently used broad spectrum chemicals. The timing of drenching is important and is designed to kill worms before larvae are deposited on pastures. By using parasite specific drench chemicals, the producer can reduce the frequency of treatment and dramatically reduce the probability of reinfestation.

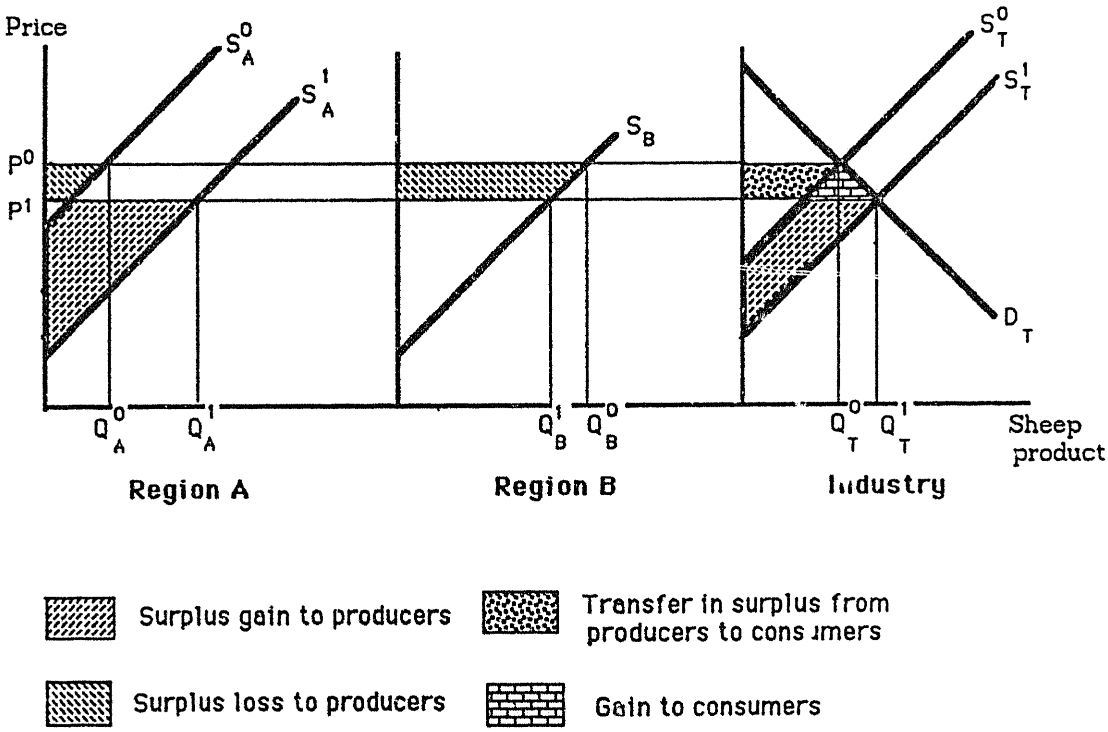
The number of drenchings and the use of less chemicals can save an estimated $1.02 in costs per sheep on an annual basis (K. Dash, CSIRO Division of Animal Health, personal communication, May-October 1989). In addition to cost savings there are benefits from the program in terms of increased wool production and liveweight gains. Beck, Moir and Meppem (1985) used a 10 per cent increase in wool production and 15 per cent increase in liveweight gain from controlling parasite infestation.

## Analytical Framework for Estimating Welfare Changes from WORMKILL

With the introduction of the WORMKILL program, the regional supply curve for sheep products will shift outwards. The industry supply curve will shift as a result, the extent of the shift being dependent on the proportion of total supply produced by the adopting region. A simple economic model depicting the effect of the adoption of the program is shown in Figure 1. The model is adapted from Edwards and Freebairn (1982) and is based on the estimation of economic welfare, measured in terms of producer and consumer surplus following a productivity gain in part of an industry. The distribution of gains between producers and consumers is sensitive to the relative demand and supply elasticities assumed in the analysis. To evaluate how sensitive results are, surpluses are estimated under different elasticity assumptions. Distribution of gains between domestic and overseas consumers is examined later in this section.

Two regions are included in the model: areas adopting the program (region A) and those areas in which it is not adopted (region B). The combined production of the two regions determines total industry supply ($S_T$). Under the assumption of a competitive market equilibrium, price is determined by equating market demand ($D_T$) with industry supply. The equilibrium price is shown as $P^0$ in Figure 1 and the corresponding output at

## Figure 1- Supply and Demand for Sheep Products




this price is given by $Q^0{}_T$. At $P^0$ regional output is shown by $Q^o{}_A$ and $Q^o{}_B$ respectively.

In region A there is an outward shift in the supply curve following the introduction of the program. The supply shift, shown as $S^1{}_A$, reflects the cost saving in labour used and drench chemicals applied plus the gain in production per sheep. For the purpose of this study a parallel supply shift is assumed. Although this assumption is rather crude, it is the only realistic strategy to adopt when the distribution of gains from the program across high and low cost producers is unknown (Rose 1980).

At price $P^0$ producers in region A are induced to increase output following the supply shift. The resultant shift in industry output leads to a fall in price to $P^1$. At the industry level there is a gain in total welfare. The distribution of gains between producers and consumers is determined by the relative supply and demand elasticities. Producers in region B reduce output and lose some surplus while those producers in region A gain. The relevant supply and demand equations in the model are derived below.

The Edwards and Freebairn model is applied to the Australian wool, lamb and mutton industries. Prices are taken at the 1988-89 average farm level return per kilogram and it is assumed producers in both regions face the same price. Estimates of demand and supply elasticities were taken from Dewbre et al (1985).

The supply elasticities measure the percentage change in quantity supplied after five years following an immediate and permanent 1 per cent increase in expected prices at farm level. Demand elasticities measure the quantity demanded in a similar manner after one year. The time periods chosen for the supply and demand response would allow for substantial adjustment to occur. If supply becomes more responsive after five years, then the annual benefits earned would be reduced. In addition, this would include the possibility of the program being adopted by overseas producers.

Elasticities are reported in Table 1. Linear price and quantity relationships were assumed and the following price dependent equations are derived for the different groups.

Region A producers, a

(1) $P_j = \delta_{ja} + \beta_{ja} Q_{ja}$

Region B producers, b

(2) $P_j = \delta_{jb} + \beta_{jb} Q_{jb}$

Domestic consumers, d

(3) $P_j = \delta_{jd} + \beta_{jd} Q_{jd}$

Overseas consumers, e

(4) $P_j = \delta_{je} + \beta_{je} Q_{je}$

Industry, T

(5) $Q_T = Q_a + Q_b$

(6) $Q_T = Q_e + Q_d$

where $\delta$ = intercept, $\beta$ = slope; a = region A, b = region B, d = domestic market, e = export market; $Q_T$ = quantity, industry, and $P_T$ = price, industry. The subscript j represents the commodities wool, lamb and mutton and the coefficients are calculated for the initial industry equilibrium and the supply shift which occurs in region A.

The estimated supply and demand coefficients are reported in Table 2. The supply shift in region A was derived using the cost saving and production gain estimated by K. Dash (CSIRO Division of Animal Health, personal communications, May-October 1989) and Beck et al. (1986). The new equilibrium price ($P^1$) following the supply shift was calculated by solving simultaneously equations (1) to (6) for each commodity j. The resultant output ($Q^1{}_j$) was estimated for each group. Initial price and quantity data used to estimate supply and demand coefficients are reported in Table 3 as well as the prices and quantities under the new equilibrium.

TABLE 1
Supply and Demand Elasticities Used in Model

| Commodity | Supply | Demand: Export | Demand: Domestic |
|---|---|---|---|
| Wool | 0.31 | -1.10 | -1.01 |
| Lamb | 0.47 | -1.25 | -0.62 |
| Mutton | 0.31(a) | -0.50(b) | -0.62 |

(a) Mutton response driven by wool. (b) Includes sheep exported live.
Note: Elasticities measure the medium term farm level response.

TABLE 2
Estimated Supply and Demand Coefficients, Equations (1)-(6)

| Commodity | Intercept ($\delta$) Initial | Intercept ($\delta$) Shifted(a) | Slope ($\beta$) |
|---|---|---|---|
| Wool | | | |
| Region A | -13.69 | -14.48 | 0.31 |
| Region B | -13.69 | -13.69 | 0.02 |
| Export | 11.74 | 11.74 | -0.01 |
| Domestic | 11.74 | 11.74 | -0.08 |
| Lamb | | | |
| Region A | -0.93 | -1.05 | 0.09 |
| Region B | -0.93 | -0.93 | 0.01 |
| Export | 1.48 | 1.48 | -0.02 |
| Domestic | 2.15 | 2.15 | -0.01 |
| Mutton | | | |
| Region A | -0.74 | -0.84 | 0.08 |
| Region B | -0.74 | -0.74 | 0.01 |
| Export | 1.98 | 1.98 | -0.01 |
| Domestic | 1.72 | 1.72 | -0.01 |

(a) Revised estimate associated with supply shift analysed for region A.

TABLE 3
Price and Quantity Estimate

| Supply shift (i) | Price | Quantity produced: Region A ($Q_A$) | Quantity produced: Region B ($Q_B$) | Quantity produced: Industry ($Q_T$) |
|---|---|---|---|---|
| | $ | kt | kt | kt |
| Wool | | | | |
| 0 | 6.15 | 63.41 | 878.59 | 942.00 |
| 1 | 6.14 | 65.90 | 878.07 | 943.97 |
| Lamb | | | | |
| 0 | 0.82 | 18.78 | 260.22 | 279.00 |
| 1 | 0.81 | 20.07 | 259.73 | 279.79 |
| Mutton | | | | |
| 0 | 0.66 | 16.49 | 228.51 | 245.00 |
| 1 | 0.65 | 17.62 | 228.02 | 245.64 |

For region A the change in producer surplus ($\Delta PS_{ja}$) represents the gain which is earned across all production of commodity j, as a result of the control program less the effect of a reduced price for the output. This change in producer surplus can be given by the following equation.

(7) $$\Delta PS_{ja} = 0.5\ [(K_j - (P_j^o - P_j^1))\ \ (Q_{ja}^o + Q_{ja}^1)]$$

where $K_j$ is a measure of the supply shift for commodity j in region A.

In Figure 1, the change in producer surplus for region A producers is shown. The change reflects the gains and losses which occur as a result of the shift in supply. In algebraic terms the gains and losses for commodity j can be represented by equations (8) and (9) respectively.

(8) $$\text{Gain}(PS_{ja}) = 0.5\ (Q_{ja}^1(P_j^1 - \delta_{ja}^1)) - [0.5\ (Q_{ja}^0(P_j^0 - \delta_{ja}^0)) - Q_{ja}^0(P_j^0 - P_j^1) - 0.5\ (P_j^0 - P_j^1)(\beta_{ja}(P_j^0 - P_j^1) - \beta_{ja}\ \delta_{ja}^0)]$$

(9) $$\text{Loss}(PS_{ja}) = Q_{ja}^1(P_j^0 - P_j^1)\ [(P_j^0 - P_j^1)(Q_{ja}^1 - Q_{ja}^0) + 0.5(P_j^0 - P_j^1)(\beta_{ja}(P_j^0 - P_j^1) - \beta_{ja}\delta_{ja}^0)]$$

For region B producers there is a loss in their surplus because the price of commodity j falls. The change in surplus ($PS_{jb}$) can be given by the following equation and is shown graphically in Figure 1.

(10) $$\Delta PS_{jb} = 0.5(Q_{jb}^0(P_j^0 - \delta_{jb}^0)) - 0.5(Q_{jb}^1 - \delta_{jb}^0))$$

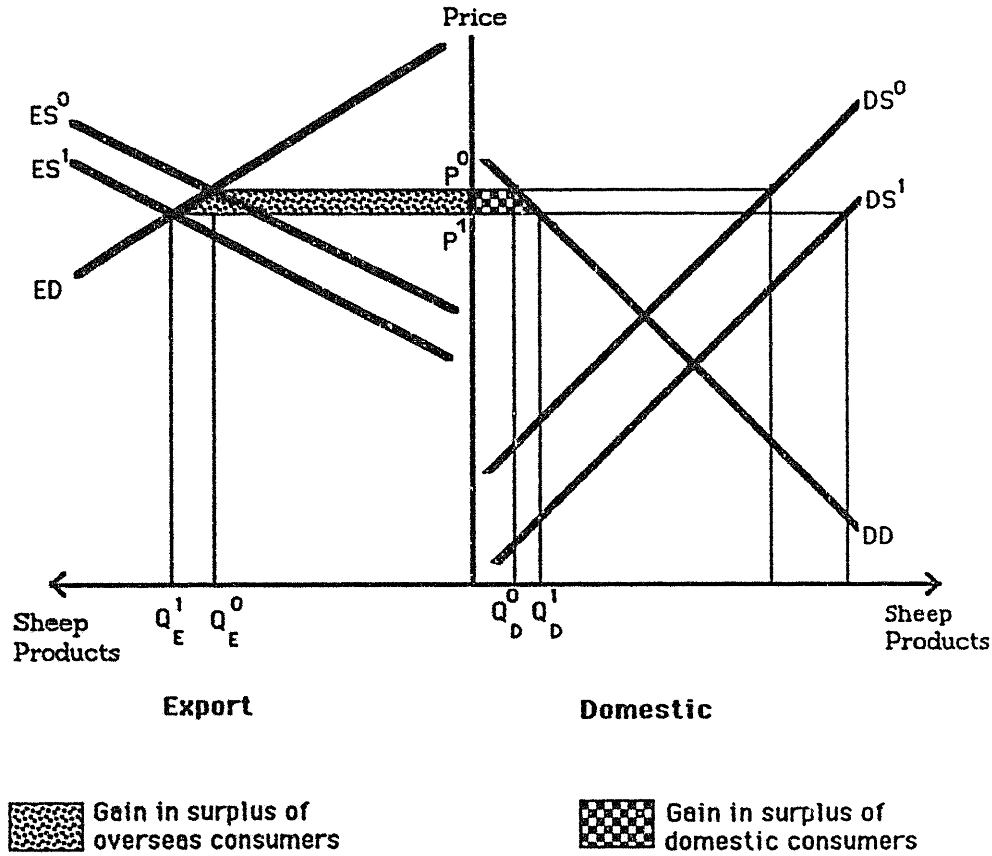
Producer surplus for the industry is given by the sum of producer surplus in regions A and B.

The distribution of consumer surplus gains between domestic and overseas consumers is dependent upon the volume of output each group initially accounts for and the relative demand elasticities facing them. In Figure 2 the distribution of surpluses is illustrated.

At price $P^0$ production ($Q_T^0$) exceeds demand ($Q_d^0$) and the difference ($Q_T^0 - Q_d^0$) is available for export, shown as the excess supply curve $ES^o$. With a shift in industry supply of $DS^o$ to $DS^1$ there is a corresponding shift in the excess supply curve ($ES^o$ to $ES^1$). The resultant gain in consumer surplus, as output increases and price falls, is shown as the shaded areas in Figure 2, comprising the gain to both overseas and domestic consumers.

Consumer surplus, CS, for commodity j, assuming no substitution between marketing and production inputs, can be expressed as:

## Figure 2- Domestic and Export Demand and Supply of Sheep Products




(9) $CS_{jd} = 0.5\ [(\delta_{jd} - P_j)\ Q_{jd}]$

(10) $CS_{je} = 0.5\ [(\delta_{je} - P_j)\ Q_{je}]$

(11) $CS_{jt} = CS_d + CS_e$

<u>Discussion</u>

Results presented in Tables 4 and 5 are given before and after the control program is adopted in region A and are for wool, lamb and mutton production.

Initially, the equilibrium price of wool is $6.15/kg (Table 3) and the majority of production is carried out in region B, the region where WORMKILL is not adopted. The supply shift occurs as a result of the combined cost saving and production gain, resulting in greater industry output and a subsequent decline in price. Output in region A increases more than the

TABLE 4

Producer Surplus Estimates (1988-89 values)

| Supply shift (i) | Region A | | Region B | | Industry | |
|---|---|---|---|---|---|---|
| | Surplus | Change | Surplus | Change | Surplus | Change |
| | $m | $m | $m | $m | $m | $m |
| Wool | | | | | | |
| 0 | 329.55 | - | 4566.38 | - | 4895.93 | - |
| 1 | 380.00 | 50.45 | 4556.08 | -10.30 | 4936.08 | 40.15 |
| Lamb | | | | | | |
| 0 | 11.82 | - | 163.84 | - | 175.66 | - |
| 1 | 14.16 | 2.33 | 162.97 | -0.86 | 177.13 | 1.47 |
| Mutton | | | | | | |
| 0 | 8.31 | - | 115.13 | - | 123.44 | - |
| 1 | 9.94 | 1.63 | 114.44 | -0.68 | 124.39 | 0.95 |

TABLE 5

Consumer Surplus Estimates (1989-89 values)

| Supply shift (i) | Domestic | | Export | | Total | |
|---|---|---|---|---|---|---|
| | Surplus | Change | Surplus | Change | Surplus | Change |
| | $m | $m | $m | $m | $m | $m |
| Wool | | | | | | |
| 0 | 184.35 | - | 2449.28 | - | 2633.64 | - |
| 1 | 185.13 | 0.77 | 2459.56 | 10.28 | 2644.69 | 11.05 |
| Lamb | | | | | | |
| 0 | 159.96 | - | 12.51 | - | 172.47 | - |
| 1 | 160.76 | 0.80 | 12.64 | 0.13 | 173.39 | 0.93 |
| Mutton | | | | | | |
| 0 | 83.39 | - | 57.96 | - | 141.34 | - |
| 1 | 83.86 | 0.47 | 58.22 | 0.26 | 142.08 | 0.73 |

reduction in region B's output. Although the price and regional adjustment in output is only marginal the impact on economic welfare is substantial.

Producer and consumer surpluses for each state of supply in region A are summarised in Tables 4 and 5. Producers in region A gain $50.45m as a result of adopting the control program. However, some of these gains are offset by the loss of surplus experienced by producers in region B as they face reduced prices. At the industry level the net effect is a $40.15m gain from the program.

Consumers of wool also gain because of the price fall. Their gain in surplus was estimated at $11.05m in 1988-89 and, given the export orientation of the Australian sheep industry, it could be expected that overseas consumers would appropriate much of this gain. It was estimated that overseas consumers appropriated over 93 per cent of the total gain in consumer surplus. As shown in Table 5, domestic consumers gained a little under $1m. Hence, the net gain from WORMKILL to Australian wool producers and consumers was estimated at $41m compared to gains to overseas consumers of a little over $10m.

Producer gains from sheepmeat production are small compared to the estimated gain from wool production. Moreover, because most sheepmeat production is consumed domestically, there is potential for domestic consumers to earn greater gains. Domestic consumers of sheepmeat stand to gain $1.27m as opposed to $0.39m for overseas consumers.

In cases where additional resources are required for an expansion in wool production, there would be second round price effects. This occurs as resources shift from their use in the production of other commodities which compete for the same resources (notably beef, lamb and crop production). As the prices of these other commodities rise in response to reduced production, their relative profitability against wool increases. Consequently, it would be expected that a portion of the surpluses estimated above would be spread across other commodities. However, for WORMKILL the second-round price effects are likely to be insignificant as the increase in wool production results predominantly from an increase in the production per sheep.

The distribution of gains between producers and consumers is dependent upon relative demand and supply elasticities. It is appropriate at this stage to make some comment in this regard.

In Table 6, changes in producer and consumer surplus for wool are given under different elasticity of supply and demand assumptions. The results are consistent with the findings of Edwards and Freebairn (1982). The combined gain to producers and consumers is little affected by greater responsiveness in the demand for wool. However, the more elastic is the demand for wool relative to its supply, the greater are the gains appropriated by producers. The converse applies if supply is more responsive to price than demand. In this case, the gains earned are competed away to a greater extent. In general, the greater the responsiveness of supply, the greater will be the aggregate gain to consumers. The value of the gain to region A producers and losses to region B producers will be greater the more elastic is region's A supply curve for its output compared to region B.

Apart from consumers enjoying greater gains at the expense of producers as the responsiveness of supply increases, much of this gain will be lost to Australia because of the export orientation of the wool industry. This is important from a funding perspective as domestic producers and taxpayers fund the development and ongoing costs of programs such as WORMKILL. In Table 7 the annual gains to producers, Australia and overseas consumers are reported over the five-year period used in the analysis above. Over five years substantial gains are earned by producers and Australia as a whole. Taking account of the $2.17m (1988-89 dollars) to develop the program, extension costs of $0.59m and ongoing costs of $0.33m per year, the program generates substantial net gains. The internal rate of return was well over 200 per cent. To ascertain whether or not WORMKILL can be viewed as a successful research project, it is necessary to compare its internal rate of return with a rate acceptable by the research organisation. The acceptable rate of return would include an allowance for failed research projects and an appropriate rate of discount.

TABLE 6
Sensitivity of Results to Changes in Demand and Supply Elasticities for Wool Production

| Surplus | Supply elasticity | Demand elasticity -0.5 | -1.0 | -2.0 |
|---|---|---|---|---|
| | | $m | $m | $m |
| Producer | 0.5 | 26.65 | 35.04 | 41.75 |
| | 1.0 | 19.78 | 28.18 | 36.59 |
| | 2.0 | 16.09 | 22.82 | 31.25 |
| Consumer | 0.5 | 25.14 | 16.76 | 10.06 |
| | 1.0 | 33.53 | 25.16 | 16.79 |
| | 2.0 | 40.25 | 33.58 | 25.22 |
| Total | 0.5 | 51.78 | 51.80 | 51.82 |
| | 1.0 | 53.31 | 53.34 | 53.38 |
| | 2.0 | 56.34 | 56.40 | 56.47 |

TABLE 7
Welfare Gains (Five-year period)

| Group | Unit | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|---|
| Elasticity (a) | | 0.01 | 0.08 | 0.16 | 0.24 | 0.31 |
| Producers | $m | 49.80 | 47.07 | 44.35 | 41.98 | 40.15 |
| Australia | $m | 49.83 | 47.31 | 44.80 | 42.61 | 40.93 |
| Overseas consumers | $m | 0.42 | 3.17 | 5.93 | 8.37 | 10.28 |

(a) Elasticities of supply were taken from Dewbre et al. (1985).

## Concluding Comments

Estimating the likely gains from programs designed to increase farm level productivity can be a daunting task. With the use of simple economic welfare models these gains can be estimated, and their distribution examined. These techniques can provide a valuable input into decisions regarding the targetting of research funds.

WORMKILL has been shown to be an effective parasite control program. For those producers adopting the program, substantial gains in terms of lower production costs per sheep and productivity increases can be earned. The net gain to these producers in 1988-89, after taking into account associated terms of trade effects, was estimated at nearly $55m. However, as not all producers adopted the program, but all faced the reduction in prices generated from increased output, the estimated gain to the industry as a whole was somewhat lower at a little over $42m. In determining the economic worth of the program the estimated industry gain should be used rather than the gains accruing only to those producers adopting the program. This is important given that industry funding is spread equally across all producers.

Consumers of sheep commodities gain from the reduction in output prices. It was estimated that consumers were better off as a result of WORMKILL in 1988-89 by almost $13m. As the Australian wool industry is heavily export oriented, overseas consumers enjoy the greatest consumer gain, estimated at nearly $11m.

The use of the Edwards and Freebairn (1982) model has been shown to be an effective method for estimating the likely gains from parasite control programs. It therefore represents a useful tool for research bodies faced with the task of allocating limited research funds among projects with the aim of generating the greatest net gains to producers and Australia as a whole.

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