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The Social Benefits from an Increase in Productivity in a Part of an Industry

G. W. Edwards and J. W. Freebairn*

Productivity often increases in a part of an industry while remaining unchanged in the rest of the industry. In assessing the social gain from a productivity increase in a part of an industry producing a tradeable commodity it is necessary to consider the relationships between the part of the industry affected, the industry in the rest of the country concerned and the industry in the rest of the world. In this paper an attempt to assess the social benefits of serrated tussock control on the tablelands of New South Wales is critically reviewed and found wanting. An analytical framework is outlined that *is* conceptually appropriate to that task, and to other situations where cost per unit of output is reduced in a part of an industry. The social gains from the control of serrated tussock on the New South Wales tablelands are recalculated. A discussion is also presented of some issues in the distribution of the gains from research.

1 Introduction

In their recent article Vere, Sinden and Campbell (1980) (hereafter VSC) endeavoured to demonstrate the use of the general social benefit-cost model to assess the welfare effects of controlling (or of not controlling) agricultural pests. The demonstration related to a project to control serrated tussock on the central and southern tablelands of New South Wales. Although VSC *applied* their model to obtain estimates "... of the absolute levels of social benefits and costs and the subsequent benefit-cost ratios ..." this was "... a secondary purpose ..." (p. 133).

We regard the more widespread application of benefit-cost analysis to possible policy initiatives, of which the introduction of a programme to control a weed in a region is an example, as a desirable development. We therefore applaud VSC for what they set out to do.

In our paper we do four things. First, it is shown that the conceptual framework used by VSC is inappropriate for examining the social consequences of their demonstration project. The model used fails to capture satisfactorily two fundamental characteristics of that project. These are the internationally traded nature of the output and the restriction of the productivity increase to one part of the Australian industry. The main thrust of the criticism appears to apply also to some other studies of the gains from research for tradeable items, for example, Nagy and Furtan (1978) and Ridge and Telford (1978). Second, a framework that *is* conceptually appropriate is outlined. We suggest that a model of this general type has widespread applicability in social benefit-cost analysis of projects or policies that will change the production of a tradeable good in a part of an industry. It can also be used in analysing supply shifts in one part of a non-traded good industry. Third, this framework is used to re-estimate the social benefits of controlling serrated tussock on the New South Wales tablelands.

* La Trobe University. Thanks are extended to K. Walls, who wrote the programmes used in our empirical analysis and to B. Johnston, J. Kennedy, A. Lloyd, J. Quilkey and R. Lindner for discussions on a draft of this paper.

Finally, a comment is made on VSC's view on the relationship between the distribution of benefits from a serrated tussock control programme and the determination of who should pay for it[1].

2 Criticisms of the VSC Model

The model used by VSC is the one applied by Akino and Hayami (1975) in making a social benefit-cost analysis of rice breeding in Japan. This model (reproduced, with VSC's labelling, as Figure 1) might be appropriate for examining the aggregate welfare effects of certain supply shifts (most clearly for a uniform shift throughout the industry) for an industry isolated from international trade. But an aggregative model of this type does *not* permit a satisfactory assessment of benefits and costs from a *national* perspective — conventionally the context of a benefit-cost analysis — or from a regional perspective of a shift in supply of a tradeable item in a region. To make this point clear, we turn to a closer examination of the conceptual specification used by VSC.

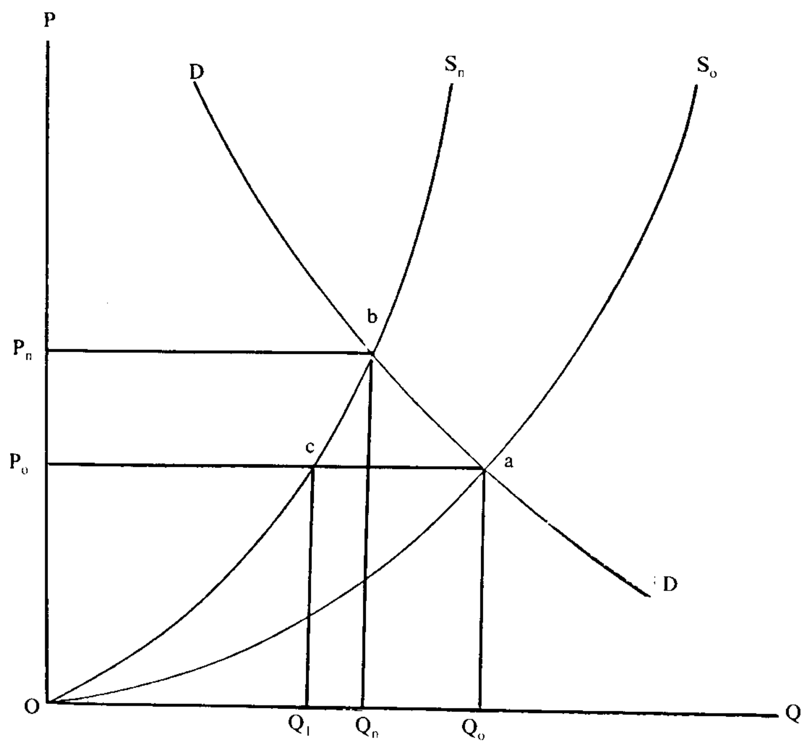

Figure 1: Social returns from the adoption of a biolcgical innovation. Source: VSC (p. 130)

1. We note that VSC do not claim to have developed fully a case for public intervention to control serrated tussock, though they appear to consider intervention both necessary and appropriate (p. 136). More detailed investigations, including study of the reasons for inadequate private control of tussocks, would be needed to compare the merits of other forms of intervention with those of the supervised pasture improvement programme considered by VSC. Some relevant discussion is to be found in Menz and Auld (1977) and Vere and Campbell (1979). Other forms of intervention could include penalties for producers who fail to control weeds satisfactorily, rewards for those who do control, and the provision of information or capital to remove problems due to ignorance or capital market inefficiencies. We do not intend to comment further on the theoretical case for public intervention or the choice of how to intervene.

The gross annual social benefit from the control of serrated tussock is defined in the VSC (Akino—Hayami) model as area *oab* (*see* Figure 1). This can be decomposed into change in producers' surplus (area *aOc* minus area bP_nP_oc) and change in consumers' surplus (area *abc* plus area bP_nP_oc). VSC proceed to calculate, within this framework, the social benefits and the changes in producers' and consumers' surplus from controlling serrated tussock. Results are presented for analyses at two levels: regional (central and southern tablelands) and national. In their subsequent Discussion section, under the heading 'Distribution of benefits', VSC note some reservations about their assessment of social benefits. But they fail to resolve the issue; in fact they create further confusion. This confusion, like the fundamental problem in their analysis, stems mainly from an inappropriate model specification.

The VSC analysis is subject to two main criticisms. Most fundamentally, the framework used does not incorporate the relationship between the unit for which social benefits are under study and the rest of the world. What is needed to determine Australia's social benefits from tussock control in a particular region is a model disaggregated into region, rest of Australia and the rest of the world. Disaggregation into region and rest of the world, including rest of Australia, would be sufficient if one was interested only in social gain to the region. The second criticism concerns the type of supply shift assumed by VSC. There is room for debate about the most appropriate specification of the supply shift resulting from the control of serrated tussock. However, on the argument advanced by VSC, the shift should be convergent rather than divergent (pivotal) as they claim.

2.1 Model Aggregation

VSC applied the aggregated model of Figure 1 twice, obtaining results for the regional level and the national level. For the national level analysis S_n and S_o are, respectively, the Australian supply curves for wool in the absence of a serrated tussock control programme in the New South Wales tablelands and with such a programme. For the regional assessment S_n and S_o define tablelands wool supply. In the regional analysis there is no mention of the supply curve for wool by the rest of Australia or the rest of the world, though social benefits to the region or to Australia (or to the world) cannot be determined without knowledge of supply and demand throughout the world. In both analyses the demand curve represents *world* demand. The outcome is that the relationship between nation and region is misspecified on both the supply and demand sides.

Consider the VSC assessment of regional social benefits from controlling serrated tussock. For the combinations of supply and demand elasticities that they use, VSC find that the increase in consumer surplus contributes all or most of the social benefit (their Table 2). However, the VSC approach results in heavy overstatement of the regional gain in consumer surplus for two reasons. First, the demand for wool from the central and southern tablelands is treated as unreasonably price inelastic because of the failure to recognize the relationship between aggregate demand and demand for production from a particular supplier. Producers on the New South Wales tablelands face not the world demand curve (with quantity referring to all wool) but an excess demand curve derived from world demand and from supply by the rest of Australia and by other countries. It can be established using a well known formula that the price elasticity of world demand for wool from the tablelands is in the range –40 to –239 if the elasticities presented are interpreted (correctly) as elasticities of demand for world wool[2]. The values used by VSC for elasticities of demand at the regional levels ranged from –0.2 to –0.8. Second, the VSC regional assessment supposes that regional wool production is consumed entirely within the region, even though the unreality of this is recognised in their Discussion section. Allowance for either of these factors — elastic demand and the region's consumption of a negligible share of its production — is sufficient to make the regional change in consumers' surplus from control of serrated tussock approximately zero.

VSC's use of unduly low elasticities of demand for regional production results in another error that tends to offset the overstatement of consumers' gains; it causes the gains to the region's producers to be understated. The increase of $14.482 million in annual producers' surplus with VSC's most elastic values for supply and demand (their Table 2) becomes approximately $24.209 million, using their model (area *aOc* in Figure 1), when the relevant elasticity of demand (–239) is used. Area bP_nP_0c then becomes neglible. VSC's understatement of the regional gain in producers' surplus is relatively greater for less elastic values of demand; for these cases, VSC obtain producer *losses* from weed control.

Finally, there appear to be two problems with the price/quantity data used by VSC in applying their model. First, given that they are estimating the social benefits of a prospective weed control programme rather than an existing one, P_n, not P_o, is equal to the recent actual wool price. It presumably follows that the increase of 8.398 kt in regional wool production should be measured as the distance between S_n and S_o at P_n. These points assume some significance given the inelastic demand assumed by VSC; this is conducive to a relatively large difference between P_o and P_n. Second, VSC use a price of 200 cents per kg ("the approximate average greasy wool price for 21 micron Merino fleece over the 1970's" (p. 131)) and an Australian production of 735 386 thousand kg (which they said was "the average national level of Merino wool production over 1975–76 to 1977–78" (p. 131)). In fact it appears that VSC have used overall wool production as their measure of quantity (national level) and associated it with a Merino wool price series.

VSC's national level analysis suffers from the same problems as the regional analysis, plus an extra one. Consumer gains are again overstated because in the formal model all production is treated as being consumed domestically and because the price elasticities of demand are too low (the values used are the same as in the regional analysis). Following the approach outlined earlier gives price elasticities of world demand for Australia's production of –1.0 to –5.4. The additional problem with the national level study is that the increase in wool production consequent upon control of serrated tussock in the tablelands region is greater than the regional increase. It is to be expected (though only with a more

2. The formula is $E = \frac{1}{f}(e-g)+g$ where E is the price elasticity of demand for the production of a component of total production, f is the component's share in total production, e is the price elasticity of demand for total production and g is the price elasticity of supply of production outside the component. See, for example, Powell (1959) and IAC (1976). It is clear from the empirical studies cited in Quilkey (1970) (who in turn, was cited by VSC) that the elasticities of demand relate consumption of world (not Australian) wool to price.

disaggregated model than that used by VSC) that national production will increase *less* than regional production (or even decline) due to the effect on production outside the region of a price fall induced by extra regional production. But why does national wool production increase more than three times as much as production in the region where the control programme is implemented? Unless this can be justified the national level and regional level evaluations relate to *different projects*. This appears, in fact, to be the explanation of the seemingly incongruous finding that social benefits at the national level exceed benefits at the regional level.

VSC's use of a global model for their regional and national level assessments explains the unresponsiveness of social benefits to changes in the price elasticities of supply and demand. They erroneously ascribe this to the smallness of the supply shift. In a model for an entire market, aggregate benefits from a supply shift are affected relatively little by the values for the elasticities of demand and supply. However, the distribution of benefits between producers and consumers is very sensitive to the values of the elasticites, as VSC point out.

2.2 Specification of Supply Shift

We turn now to the second main criticism mentioned early in this section — that is, the type of supply shift assumed. As VSC note, Lindner and Jarrett (1978) have shown that the size of measured benefits from research can be influenced strongly by the manner in which the supply shift is specified[3]. So can the distribution of gains between producers and consumers (Duncan and Tisdell 1971). Lindner and Jarrett point out that the divergent (pivotal) supply shift assumed by Akino-Hayami (and by VSC) leads to understatement of the size of regional social benefits from weed control if the shift in reality takes just about any other form. Lindner and Jarrett also noted that a divergent supply shift, together with inelastic demand, is a specification particularly conducive to producer losses from an outward movement in supply.

If it is known that a particular specification of the supply shift will understate social gains from weed control if the true shift takes almost any alternative form, it is important to present a sound reason for expecting the supply shift to take that particular form. VSC advance an argument which they claim supports the divergent supply shift specification. The argument is not convincing. But worse, its acceptance implies the opposite of what they claim. In an apparent misunderstanding of Lindner and Jarrett, VSC say the supply shift is likely to be highly divergent ". . . if it can be assumed that the majority of landholders affected by serrated tussock are low cost (or 'inframarginal') producers" (p. 129). In fact, as Lindner and Jarrett make clear (on p. 55, for example), the situation described involves a *convergent* supply shift.

Taking the argument back a step, why would a control programme for serrated tussock be expected to benefit mainly low cost (efficient) producers? VSC say ". . . because country heavily infested with serrated tussock can only support very low stock numbers, input usage is low (for example, there will be

3. The general validity of this point is not affected by the criticisms levelled at the Lindner and Jarrett analysis by Rose (1980) and by Wise and Fell (1980), and noted by VSC.

no fertilizer or pasture costs), and so are the average costs per unit of commodity produced relative to wool production from improved pastures" (p. 129). If this is correct why would anyone improve pastures[4]? Our reading of Rose (1980) and Lindner and Jarrett (1978, 1980) leads us to the view that great caution needs to be exercised in postulating a linkage between high or low cost on the one hand and marginal or intramarginal production on the other. Unless a better reason than that advanced by VSC can be adduced to support either a divergent or a convergent shift, we consider that, in this instance, the estimate of social benefits from weed control is least likely to be biassed seriously if the advice of Rose is followed: "The only realistic strategy is to assume that the supply shift is parallel" (p. 837).

There is another point that should be noted about the specification of the supply shift assumed by VSC. The costs of controlling serrated tussock are not incorporated in the 'with control' supply curve. VSC assume that the public sector initiates and supervises the control programme. Implicitly it seems also to be assumed that governments meet the costs, though these are mainly the costs of establishing and maintaining improved pasture. If control was financed by tablelands producers (either directly or through a tax on their production) the 'with control' supply curve and price would be higher, production would be lower and the net social benefits from control would be reduced.

3 An Alternative Model

In this section a model is presented which can be used to estimate gains at the regional, national and global levels of a project or policy which causes the regional supply curve to shift outwards. The model is shown in Figure 2.

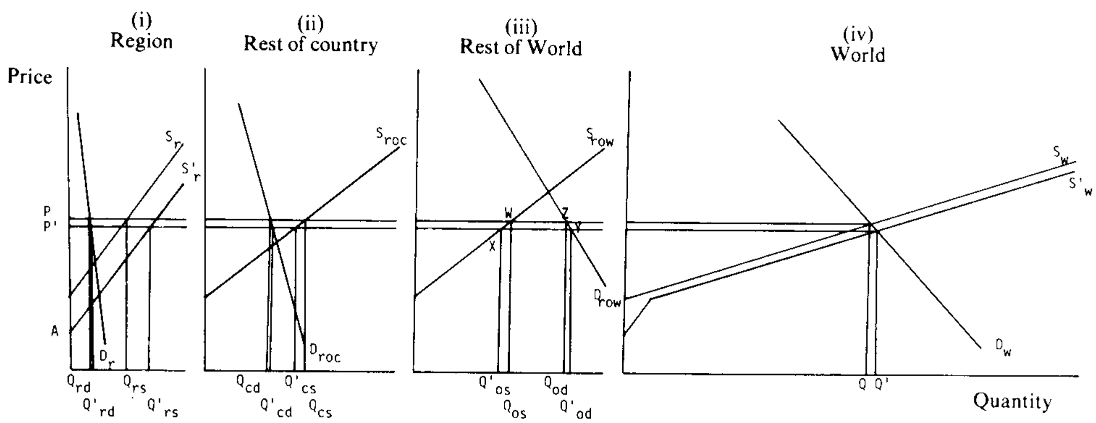

Figure 2: A model for determining the social benefits from a shift in the supply curve for a product in one region of a trading country

4. In another benefit-cost study of the control of serrated tussock in the central and southern tablelands it was implicitly assumed that control benefited only *high cost* production. This followed from the non-inclusion of any cost saving on production occurring without the control programme. That study also differed from the VSC one in making no allowance for a fall in wool price consequent upon weed control in the tablelands (Vere and Campbell 1979).

The model is a competitive, market equilibrium one. It differs most fundamentally from the VSC (Akino-Hayami) model in disaggregating production and consumption and in explicitly incorporating trade. This is done by specifying separate supply and demand curves for: a region within a country (panel 1); the rest of that country (panel 2); and the rest of the world (panel 3). Horizontal summation of the three supply curves gives world supply (panel 4). The three demand curves are summed in the same way to obtain world demand. The intersection of world supply and demand determines the world price, which applies to producers and consumers throughout the world. Imports of a commodity by the rest of the world (WZ at price P and XY at price P') equal exports by the country depicted in panels 1 and 2. Less important characteristics of this model which differentiate it from the model used by VSC include linear specification of supply and demand (compared with constant elasticity in VSC) and a parallel supply shift (compared with a divergent (pivotal) shift in VSC). The implicit VSC assumption of public funding of the project is retained. Of course, the most appropriate specification of demand and supply, and of the shift in supply, will vary from situation to situation.

A productivity gain in the production of the product at the regional level is depicted as a shift in the regional supply curve from S_r to S'_r. This causes a horizontal shift in world supply equal to the horizontal shift in supply in the region. Price falls from P to P' and quantity supplied and demanded at the world level increases from Q to Q'. Quantity supplied changes from Q_{rs} to Q'_{rs} in the region, from Q_{cs} to Q'_{cs} in the rest of the country and from Q_{os} to Q'_{os} in other countries. Quantity demanded increases from Q_{rd} to Q'_{rd} in the region, from Q_{cd} to Q'_{cd} in the rest of the country and from Q_{od} to Q'_{od} in other countries. The *vertical* shift in the regional supply curve is denoted by j. The social gain to the region, the rest of the country, the country as a whole and the world from the supply shift at the regional level can be expressed as follows, with superscripts c and p denoting gains to consumers and producers, respectively.

Gain to region

$$G_r^c = \tfrac{1}{2} (P-P')(Q_{rd} + Q'_{rd}) \tag{1}$$

$$G_r^p = \tfrac{1}{2} [j-(P-P')] (Q_{rs} + Q'_{rs}) \tag{2}$$

$$G_r = G_r^c + G_r^p$$

$$= jQ_{rs} + \tfrac{1}{2}j(Q'_{rs}-Q_{rs}) + \tfrac{1}{2}(P-P') [(Q_{rd}+Q'_{rd}) - (Q_{rs}+Q'_{rs})] \tag{3}$$

Gain to rest of country

$$G_c^c = \tfrac{1}{2}(P-P')(Q_{cd} + Q'_{cd}) \tag{4}$$

$$G_c^p = -\tfrac{1}{2}(P-P')(Q_{cs} + Q'_{cs}) \tag{5}$$

$$G_c = G_c^c + G_c^p$$

$$= \tfrac{1}{2}(P-P') [(Q_{cd} + Q'_{cd}) - (Q_{cs} + Q'_{cs})] \tag{6}$$

Gain to country

$$G_y^c = G_r^c + G_c^c \qquad (7)$$

$$G_y^p = G_r^p + G_c^p \qquad (8)$$

$$G_y = G_y^c + G_y^p \qquad (9)$$

Gain to rest of world

$$G_o^c = \tfrac{1}{2}(P-P')(Q_{od} + Q'_{od}) \qquad (10)$$

$$G_o^p = -\tfrac{1}{2}(P-P')(Q_{os} + Q'_{os}) \qquad (11)$$

$$G_o = G_o^c + G_o^p$$

$$= \tfrac{1}{2}(P-P')\,[(Q_{od} + Q'_{od}) - (Q_{os} + Q'_{os})] \qquad (12)$$

Gain to world

$$G^c = G_r^c + G_c^c + G_o^c$$

$$= \tfrac{1}{2}(P-P')(Q+Q') \qquad (13)$$

$$G^p = G_r^p + G_c^p + G_o^p$$

$$= \tfrac{1}{2}j(Q_{rs} + Q'_{rs}) - \tfrac{1}{2}(P-P')(Q+Q') \qquad (14)$$

$$G = G^c + G^p$$

$$= j\,Q_{rs} + \tfrac{1}{2}j(Q'_{rs}-Q_{rs}) \qquad (15)$$

In the context of evaluating the social benefits from the control of serrated tussock in the central and southern tablelands of New South Wales it is clear that gains to the region (equation (3)) exceed gains to Australia (equation (9)). The excess of wool supply over demand, which determines the loss from the fall in price from P to P', is larger for Australia than for the N.S.W. tablelands. It is also clear that if the region is a net exporter its gain will be less than the world gain[5].

4 Applying the Model

The model outlined in the previous section is used to re-estimate the social gains from controlling serrated tussock in the tablelands of N.S.W. The analysis

5. Confining attention to the component of the change in economic surplus that is due to the price fall, regional producer losses then exceed consumer gains; at the world level the two balance out, production and consumption being equal.

is extended in two directions beyond that undertaken by VSC[6]. First, social benefits accruing to the world as a whole are calculated, as well as benefits accruing to the New South Wales tablelands and to Australia. Second, the sensitivity of social benefits to changes in several parameters (wool price, the number of years over which the shift in supply occurs, the number of years over which benefits accrue and the rate of discount) is examined. The combinations of supply and demand elasticities used also cover a wider range than that used by VSC.

Apart from the differences in the models used and in the specification of the supply shift, there is a difference of detail in our data and that of VSC. We use a price of 158.4 cents per kg for wool and an initial (without weed control) Australian wool production (all types) of 711 kilotonnes greasy. These figures are taken from Bureau of Agricultural Economics (1981) and are averages for all wool in the three years 1975–76 to 1977–78. As noted earlier, VSC used a price of 200 cents per kg and an Australian production of 735.4 kilotonnes. We accept that our analysis, like that of VSC, is subject to the limitation that it treats wool as a homogeneous commodity.

The horizontal shift in our regional supply curve is equal to VSC's absolute value of k; that is 8.398 kt. The vertical shift that corresponds to this horizontal shift is equal to the horizontal shift divided by the slope of the supply curve. Note that the slope of the supply curve is $\delta_r \times \frac{Q_r}{P}$, where δ_r is the elasticity of supply in the region, Q_r is quantity supplied in the region and P is price. For a given horizontal shift of the supply curve, the size of the vertical shift will be greater the more inelastic is supply. The social benefits from the supply shift are closely related to the vertical shift (cost reduction). To facilitate comparison of results we use the same horizontal supply shift as VSC and a range of values for the elasticity of supply encompassing the values used by them. However, our estimates of social benefits are unrealistically high (because the corresponding cost reductions are unrealistically high) when the elasticity of supply is low. This problem does not arise if, in line with the preference of Lindner and Jarrett (which we share), the specification of supply shifts is vertical.

To apply our model we have set Rest of World wool production and consumption at 1 833 and 2 534 kilotonnes greasy, respectively, these being average levels for the three years 1975–76 to 1977–78.

The re-estimated annual social benefits to the tablelands of N.S.W. and to Australia from the control of serrated tussock are shown in Table 1, together with corresponding results obtained by VSC[7]. Because of the reasonable assumption

6. Nevertheless, we regard sorting out the conceptual framework as the more important task (as did VSC).

7. Operation of the model requires data on prices and quantities before and after the research innovation. The initial or pre-innovation prices and quantities are given. Given supply and demand elasticities are used to specify respective supply and demand curves passing through the initial prices and quantities. To estimate the after-innovation prices and quantities the supply curve for the tablelands region is shifted to reflect the cost saving; all other demand and supply curves remain unchanged. Then the new set of equations are solved to determine the after-innovation prices and quantities. These are then entered into equations (1) through (15). In our empirical work we were able to make use of a rearranged version of the open economy model reported in Edwards and Freebairn (1981).

Table 1: Estimated Annual Social Benefits to the Region, Australia and the World from the Control of Serrated Tussock on the Central and Southern Tablelands of New South Wales[(a)]

Price elasticity of supply [(c)] δ	Change in consumers' surplus					Change in producers' surplus					Total social benefits				
	$\eta^{(b)(c)}$					$\eta^{(b)(c)}$					$\eta^{(b)(c)}$				
	0.05	0.10	0.20	0.50	0.80	0.05	0.10	0.20	0.50	0.80	0.05	0.10	0.20	0.50	0.80
	$m	$m	$m	$m	$m	$m	$m	$m	$m	$m	$m	$m	$m	$m	$m
Regional level															
0.10	0	0	0 (74)	0	0	161	162	162 (−29)	162	162	161	162	162 (46)	162	162
0.20	0	0	0	0	0	81	81	81	81	81	81	81	81	81	81
0.40	0	0	0	0 (31)	0	40	40	40	40 (5)	40	40	40	40	40 (36)	40
0.60	0	0	0	0	0	27	27	27	27	27	27	27	27	27	27
0.80	0	0	0	0	0	20	20	20	20	20	20	20	20	20	20
1.00	0	0	0	0	0 (22)	16	16	16	16	16 (14)	16	16	16	16	16 (36)
2.00	0	0	0	0	0	8	8	8	8	8	8	8	8	8	8
National level															
0.10	*	*	* (207)	*	*	137	144	150 (−146)	156	158	138	144	150 (62)	156	158
0.20	*	*	*	*	*	66	69	72	76	77	66	69	72	76	78
0.40	*	*	*	* (88)	*	32	33	34	36 (−28)	37	32	33	34	36 (60)	38
0.60	*	*	*	*	*	21	22	22	24	24	21	22	22	24	24
0.80	*	*	*	*	*	16	16	17	17	18	16	16	17	17	18
1 00	*	*	*	*	* (63)	13	13	13	14	14 (−3)	13	13	13	14	14 (60)
2.00	*	*	*	*	*	6	6	6	7	7	6	6	6	7	7
World level															
0.10	89	67	44	22	15	74	96	118	140	148	162	162	162	162	162
0.20	53	44	33	19	13	28	37	48	62	68	81	81	81	81	81
0.40	30	27	22	15	11	11	14	18	26	29	41	41	41	41	41
0.60	20	19	17	12	10	7	8	10	15	18	27	27	27	27	27
0.80	16	15	13	10	9	5	5	7	10	12	20	20	20	20	21
1.00	13	12	11	9	8	4	4	5	7	9	16	16	16	16	17
2.00	7	6	6	6	6	2	2	2	3	3	8	8	8	9	9

(a) Figures in brackets are results presented by VSC. See text for discussion.

(b) η = absolute value of price elasticity of demand.

(c) Price elasticities of supply are point elasticities applying in the region, the rest of Australia and the rest of the world at the initial (without weed control) equilibrium. Price elasticities of demand are point elasticities applying on the rest of Australia's demand curve and the rest of the world's demand curve at the initial equilibrium. The price elasticity of world demand for regional and national production is higher — see text.

* Less than $0.5 million.

of zero wool consumption within the region, there were no gains to tablelands consumers. Gains to Australian consumers were in all cases less than half a million dollars a year. VSC, by contrast, found that the change in consumers' surplus contributed most of the social benefits in their regional analysis and more than all of aggregate consumer and producer gains in their national analysis. Our estimates of producer gains are in general much larger than those of VSC (notwithstanding their use of a higher wool price and higher production) and are always positive. Although Australian producers outside the tablelands region lose from the fall in price caused by the regional supply shift (this loss ranges from $1 million to $24 million per year and can be found by subtracting national producers' gains from regional producers' gains) this is necessarily less than the gain to producers within the region. Because of the offsetting errors in their estimates of producer and consumer gains, VSC's estimates of total social benefits are closer to ours, though the differences are in general still large.

The bottom part of Table 1 shows the results of applying a catholic welfare analysis, treating gains and losses accruing overseas (to consumers or producers) in the same way as gains or losses within Australia. Three points may be made about these results. First, although rounding hides the fact in many instances, total world gains are slightly higher than gains at the regional level. Second, the size of world gains is insensitive to the elasticity of demand but is influenced substantially by the elasticity of supply. This is because the vertical shift of the supply curve that corresponds to a given horizontal shift is greater the more inelastic is supply, and world gains are approximately proportional to the vertical shift (unit reduction in costs). Third, the distribution of world gains between producers and consumers is influenced strongly by these elasticities.

In Table 2 annual social benefits from the control of serrated tussock are expressed in present value terms, summed over ten years. (Net social benefits may be found by subtracting $34 million, the present value of annual social costs in VSC's analysis). The one corresponding result in VSC is shown in brackets. In both the regional and national assessments the VSC result greatly overstates social gains and greatly understates the share of gains accruing to producers. The bottom part of the table indicates that, at the world level, a substantial share of the gains from tussock control in the New South Wales tablelands accrues to consumers. If the elasticity of demand for world wool is in the range –0.5 to –0.20 (which is almost identical with the range assumed by Campbell, Gardiner and Haszler (1980) in estimating the effects of wool price stabilization on Australia's revenue from wool), consumers obtain at least 40 per cent of world benefits for values of 0.2 and higher for the price elasticity of wool supply.

The sensitivity of gains from a regional supply shift for wool to changes in some of the parameters used in its estimation is indicated in Table 3. The left hand column of results are treated as base results. They are calculated on the assumptions that the supply shift occurs over one year, gains accrue over ten years, the initial price of wool is 158.4 cents per kg and the discount rate is 10 per cent. Subsequent columns show the effect of varying different parameters. The effect of using a wool price of 200 cents (as VSC did) rather than 158.4 (as we did) is to increase gains in approximately the same proportion as the price of wool. The third column of results shows the reduction in social benefits if the supply shift occurs over five years instead of in one year. It seems certain that one year is too short a time to complete a control programme requiring the

Table 2: The Value and Distribution of Social Benefits to the Region, Australia and the World from the Control of Serrated Tussock on the Central and Southern Tablelands of New South Wales[(a)]

(Present values summed over ten years: discount rate 10 per cent)

Price Elasticity of Supply[(c)] δ	Social Benefits $\eta^{(b)(c)}$					Per cent of social benefits accruing to producers $\eta^{(b)(c)}$				
	0.05	0.10	0.20	0.50	0.80	0.05	0.10	0.20	0.50	0.80
	$m	$m	$m	$m	$m	%	%	%	%	%
Regional level										
0.10	992	994	995	997	997	100.0	100.0	100.0	100.0	100.0
0.20	496	496	497	498	498	100.0	100.0	100.0	100.0	100.0
0.40	248	248	248	249	249	100.0	100.0	100.0	100.0	100.0
0.60	165	165	165	166	166	100.0	100.0	100.0	100.0	100.0
0.80	124	124	124	124	124	100.0	100.0	100.0	100.0	100.0
1.00	99	99	99	99	99 (221)	100.0	100.0	100.0	100.0	100.0 (40.1)
2.00	49	49	50	50	50	100.0	100.0	100.0	100.0	100.0
National level										
0.10	846	884	922	960	973	99.7	99.8	99.9	99.9	100.0
0.20	408	423	442	467	476	99.7	99.7	99.8	99.9	99.9
0.40	199	204	212	224	231	99.6	99.7	99.7	99.8	99.9
0.60	131	134	138	146	150	99.6	99.7	99.7	99.8	99.8
0.80	98	99	102	107	111	99.6	99.7	99.7	99.8	99.8
1.00	78	79	81	85	87 (369)	99.6	99.6	99.7	99.7	99.8 (−5.0)
2.00	39	39	40	41	42	99.6	99.6	99.6	99.7	99.7
World level										
0.10	997	997	997	998	998	45.3	59.0	72.7	86.3	90.9
0.20	498	499	499	499	500	34.4	45.3	59.0	76.6	83.5
0.40	249	249	249	250	250	27.1	34.4	45.3	63.5	72.4
0.60	166	166	166	167	168	24.3	29.7	38.5	55.1	64.3
0.80	125	125	125	125	126	22.8	27.1	34.4	49.3	58.2
1.00	100	100	100	101	102	21.9	25.4	31.6	44.9	53.2
2.00	50	50	51	53	55	19.9	21.7	25.0	32.6	37.2

(*a*) Figures in brackets are results obtained by VSC.

(*b*) η = absolute value of price elasticity of demand.

(*c*) Price elasticities of supply are point elasticities applying in the region, the rest of Australia and the rest of the world at the initial (without weed control) equilibrium. Price elasticities of demand are point elasticities applying on the rest of Australia's demand curve and the rest of the world's demand curve at the initial equilibrium. The price elasticity of world demand for regional and national production is higher — *see* text.

Table 3: Sensitivity of Social Benefits from the Control of Serrated Tussock to: the Price of Wool; the Timing of Cost Reductions; the Period over which Benefits Accrue; and the Rate of Discount[a]

(Present value of social benefits)

Price elasticity of supply δ and demand η[b]	Base results P = 158.4 c.per kg N = 1 year S = 10 years D = 0.10	P (price of wool) 200.00c. per kg	N (number of years over which cost reduction occurs) 5	S (number of years over which benefits accrue) 20	 30	D (rate of discount) 0.05	 0.15
	$m	$m	$m	$m	$m	$m	$m
Regional level							
$\delta=0.10, \eta=-0.05$	992	1253	706	1375	1522	1247	811
$\delta=0.10, \eta=-0.80$	997	1259	709	1382	1530	1253	815
$\delta=1.00, \eta=-0.05$	99	125	70	137	152	124	81
$\delta=1.00, \eta=-0.80$	99	125	71	138	152	125	81
$\delta=2.00, \eta=-0.05$	49	62	35	69	76	62	40
$\delta=2.00, \eta=-0.80$	50	63	35	69	76	62	41
National level							
$\delta=0.10, \eta=-0.05$	846	1069	599	1173	1299	1064	691
$\delta=0.10, \eta=-0.80$	973	1228	691	1348	1493	1223	795
$\delta=1.00, \eta=-0.05$	78	99	55	108	120	98	64
$\delta=1.00, \eta=-0.80$	87	110	62	121	134	110	71
$\delta=2.00, \eta=-0.05$	39	49	27	54	60	49	32
$\delta=2.00, \eta=-0.80$	42	53	30	58	64	53	34
World Level							
$\delta=0.10, \eta=-0.05$	997	1259	709	1381	1530	1253	814
$\delta=0.10, \eta=-0.80$	998	1260	710	1383	1532	1255	816
$\delta=1.00, \eta=-0.05$	100	126	71	138	153	125	81
$\delta=1.00, \eta=-0.80$	102	127	72	141	157	128	83
$\delta=2.00, \eta=-0.05$	50	63	36	69	77	63	41
$\delta=2.00, \eta=-0.80$	55	66	39	77	85	70	45

(a) Cost reductions are assumed to occur in linear fashion over the number of years indicated.

(b) Price elasticities of supply are point elasticities applying in the region, the rest of Australia and the rest of the world at the initial (without weed control) equilibrium. Price elasticities of demand are point elasticities applying on the rest of Australia's demand curve and the rest of the world's demand curve at the initial equilibrium. The price elasticity of world demand for regional and national production is higher — see text.

establishment of improved pastures, though five years may err in the other direction. It is clear, however, that the social benefits are quite sensitive to the time taken to achieve the supply shift. The fourth and fifth columns show that social benefits are increased significantly if the benefits of weed control are sustained over twenty or thirty years rather than ten. Allowing for pasture maintenance and other costs over the longer periods (Vere, Campbell and Scarsbrick 1981) would reduce the margin of benefits over the base situation, but not change the overall picture. Finally, the present value of social benefits is influenced significantly by the rate of discount. Substituting a discount rate of 5 per cent for the 10 per cent base rate has an effect on social benefits very similar to an increase from 158.4 cents to 200 cents in the price of wool.

5 VSC on the Distribution of Benefits

We feel that some comment should be made on the Discussion section of VSC's paper. Here the authors expressed certain qualifications about their model, especially regarding the distribution of benefits from a programme to control serrated tussock.

Our strongest disagreement with VSC in this section of their paper concerns the argument about who should pay for a weed control programme. According to VSC, producers should meet most of the costs if they obtain most of the benefits, and Australian consumers should pay if they are the beneficiaries. This argument disregards an important symmetry. Regardless of the initial share of costs borne by tablelands producers in the form of a levy per unit of production, the ultimate distribution between them and (all) consumers will be the same as the distribution of the benefits from the control programme (Tisdell 1974, IAC 1976). The analysis is essentially the same as the standard analysis of the effects of an indirect tax. Briefly, a gain in productivity shifts the supply curve down while a levy on production to finance the investment in research shifts the supply curve up. An implication of this symmetry is that it is not necessary to have knowledge of elasticities of supply and demand to achieve what VSC consider to be an equitable distribution of the costs of a control programme. Equity (meaning that the costs of control are shared between consumers and regional producers in the same proportions as the benefits) will follow automatically if the programme is funded by a tax on regional wool production[8]. Other researchers, including Nagy and Furtan (1978), have also overlooked this point.

The notion of equity is in fact made more complex in the case under consideration (though VSC do not recognize this) by the existence of Australian production outside the New South Wales tablelands. Producers in the rest of Australia lose from a successful regional weed control programme, the loss being greater the more price inelastic is world demand. For them, also, a symmetric

8. A. G. Lloyd has correctly pointed out that this analysis is static, while in fact the market adjusts gradually to a production levy and to a (subsequent) cost reduction. Recognizing that adjustment is not instantaneous and the existence of a delay between raising a levy and achieving a productivity increase results in increases in producers' shares, in present value terms, in both the levy and in the benefits from the productivity increase. In some back-of-the-envelope calculations that we carried out the effect of incorporating these effects was to increase producers' shares in costs and benefits by similar percentages, thus retaining the symmetry discussed in the text. Apart from noting this point, we disregard the complications raised by Lloyd, as did Tisdell (1974) and the IAC (1976).

situation exists: the ratio of their loss to the gain to consumers plus regional producers from the control programme equals the ratio of their gain to the loss to consumers plus regional producers from the levying of a tax on regional production to fund the control programme. Because production occurs in the rest of Australia, a tax on each unit of wool *consumption* would not meet VSC's criterion for an equitable distribution of the costs of weed control in the tablelands. Part of a consumption tax would be borne by producers, with producers in the rest of Australia (losers from tablelands weed control) bearing the same tax (fall in producer price) as producers in the tablelands region who gain from the control programme.

With public funding of weed control, assumed implicitly by VSC, the regional supply curve moves down more than it does if producers pay initially through a levy. The benefits of the subsidy, like the benefits of the productivity gains arising from weed control, accrue to regional producers and to all consumers. Producers outside the region lose from the subsidy, as they do from the control of tussock in the New South Wales tablelands. Hence, the public funding approach to weed control also fails to meet VSC's equity criterion[9].

VSC suggest that there are in fact reasons for thinking that consumers are the main beneficiaries of a weed control programme. Their argument relies on two issues pressed by Emerson and Plato (1978) in a study of weed control in the United States. One is: "Pure economic profits accruing to producers through increased production from weed control would be rapidly bid away by the entry of new resources . . ." (VSC, p. 135). Given the highly elastic world demand for the region's production, this supposes that supply is very elastic — a supposition not supported by most supply response studies for agriculture (or by VSC's own choice of elasticities of supply). In four Australian studies of wool supply summarized by Hall (1981) values between 0.33 and 0.36 were obtained for the price elasticity of supply of wool in the medium to longer term. Admittedly, because the wool industry in the tablelands can attract resources from or lose them to the wool and other industries in the rest of Australia, the regional elasticity of supply measured along 'the with control' supply curve may be substantially higher than the elasticity for Australia as a whole. Nevertheless, we would expect there to be sufficient inelasticity in the supply of agriculture-specific resources such as land, operator labour, management and some classes of capital for increases in economic rent to be earned for a significant period. But in the event that most of the gains from weed control *do* accrue ultimately to consumers, they will also pay most of any production levy imposed on tablelands producers to finance a control programme.

The second issue is the treatment of increased foreign exchange earnings as a benefit to consumers. We consider that VSC, and Emerson and Plato, are in error in introducing this concept into the analysis. The extra foreign exchange is the counterpart of producers' increase in revenue. Clearly, it would be illegitimate to count both the increase in producers' economic rent and the increase in export earnings in assessing a project (neither VSC nor Emerson and Plato did so). We consider that it is also invalid to include the addition to foreign exchange resulting from a project if, as in the paper by Emerson and Plato,

9. There is an additional reason why public funding does not meet a more general version of the equity criterion used by VSC. Except with very special assumptions, taxpayers will not benefit from the productivity increase in proportion to the costs they bear.

economic rents are not counted because they are held to be quickly competed away. If rents could be disregarded on this ground (which we argued against above in the context of a tussock control project on the New South Wales tablelands), it would be because the change in woolgrowers' revenue was equal to the change in their costs. We regard it as illegitimate to treat the foreign exchange counterpart of producers' extra revenue as a gain from the project while ignoring the cost, of equal magnitude, incurred in achieving the gain.

In summary, we find unconvincing VSC's effort to argue the plausibility of a distribution of benefits similar to the one they obtained.

6 Conclusion

Our main objective has been to develop an appropriate model for estimating the size and distribution of the gross benefits resulting from an increase in productivity in one sector of an industry. Specifically, we disaggregate an industry into three sectors: the sector or region of the industry where the productivity increase causes the supply curve to shift down, the industry in the rest of the country where there is no productivity gain, and the industry in the rest of the world. The model could be applied in a diversity of *ex ante* and *ex post* assessments of the benefits of productivity gains due to disease and pest control, genetic improvement, improved animal, plant and soil management techniques and generally to supply-shifting technological change[10]; it is sufficient that the productivity increase can be adopted successfully by an identifiable component of an industry. The model is also applicable if supply shifts in two or more sectors of an industry at different rates.

As an illustration we applied the model to estimate the benefits from improved control of serrated tussock on the central and southern tablelands of New South Wales, a problem previously analysed by Vere, Sinden and Campbell (VSC). Technology change in one sector of the industry, weed control on the tablelands of New South Wales, effectively shifts down the supply curve in that sector of the industry but not in other sectors, the wool industry in other parts of Australia and in the Rest of the World. Adopting the arguments of Rose (1980) and of Lindner and Jarrett (1978, 1980) we assume a parallel shift of the regional supply curve. The regional supply shift causes a fall in the commodity price in all sectors of the market. Using changes in economic surplus as measures of welfare effects of the new technology, the model shows that consumers gain, producers in the region gain, producers in the other regions lose, and there is a net social gain both for the world and for the country. The inappropriate model used by VSC provides markedly different and erroneous measures of the distribution of benefits and quite different estimates of aggregate benefits.

It would be easy to extend the model in several ways. While our analysis has focussed on an export industry the model could be readily applied to an import industry or to a nontraded industry. Conceptually the model can be readily generalized for many sectors or components of an industry, although further disaggregations will place a greater demand on required data on supply and

10. The model can also be used to examine the effects of input price changes which have non-identical effects on supply curves in different sectors of an industry.

demand quantities and price elasticities. As we have shown in our illustration, the model can be easily subjected to sensitivity analyses for uncertain parameters.

Finally, we argue that the use of a levy on regional production to fund a programme necessary to achieve a regional increase in productivity is consistent with the equity criterion that producers and consumers should share the costs of the programme in the same proportion as they share the benefits. Public funding of the programme is not consistent with this criterion.

References

AKINO, M. and HAYAMI, Y. (1975), "Efficiency and equity in public research: rice breeding in Japan's economic development", *American Journal of Agricultural Economics* 57(1), 1–10.

BUREAU OF AGRICULTURAL ECONOMICS (1981), *Quarterly Review of the Rural Economy* 3(1).

CAMPBELL, R., GARDINER, B. B. and HASZLER, H. (1980), "On the hidden revenue effects of wool price stabilisation in Australia: initial results", *Australian Journal of Agricultural Economics* 24(1), 1–15.

DUNCAN, R. and TISDELL, C. (1971), "Research and technical progress: the returns to producers", *Economic Record* 47(117), 124–29.

EDWARDS, G. W. and FREEBAIRN, J. W. (1981), *Measuring a Country's Gains from Research: Theory and Application to Rural Research in Australia.* A Report to the Commonwealth Council for Rural Research and Extension, Australian Government Publishing Service, Canberra.

EMERSON, P. M. and PLATO, G. E. (1978), "Social returns to disease and parasite control in agriculture: witchweed in the United States", *Agricultural Economics Research* 30(1), 15–22.

HALL, N. H. (1981), Product supply elasticities for the Australian grazing industries, estimated with a programming model, Bureau of Agricultural Economics Working Paper 81–15.

INDUSTRIES ASSISTANCE COMMISSION (1976), *Financing Rural Research*, Australian Government Publishing Service, Canberra.

LINDNER, R. K. and JARRETT, F. G. (1978), "Supply shifts and the size of research benefits", *American Journal of Agricultural Economics* 60(1), 48–58.

LINDNER, R. K. and JARRETT, F. G. (1980), "Supply shifts and the size of research benefits: a reply", *American Journal of Agricultural Economics* 62(4), 841–44.

MENZ, K. M. and AULD, B. A. (1977), "Galvanised burr, control and public policy towards weeds", *Search* 8(8), 281–87.

NAGY, J. G. and FURTAN, W. H. (1978), "Economic costs and returns from crop development research: the case of rapeseed breeding in Canada", *Canadian Journal of Agricultural Economics* 26(1), 1–14.

POWELL, A. A. (1959), "Export receipts and expansion in the wool industry", *Australian Journal of Agricultural Economics* 3(2), 64–74.

QUILKEY, J. J. (1970), "The merino export embargo — a comparative static analysis", *Australian Journal of Agricultural Economics* 14(1), 63–71.

RIDGE, P. E. and TELFORD, T. E. (1978), "A cost-benefit study of funds invested in barley improvement in Victoria", *The Journal of the Australian Institute of Agricultural Science* 44(3 and 4), 190–194.

ROSE, R. (1980), "Supply shifts and research benefits: comment", *American Journal of Agricultural Economics* 62(4), 834–7.

TISDELL, C. A. (1974), "Research and promotional levies for Australian rural products — a brief economic review emphasising wool", *Farm Policy* 14(2), 63–75.

VERE, D. T and CAMPBELL, M. H. (1979), "Estimating the economic impact of serrated tussock (*Nasella trichotoma*) in New South Wales", *Journal of the Australian Institute of Agricultural Science* 45(1), 35–45.

VERE, D. T., CAMPBELL, M. H. and SCARSBRICK, B. D. (1981), *Costs and Returns for Control of Serrated Tussock in New South Wales*, New South Wales Department of Agriculture, Division of Marketing and Economics, Farm Management Bulletin No. 3.

VERE, D. T., SINDEN, J. A. and CAMPBELL, M. H. (1980), "Social benefits of serrated tussock control in New South Wales", *Review of Marketing and Agricultural Economics* 48(3), 123–38.

WISE, W. S. and FELL, E. (1980), "Supply shifts and the size of research benefits: comment", *American Journal of Agricultural Economics* 62(4), 838–40.