THE MEASUREMENT OF GAINS AND LOSSES FROM AGRICULTURAL RESEARCH

by

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DECLARATION

Except where otherwise indicated, this dissertation is my own work.

R. Fard Sarhangi

May, 1977
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Canberra
May, 1977

R. Fard Sarhangi
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This thesis is a survey of research over the last two decades stemming from the now classical study by Griliches on evaluating the gains from agricultural research. The thesis points to a number of areas in which there are problems which need to be resolved, and hopefully, in a few instances provides the basis on which future research may proceed.

The most important point of concern is the under-estimate of social gains (losses) provided by the supply-shift approach developed by Griliches. Wisecarver has shown that estimates based on shifts in input-demand curves are an appropriate method of estimating such gains.

The several studies which have attempted to estimate the distribution of productivity gains between consumers and producers were shown by Scobie to have used formulations of consumers' and producers' surplus which give different, and even contradictory results for the same question. This problem was shown to be mainly attributable to the different mathematical approaches adopted. However, the important point which arises from this issue is that there needs to be questioning about the appropriateness of the supply and demand, or input-demand specifications adopted. Further, it is desirable that the formulae derived adopt standard specifications for the shifts in the supply or input-demand curves and elasticity estimates.
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"Technological change" by definition consists of two major types:

(a) reduction of real costs per unit of output
    (increasing productivity in resource use); and

(b) improvements in the quality and variety of final consumption goods.

John W. Kendrick (1964) considered the "gains and losses" from technological change on two different levels. Firstly, the absolute gains and losses which accrue, on net balance, in the economy as a whole and its sectors. Secondly, relative gains and losses that accrue as a result of changes in relative prices of the various factors of production and intermediate inputs. The first type of gain or loss may be easily quantified, but relative gains and losses are much more difficult to quantify, since relative input prices change for reasons other than technological change and we have to attempt to separate out the relative price changes among the several causative factors.

Technological advance is reflected in net changes in total factor-productivity. Annual gains can be estimated by applying the average productivity of the previous year to the factors which are employed in a given year and subtract this from the net national product valued at the given year's prices. But as mentioned by Kendrick, "since annual productivity changes are influenced by changes in rates of utilisation of capacity, as well as changes in technology broadly defined,
it would be better to compute productivity increments over longer periods of time which can be done by the same technique". In a similar fashion the total productivity increase can be assigned to all the original industries. So much work has been done on the absolute level of productivity gains, but what about the distribution of the benefits and losses which are realised in the process; especially the earnings lost by those unemployed people whose displacement may be traced to technological change?

Part of the costs of persons thrown out of employment on account of technological progress is borne by the community in the form of unemployment benefits. The employer may bear part of the cost in terms of redundancy payments, and the employee bears part of the costs in terms of income foregone. To what extent and in what manner should these costs be taken into account when assessing the impact of technological change?

As well as having the effect of increasing or decreasing the earnings potential of some labour, technological change can also increase or decrease the income earning potential of existing capital and land.

The extent to which these effects occur and the incidence with which they occur between firms must to a large extent be due to the investment and innovation capabilities of the entrepreneurs. The speed with which any "super-normal" profits are reduced will depend, among other things, upon the speed of diffusion of the innovation throughout the industry and on the extent of monopoly power over the innovation possessed by firms.
All of the important problems involved in answering the various questions implicit in the above statements about distribution have been barely touched upon in research in this area. This thesis sets out to review the progress made so far in looking at the benefits and costs of research and the distribution of these. The thesis points out a number of areas where further research is needed, and attempts to reconcile some of the differences which have arisen in the development of research techniques.

Organization of the Study

Measurement of total social gains from research is discussed in Chapter 2. Two issues are elaborated; one is sorting out the real supply shift due to a particular research program from other factors influencing supply. A second has to do with the type of supply shift. The Lindner-Jarrett discussion (1976) stresses the fact that research produced technology is not generally equally relevant to all producing environments and that this fact can affect the measurement of the supply shift. Two techniques which have been used for measuring the gains from research are discussed - the supply-shift method and the input-demand method. In the light of the analysis by Wisecarver (1974) of the validity of the answers provided by the supply-shift method, the continued use of this technique should be questioned. Chapter 3 considers the allocation of relative gains (losses) from research among producers and consumers, and the role of export markets. Chapter 4 presents the development of a generalized formulae for both consumers' surplus and producers' surplus, and discusses the various forms of these formulae used in empirical work and the different results given by each under
the same circumstances. Chapter 5 deals with the allocation of
the Producer gains (losses) from research among factors of production.
It presents a number of serious criticisms of the much-quoted study
by Schmitz and Seckler and offers possible directions for further
work in this area. Chapter 6 concludes the thesis.
2.1 **Introduction**

In this chapter the development of the two different techniques of analysing social gains (losses) generated from productivity-increasing research are reviewed. The two methods of estimation of social gains (losses) presented in this chapter are:

(i) the Supply-Shift method; and
(ii) the Input-Demand method.

The first method measures social gains in terms of the output response to lowering the costs of production. The Input-Demand method measures the social gains from research by estimating the increase in the demand for that input whose productivity has been increased as a result of research.

Of those studies which have used the Supply-Shift method, some analyses have been inconsistent and some show a number of other problems in their use of this technique. These problems will be discussed in Section 2.2 in which those studies which have been mainly responsible for the development of the supply-shift method will be reviewed. In Section 2.3 the input-demand technique will be discussed. In Section 2.4 the controversy over whether it is valid to use the product supply curve or the input-demand curve (to measure welfare gains from research) will be discussed by referring to the debate between Schmalensee (1971) and Wisecarver (1974).
2.2 Supply-Shift Method

At the industry level, the effect of the adoption of a cost-reducing innovation can be represented diagrammatically by a downward shift of the supply curve. This means that more output can be produced at a given price, or the same output can be produced more cheaply. Economists now generally have agreed that the gross social benefits of the research which produces the innovation can be measured by the area between the two supply curves and below the demand curve. In Fig. 1, $S_0$ represents industry supply curve in the absence of the innovation, and $S_1$ is the supply curve when the innovation is adopted. The area to be measured is given by $A M M M A_1$.

Although there is now general agreement about the area to be measured, the estimation methods used have varied greatly, and there has been a tendency to cover up the implications of the assumptions about the nature of the shift of the supply curve.

2.2.1 Griliches' Method

Let us start with Zvi Griliches (1958) and his path-breaking article on hybrid corn. By using the concepts of consumers and producers surplus Griliches analysed two extreme cases: firstly, supply is completely elastic and the original supply curve is $S'$ (Fig. 2.1). After the development of hybrid corn, the new supply curve is $S$. Since supply is completely elastic, producers surplus does not exist and the net gain, $A + B$, represents the addition to consumer surplus. In other words, the "disappearance" of hybrid corn causes the supply curve to shift upward by the percentage reduction in the yield of corn. Thus,
FIGURE 2.1
DOWNWARD SHIFT IN THE SUPPLY CURVE DUE TO ADOPTION
OF COST-REDUCING INNOVATION
FIGURE 2.2
UPWARD SHIFT IN THE PERFECTLY ELASTIC SUPPLY CURVE
DUE TO THE "DISAPPEARANCE" OF HYBRID CORN
the "loss" to society, in this case is the total area under the demand curve and between the new and old supply curves, which is \((A + B)\). Griliches considers the rectangle \(A\) as the increase in the total cost of producing the quantity \(Q_2\) in the new situation, and the triangle \(B\) as the loss in consumer's surplus caused by the rise in price. A linear approximation of the area \((A + B)\) is given by the following formula:

\[
\text{Loss } 1 = KP^1Q^1(1-\frac{K}{\eta})
\]

where,

- \(K\) = % change in yield (marginal cost and average cost)
- \(P^1\) = previous equilibrium price of corn produced
- \(Q^1\) = previous equilibrium quantity of corn produced
- \(\eta\) = price elasticity of demand for corn

Secondly, he assumes that the elasticity of the supply curve is zero (Fig. 2.3). In this case, the loss should be measured by the area \(O_2P_2P_1\) (or \(D + F\)). The rectangle, \(F\), measures the loss is corn production at \(P_1\) which is the old price. The triangle, \(D\), is the deadweight loss in economic welfare. \(C + D\) is the loss in consumer surplus. The total loss is given by the formula:

\[
\text{Loss } 2 = KP^1Q^1(1+\frac{K}{\eta})
\]

It is obvious that his second assumption leads to a higher estimation of the loss. R.K. Lindner and F.Q. Jarrett (1976) have shown that Griliches' claim that the "two estimates bracket estimates implied by assuming other intermediate supply elasticities" is not generally valid. They refer to the special case of a perfectly inelastic demand curve and a proportionate shift in the supply curve (Fig. 2.4), which
FIGURE 2.3
LEFTWARD SHIFT IN THE PERFECTLY INELASTIC SUPPLY CURVE
DUE TO THE "DISAPPEARANCE" OF HYBRID CORN
FIGURE 2.4
PROPORTIONATE SHIFT OF SUPPLY

Source: R.K. Lindner and F.G. Jarrett (1976)
implies that the reduction in average cost of production is greater at the margin than at intra-marginal levels of output.

They point out that an innovation of hybrid corn type is likely to result in a proportionate shift rather than a parallel shift in the supply curve because it is almost certain that the long-run corn supply curve will be less than perfectly elastic, and positive change in yields of hybrid corn may be relatively constant in all areas. If this is the case, Griliches' estimates of actual benefits could have been biased upwards.

Lindner and Jarrett have also shown that for a parallel shift of a partly elastic supply curve Griliches' formula under-estimates actual benefits when demand is not perfectly elastic, and that the error magnitude becomes larger as the demand curve elasticity increases. As a result, "Two biases operating in opposite directions will be introduced by using Griliches' formula to estimate research benefits when both demand and supply are neither perfectly elastic, nor perfectly inelastic. It is therefore not possible a priori to reach a definite conclusion about whether Griliches has over-estimated the returns to hybrid corn research."

Griliches' formula for calculating research benefits is given by: \( \text{loss}_1 = K\hat{P}_1\hat{Q}_1(1-\frac{1}{2\hat{\eta}}) \), in which the supply function is assumed to be perfectly elastic. Lindner and Jarrett believe (from Griliches' formula) that "research benefits could in principle be negative", i.e., when \( K \) and \( \hat{\eta} \) (absolute value of \( \eta \)) become large, then \( \frac{1}{2\hat{\eta}} > 1 \). When \( \hat{\eta} = 0 \) (denoting a perfectly inelastic demand curve), the formula will
be reduced to $\text{KP}_1^Q$. This $\text{KP}_1^Q$ actually measures the area $\text{P}_0^O\text{M}_1^Q\text{P}_1^O$ in Fig. 2.4. Now, we should refer to W. Clayton Dodge (1972) for the Law of Parallelograms, which says "the area of any parallelogram is equal to that of a rectangle with the same base and altitude". Thus, taking this Theorem into account, the area $\text{P}_0^O\text{M}_1^Q\text{M}_1^Q\text{P}_1^O$ is equal to the area $\text{A}_0^O\text{M}_1^Q\text{A}_1^Q\text{A}_1^Q$. According to Lindner and Jarrett, since the area $\text{A}_0^O\text{M}_1^Q\text{A}_1^Q\text{A}_1^Q$ would represent the level of research benefits for a parallel downward shift of the supply curve, the above formula will over-estimate these benefits (by the triangle $\text{A}_1^Q\text{M}_1^Q\text{A}_1^Q$ in Fig. 2.4) whenever the absolute fall in average costs of production is greater (at the margin) than the reduction of costs infra-marginally and as long as demand is perfectly inelastic.

Duncan and Tisdell (1971) have shown that differences in the reduction of costs at the margin compared with infra-marginal reductions for different demand elasticities are important in assessing the influence of cost-reducing technical progress on an industry's profit, or producer's surplus. As shown in Table 2.1, the columns of their matrix represent the nature of the elasticity of demand and the rows show the differential effect of technical progress on marginal and infra-marginal costs. The signs +, - and o denote the variation in the industry's surplus. In the bottom row, the question mark denotes that the outcome will only be clear if exact specification of the demand curve and the shift in costs are available.

Duncan and Tisdell present three "propositions" which correspond to the columns. For simplicity, let us examine only the second "proposition", and go back to Griliches' under-estimate of research benefits.
**TABLE 2.1**

Demand Elasticity/Reduction of Costs Matrix

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<tr>
<th>Reduction of Costs at Margin Compared with Infra-Margin</th>
<th>Nature of Demand Curve</th>
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<tr>
<td></td>
<td>Perfectly Elastic</td>
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<tr>
<td>Less</td>
<td>+</td>
</tr>
<tr>
<td>Equal</td>
<td>+</td>
</tr>
<tr>
<td>Greater</td>
<td>+</td>
</tr>
</tbody>
</table>

Source: Duncan and Tisdell (1971) Table II.

Proposition Two assumes a perfectly inelastic demand curve, in which a downward shift in the supply curve results in the fall of the industry's surplus. Of course, the result depends upon differential elements.

(i) The surplus falls if the reduction in costs at the margin is greater than the cost reduction for infra-marginal units of production.

(ii) The surplus remains unchanged if the cost reduction is equal for marginal and infra-marginal units

(iii) Increase in the surplus happens when the cost reduction on the infra-marginal units is greater than for the marginal units.

They have illustrated these cases as reproduced in Fig. 2.5.

In summary, Duncan and Tisdell show that "the differential effect of technical progress on costs as well as the elasticity of the demand curve are important factors in determining whether cost-reducing research increases an industry's surplus. Since under certain circumstances producers can lose as a result of cost-reducing research."
FIGURE 2.5

CHANGES IN INDUSTRY SURPLUS WITH PERFECTLY INELASTIC DEMAND

Source: Duncan and Tisdell (1971)
Lindner and Jarrett have depicted in Fig. 2.6 a different case, i.e., when demand and supply are neither perfectly inelastic nor perfectly elastic. In this Figure, \( S_1 \) is parallel to \( S_o \), and the vertical distance between \( S_o \) and \( S_1 \) is measured by \( KP_1 \), in which \( K \) should be interpreted as the proportionate reduction in costs at output level \( Q_1 \) only. Griliches' formula in this case is \( KP_1 Q_1 (1-\frac{1}{2}KN) \) which under-estimates the correct area \( A M M_o A_o \) as follows:

1. \( KP_1 Q_1 (1-\frac{1}{2}KN) = KP_1 Q_1 - (\frac{1}{2}KN) KP_1 Q_1 \)

   the term \( KP_1 Q_1 \) measures \( P'M'M_o P_1 \)

2. \( P'M'M_o P_1 = A_o M'M_o A_o \) (by the law of parallelograms)

   since \( \eta = \) the absolute value of the price-elasticity of demand for corn.

3. Then \( \eta = \frac{\Delta Q}{\Delta P} \)

   \( = \frac{Q_1 - Q_o}{P_o - P_1} \frac{P_1}{Q_1} \)

4. Substituting for \( \eta \) at \( P_1, Q_1 \) in the second term, \( KP_1 Q_1 (\frac{1}{2}KN) \) gives:

5. \( KP_1 Q_1 (\frac{1}{2}KN) = KP_1 Q_1 \left[ \frac{1}{2} K \frac{Q_1 - Q_o}{Q_1} \frac{P_1}{P_o - P_1} \right] \)

   \( = KP_1 Q_1 \left[ \frac{1}{2} K \frac{Q_1 - Q_o}{Q_1} \frac{P_1}{P_o - P_1} \right] \)

   \( = \frac{1}{2} KP_1 \left[ Q_1 - Q_o \right] \left[ \frac{KP_1}{P_o - P_1} \right] \)

since the area of the triangle \( M'M_o M_1 = \frac{1}{2} KP_1 (Q_1 - Q_o) \) and,
FIGURE 2.6

PRODUCERS' AND CONSUMERS' SURPLUS CHANGES FROM SUPPLY SHIFT

6. \( KP_1 = P'_1 - P_1 = (P'_1 - P_0) + (P_0 - P_1) \)

Therefore,

7. \( KP_1 Q_1 \left( \frac{1}{2} K_2 \right) = \text{area of triangle } M'M'M_1 \left[ 1 + \frac{P'_1 - P_0}{P_0 - P_1} \right] \)

finally, the area which is to be measured correctly is equal to \( A M_1 M_2 A_1 \) or

8. \( A M_1 M_2 A_1 = A M'_1 M'_2 A_1 - M'M_1 M_1 \)

This area is greater than the one measured by \( KP_1 Q_1 \left( 1 - \frac{1}{2} K_2 \right) \), by the amount

\[
\text{area of } M'M_1 M_1 \left[ 1 + \frac{P'_1 - P_0}{P_0 - P_1} \right].
\]

I extend the equation 8, so:

9. \( A M'_1 M'_2 A_1 - M'M_1 M_1 > KP_1 Q_1 \left( 1 - \frac{1}{2} K_2 \right) \)

or \( > KP_1 Q_1 - KP_1 Q_1 \left( \frac{1}{2} K_2 \right) \)

or \( > Q_1 \left[ (P'_1 - P_0) + (P_0 - P_1) \right] - KP_1 Q_1 \left( \frac{1}{2} K_2 \right) \)

or \( > Q_1 \left[ (P'_1 - P_0) + (P_0 - P_1) \right] - M'M_1 M_1 \left[ 1 + \frac{P'_1 - P_0}{P_0 - P_1} \right] \)

The term \( M'M_1 M_1 \) will be cancelled out on both sides, thereby I can write:

10. \( A M'_1 M'_2 A_1 > Q_1 \left[ (P'_1 - P_0) + (P_0 - P_1) \right] - M'M_1 M_1 \left[ \frac{P'_1 - P_0}{P_0 - P_1} \right] \)

11. \( A M'_1 M'_2 A_1 > Q_1 P'_1 - Q_1 P_0 + Q_1 P_0 - Q_1 P_1 - M'M_1 M_1 \left[ \frac{P'_1 - P_0}{P_0 - P_1} \right] \)

or \( > Q_1 P'_1 - Q_1 P_1 - M'M_1 M_1 \left[ \frac{P'_1 - P_0}{P_0 - P_1} \right] \)

since \( A M'_1 M_1 A \) should be equal to \( Q_1 P'_1 - Q_1 P_1 \) (to hold the inequality)
and $O_1P'_1 - O_1P_1$ is equal to the area of rectangles $O_1Q'M'P'$ and $O_1Q'M_1P_1$ respectively in Fig. 2.6, thereby:

$$A_{M'M'A_1} = O_1Q'M'_P - O_1Q'M_1P_1 = P'M'_P'M_1$$

so, \[\text{[the area of } M'M_1] \times \frac{p - P}{p_0 - P_1}\] is virtually the difference between the area measured by $KP_1Q_1$ $(1-K\eta)$ and the area $A_{O_1Q_1A_1}$.

From the above, Lindner and Jarrett concluded that this under-estimation of research benefits by the formula (when demand is relatively elastic) generally will be balanced by the nature of the formula to over-estimate benefits when reductions in cost for infra-marginal production are less than those at the margin, "and the net bias introduced by using this formula is indeterminate". They developed an alternative general formula by which research benefits can be measured carefully and exactly which will be discussed later.

2.2.2 Peterson's Method

Peterson's (1967) measurement technique is based on the value of consumer surplus (obtained by the use of new or improved inputs) which is equal to the area between the old and new supply curves and below the demand curve. He employs $K$ as the shift in the supply of Poultry Production function that would occur should the new inputs used by poultry farmers to get greater efficiency disappear. His derived general formula for the measurement of annual research benefits, has a number of errors which have been shown by Lindner and Jarrett (1976). Peterson's diagram is shown in Fig. 2.7.
FIGURE 2.7
SHIFT IN THE SUPPLY SCHEDULE RESULTING FROM THE USE OF NEW INPUTS

The first error is about the area between the two supply curves and below the demand curve. He refers to it as consumer surplus, whereas it is in general the sum of producer surplus and consumer surplus. However, when supply is perfectly elastic, or when demand is perfectly inelastic AND there is a parallel shift in the supply curve, then increased social benefit will consist completely of consumer surplus.

The second error relates to the treatment of the variable K, defined as the percentage decrease in the supply function of poultry products that occurs if the new inputs used by poultry farmers to obtain higher efficiency disappear. However, in his actual treatment of K it is represented as the change in the equilibrium quantity of output if the innovation disappears; and, it is expressed as a proportion of the equilibrium level of output produced with the innovation, for example, \( K = \frac{Q_0' - Q_1}{Q_1} \) in Fig. 2.7. Peterson, in fact, is contradicting himself by this definition of K which implies a horizontal, rather than a vertical shift of the supply curve. In addition, it understates the extent of the shift since it includes the effect of the equilibrating process which involves supply and demand together. "This approach makes it more difficult to interpret the effect of agricultural research per se on the supply function, and would require the further education of scientists into the mysteries of supply and demand elasticities." (Lindner and Jarrett, 1976).

His third error is about the claim that "area A + C + D + E + F is approximately equal to area B + C + D + F". Since his supply curves do not intersect the vertical axis, Lindner and Jarrett find it difficult to show why this statement is wrong (see Peterson's diagram). Therefore,
they present a more precise diagram (Fig. 2.6), which shows the special case of a parallel shift in the supply curve and a demand curve which is unitary and elastic. By using this figure, they show that Peterson's assertion about the equality of the above two areas is wrong and they cannot, in general, be even approximately equal.

The areas $A + C + D + E + F$ and $B + C + D + F$ (from Peterson's diagram in Fig. 2.7) correspond to areas $\Delta MMMA$ and $\Delta MLOL$ (in Fig. 2.6) respectively. When demand is unitary they are elastic: $\Delta MMMA = P M M P$. By the Law of Parallelograms, area $\Delta MMMA = area P'M'MP$. So area $\Delta MMMA = area P'M'MP$. Also $\Delta MLOL > P'M'MP$. by the area $P'M'MP$.

Greg Martin et al. (1977) believe that Peterson's formula is backward looking - completely ex post, which requires the maximum possible amount of information and almost impossible to apply "ex ante".

Peterson's formula for calculation of the absolute size of the benefits is as follows:

$$B = K \frac{Q_1 P_1}{\eta} + \frac{1}{2} K^2 \frac{P_1}{\eta} - \frac{1}{2} \frac{Q_o}{P_0} K^2 \frac{P_1}{\eta+e} \frac{(P_1 - (\eta)) (\eta - 1)}{\eta}$$

where,

$K$ is defined as the percentage shift to the left of the supply function, if the innovation had not been available to farmers.

$\varepsilon$ and $\eta$ are the supply and demand elasticities.

$P_1 Q_1$ are the equilibrium price and quantity of poultry products after innovation.

$P_0 Q_0$ are the equilibrium price and quantity of products before innovation.
Martin et al. believe that the above formula is incorrect. However, they present a simpler and more elegant ex ante formula:

$$ B = K P_o Q_o [1 + \frac{K(1-K) \eta - K \xi}{2 \xi \eta}] $$

where K is defined (vertically) as the proportionate reduction in unit costs as a result of the innovation. Also K is relatively simpler to obtain empirically.

2.2.3 Comparison of an Alternative Formula

As was pointed out earlier, both Griliches (1958) and Peterson (1967) assumed that an agricultural innovation would shift the supply function by the same percentage amount at all levels of output, and went forward to measure the benefits from the innovation by raising the question: "What would have been the losses if this innovation were to disappear?". However, (instead of this indirect approach) Lindner and Jarrett (1976) suggest that it will be more helpful in evaluating the impact of research on agricultural production if we take the direct approach of measuring the gains from research relative to the pre-innovation market equilibrium. A research manager, in making decisions about the amount of resources required or desired to be allocated to agricultural research, knows the situation of the current supply and has to make estimates of the impact of the research on future supply conditions. That is to say, he needs to estimate "ex ante" what the social benefits of research and their distribution are likely to be.
For simplicity, Lindner and Jarrett assume, as an approximation, linear supply and demand functions. Now, with reference to Fig. 2.8, $S_0$ and $D_0$ denote the initial supply and demand functions prior to innovation. According to them, if we postulate a proportionate shift in $S_0$, which implies that the reduction in average costs is greater at the margin than at infra-marginal levels of output, then $S_1$ will reflect the new, post-innovation, supply function. They suggest that "treating the movement of the supply function as a vertical, rather than a horizontal, shift emphasizes the cost-reducing nature of innovations, and is the way in which research scientists can more easily understand the effect of their research on the supply of agricultural output".

In Fig. 2.8, the area $A_{1M_1M_0A_0}$ which represents the gain in consequent to the innovation, can generally be measured by the rule of cross-multiplication. This rule is developed by J.F. Durrant and H.R. Kingston (1946) and relies on the co-ordinates of the points $A_1', M_1', M_0', A_0$ which are expressed in an anti-clockwise direction. The co-ordinates are: $0, A_1', Q_1', P_1, Q_0, P_0$ and $0, A_0$ respectively. Now the area of this rectilinear figure ($A_{1M_1M_0A_0}$) which can be separated into the areas of a series of triangles may be obtained by:

$$\frac{1}{2} [0 \times P_1 + P_0 \times Q_1 + Q_0 \times A_0 + 0 \times A_1 - 0 \times A_0 - 0 \times P_0 - P_1 \times Q_0$$

$$- Q_1 \times A_1] \quad \ldots \ldots \ldots \ldots (1)$$

which is equal to

$$\frac{1}{2} \left[ P_0 Q_1 - P_1 Q_0 + Q_0 A_0 - Q_1 A_1 \right] \quad \ldots \ldots \ldots \ldots (2)$$
FIGURE 2.8
PARALLEL AND NON-PARALLEL SHIFT IN SUPPLY WITH UNITARY ARC ELASTIC DEMAND

The above two expressions presented by Lindner and Jarrett can be derived as follows.

First, I consider the quadrilateral $Z_1Z_2Z_3Z_4$ (Fig. 2.9) where, by construction, we have:

- $BCDE$ as a rectangle
- $BZ_3GZ_4$ as another rectangle

Therefore,

$$\Delta BZ_3Z_4 = \Delta Z_3GZ_4$$

Similarly,

$$\Delta CZ_2Z_3 = \Delta Z_3Z_2H$$
$$\Delta DZ_1Z_2 = \Delta Z_2Z_1I$$
$$\Delta EZ_1Z_4 = \Delta Z_1KZ_4$$

Adding both sides of all equations and using Fig. 2.9 we have:

$$BCDE - Z_1Z_2Z_3Z_4 = Z_1Z_2Z_3Z_4 + IHGK$$

or

$$2Z_1Z_2Z_3Z_4 = BCDE - IHGK$$

since area $BCDE = (Y_3 - Y_1)(X_2 - X_4)$

$$= BE \times DE$$

and area $IHGK = (Y_2 - Y_4)(X_3 - X_1)$

$$= IK \times GK$$

Therefore,

$$2Z_1Z_2Z_3Z_4 = BCDE - IHGK$$

$$= (Y_3 - Y_1)(X_2 - X_4) - (Y_2 - Y_4)(X_3 - X_1)$$
FIGURE 2.9

Diagrammatical representation of equation to measure "ex ante" gains from research which will result in a shift of the supply curve.
\[ Y_3 X_2 + Y_1 X_4 - Y_1 X_2 - Y_3 X_4 \]

\[ = Y_2 X_3 + Y_4 X_1 - Y_4 X_3 - Y_2 X_1 \]

\[ = Y_3 X_2 + Y_1 X_4 + Y_4 X_3 + Y_2 X_1 - Y_1 X_2 \]

\[ Y_3 X_4 - Y_2 X_3 - Y_4 X_1 \]

Therefore,

\[ Z Z Z Z = \frac{1}{2} \left[ Y_3 X_2 + Y_1 X_4 + Y_4 X_3 + Y_2 X_1 \right] - \left[ Y_2 X_3 - Y_4 X_1 - Y_4 X_3 - Y_2 X_1 \right] \]

\[ ........... (3) \]

In Fig. 2.8, we have the rectilinear \( M_1 M_0 A_0 \), but for simplicity,

\[ A_0 = (0, A_o) \]

\[ M_0 = (Q_o, P_o) \]

\[ A_1 = (0, A_1) \]

\[ M_1 = (Q_1, P_1) \]

let us call it \( Z_1 Z_2 Z_3 Z_4 \).

Then,

\[ X_1 = 0 \text{ and } Y_1 = A_1 + Z_1 = (X_1', Y_1) \]

Similarly,

\[ X_2 = Q_1 \text{ and } Y_2 = P_1 + Z_2 = (X_2', Y_2) \]
\[ X_3 = P_0 \quad \text{and} \quad Y_3 = P_0 + Z_3 = (X_3, Y_3) \]

\[ X_4 = 0 \quad \text{and} \quad Y_4 = A_0 + Z_4 = (X_4, Y_4) \]

If we substitute the above in (3), we will have the same expression as in (2). Hence,

\[
ZZZZ = \frac{1}{2} \left[ P_0 \times Q_1 + A_1 \times 0 + A_0 \times Q_0 + P_1 \times 0 - P_1 \times Q_0 - A_0 \times 0 - P_0 \times 0 - A_1 \times Q_1 \right]
\]

\[ = \frac{1}{2} (P_0 \times Q_1 + A_0 \times Q_0 - P_1 \times Q_0 - A_1 \times Q_1) \quad \ldots \quad (2') \]

From (3), we can write (in a vector form)

\[
ZZZZ = \frac{1}{2} \begin{bmatrix} Y_2 - Y_4 \\ Y_3 - Y_1 \\ Y_4 - Y_2 \\ Y_1 - Y_3 \end{bmatrix}
\]

Equation (4) is equal to (3).

Now, if we substitute for \( X_1, Y_1 \) in equation (4) we will have:

\[
ZZZZ = \frac{1}{2} \begin{bmatrix} P_1 - A_0 \\ P_0 - A_1 \\ A_0 - P_1 \\ A_1 - P_0 \end{bmatrix}
\]

\[ = \frac{1}{2} [Q_1 (P_0 - A_1) + Q_0 (A_0 - P_1)] \quad \ldots \quad (2'') \]

As was mentioned earlier, Griliches' measure of research benefit assumes a perfectly elastic supply curve. Lindner and Jarrett argue that in terms of Fig. 2.4, \( A_0 \) in equation (2) now equals \( P_0 \) and \( A_1 = P_1 \).
The expression for the surplus in this special case is
\[ \frac{1}{2} [P_0 Q_1 - P_1 Q_o + P_0 Q_o - P_1 Q_1]. \]

The expression used by Griliches is

\[ \text{Loss } 1 = K P_1 Q_1 [1 - \frac{1}{2} K \eta]. \]

\( K \) is the proportionate shift in the supply function measured in a vertical direction and \( K = \frac{P_0 - P_1}{P_1} \) in Fig. 2.4.

If we evaluate the absolute value of the elasticity of demand \( \eta \) (at \( P_1, Q_1\)), then:

\[ \eta = \frac{\Delta Q}{\Delta P} \cdot \frac{P_1}{Q_1} = \frac{Q_1 - Q_o}{P_1 - P_0} \cdot \frac{P_1}{Q_1} \]

If we substitute for \( K \) and \( \eta \) in the expression for \( \text{Loss } 1 \) then:

\[ \text{Loss } 1 = \frac{P_0 - P_1}{P_1} \cdot P_1 Q_1 \left[ 1 - \frac{1}{2} \frac{P_0 - P_1}{P_1} \cdot \frac{\Delta Q}{\Delta P} \cdot \frac{P_1}{Q_1} \right] \]

and this reduces to:

\[ \text{Loss } 1 = \frac{1}{2} [P_0 Q_1 - P_1 Q_o + P_0 Q_o - P_1 Q_1] \quad \ldots \ldots \ldots (5) \]

From above, Lindner and Jarrett claim that equation (5) is the same as the result derived from the general expression in equation (2). Also, in the more general case when supply is less than perfectly elastic, the formulae in equations (2) and (3) are obviously not equal. The important point in equation (3) is that it measures the level of consumer benefits arising from adoption of the innovations, whereas, equation (2) measures total social producer benefit plus consumer benefit.

If we subtract equation (5) from equation (2), we will have a measure of producer benefit.
Therefore,

\[ \frac{1}{2}[P_0Q_1 - P_1Q_0 + Q_oA_o - Q_1A_1] - \frac{1}{2}[P_oQ_1 - P_1Q_0 + P_0Q_o - P_1Q_1] \]

\[ = \frac{1}{2}[Q_oA_o - Q_1A_1 - P_oQ_o + P_1Q_1] \quad \cdots \cdots (6) \]

Within the assumptions made, equations (2), (5) and (6) are Lindner and Jarrett's general results. Their applications require a knowledge of the original equilibrium price and quantity \( P_o, Q_o \); the new equilibrium price and quantity \( P_1, Q_1 \); and values for \( A_o \) and \( A_1 \). They point out that where research results have already been incorporated into production processes and an "ex post" measure of research benefits is to be calculated, data on \( P_1 \) and \( Q_1 \), i.e., current equilibrium price and quantity, can be obtained. Nevertheless, the variables \( P_o, Q_o, A_o \) and \( A_1 \) have to be estimated indirectly. We may get extra difficulties in applying the formulae "ex ante", as variables cannot be observed directly. The reason is that \( P_o, Q_o \) are sensitive to other unknown influences in addition to the adoption or non-adoption of the innovation. However, given a relatively stable condition of demand and supply, we can obtain reasonable estimates of \( P_o \) and \( Q_o \) from current levels of industry price and output. In order to estimate \( P_1 \) and \( Q_1 \), the following formulae can be used:

\[ P_1 = P_o \left[ 1 + \frac{KE}{\varepsilon + \eta} \right] \quad \cdots \cdots (7) \]

\[ Q_1 = Q_o \left[ 1 - \frac{KE\eta}{\varepsilon + \eta} \right] \quad \cdots \cdots (8) \]

In the above two formulae (adapted by Lindner and Jarrett from those used by Pinstrup-Andersen, et al., 1976), \( K \) is the proportionate
reduction in average costs of production, measured at $Q_0$, from adopting the new technology; $\xi$ and $\eta$ are the price elasticity of supply and demand respectively. We can make cost-reduction estimates by using the methods pioneered by Griliches (1958) and Petersen (1967) for "ex post" calculations, but "guess-timates" would have to be made in any "ex ante" evaluation of research proposals. The values of $\xi$ and $\eta$ in the nearness of $P_0$, $Q_0$ and $P_1$, $Q_1$ can be estimated by widely-known econometric techniques.

The problems associated with estimation of $A_1$ in the case of "ex post" studies, or $A_0$ for "ex ante" studies, are not so easy to control. In general, Lindner and Jarrett do not believe that econometrically estimated supply curves will provide reliable estimates of $A_1$ (or $A_0$) because the available observations on $P$ and $Q$ used to calculate supply parameters are typically far removed from the point where the supply curve intercepts the vertical axis. Actual estimates of supply curves often involve negative intercept terms. Such an abnormal case need not matter if the estimated supply curve is only to be used to project prices and/or quantities in the nearness of the original data set, but in their case, it is obviously illogical as it implies that producers are prepared to supply positive quantities at zero price in the long-run. Instead, they believe that $A_1$ (or $A_0$) can best be estimated by asking industry experts the following question: Ceteris Paribus, to what level would prices have to fall for industry output to fall to zero in the long run?" A subjective procedure of this type is obviously expected to make ready widely differing estimates depending upon the particular experts consulted. Lindner and Jarrett cannot help avoiding this problem but it is made less severe by the
fact that the estimated level of research benefit is relatively insensitive to the value of $A_1$ (or $A_0$) used in the formula.

Estimated benefits of research are, nevertheless, much more sensitive to the nature of the shift in the supply curve induced by adoption of the innovation which, given $A_1$, determines $A_0$, or the other way round. Griliches' arguments (1958) for a proportionate shift in the case of hybrid corn, seem convincing, but they are only applicable to low-cost innovations which increase yields by an equal proportionate amount for all producers.

The above discussion indicates that the total level of annual social benefits from adoption of an innovation is affected by the nature of the shift of the supply curve. Consequently, to estimate aggregate benefits from research, it is necessary to estimate the effect of adoption of the innovation on the average cost of infra-marginal production together with its effect on equilibrium price and quantity of industry output. The most conspicuous part of this discussion is the need to give explicit recognition to the relationship between $A_0$ and $A_1$, that is, to the nature of the shift in supply function. If we contrast Lindner and Jarrett's results with the attempts of Griliches (1958), Peterson (1967) and Akino and Hayami (1975) in their studies at measuring research benefits, we will notice that each of these studies has virtually made implicit assumptions about $A_0$ and $A_1$. For example, Griliches, by assuming perfectly elastic supply curve, uses $P_0$ and $P_1$ as the estimate of $A_0$ and $A_1$ respectively; whereas Akino and Hayami assume that $A_0$ and $A_1$ are both coincident with the origin. Such assumptions do not seem very plausible. Moreover, Lindner and Jarrett consider Peterson's approach, where the assumptions about $A_0$
are subsumed in the estimating procedures used to calculate the supply
elasticity, and where \( A_1 \) is pre-calculated by \( A_0 \) and the assumption of
a proportional shift in the supply function, as equally "unsatisfactory". Particularly, when we do not see any good reason (in general) why the
shift in the supply curve should be proportional rather than parallel,
pivotal about \( A_0 \), or convergent.

In conclusion, as it seems unreasonable from empirical
evidence to support Griliches' assumption of a perfectly elastic supply
curve, then it follows that his formula will over-estimate the measure
of research benefits. Similarly, even though Peterson's formula takes
into account the effects of supply and demand elasticities, over-
estimation of benefits will still result.

The usefulness of the methods to the problem of allocation
of resources in research is important. Both Griliches and Peterson's
approaches are restricted to evaluation of research results after the
research has been done and made available to producers. However,
equation (2) from Lindner and Jarrett allows prediction of benefits
prior to undertaking the research and thus decisions can be made on
whether or not to undertake the research.

Certainly the proposed alternative of estimating \( A_0 \) and \( A_1 \)
directly is not a simple task, and involves simplifying assumptions.
By doing a simple sensitivity analysis the above procedure suggested
by Lindner and Jarrett seems fairly rigorous.
2.3 Input-Demand Method

R.C. Duncan (1972) attempted to identify pasture research findings which have been important for the development of improved pastures in some agricultural regions in Australia and to estimate the IRR on the investment in pasture research in those regions. His technique is based on the estimation of input-demand functions for the stock of improved pastures.

He estimated the contribution made by individual research findings rather than estimating the benefits flowing from research by the output supply-shift used by Griliches since this method would not have been suitable in those circumstances. This is so because the adoption of new pasture technology by farmers is not directly observable in yield responses such as an increase in wool or beef. The input-demand method becomes a means of estimating the benefits generated by an increase in the productivity of an input, which in this case has been improved pastures.

To illustrate, take Fig. 2.10 in which the input-demand curve is assumed to have a negative slope; \( ID_1 \) and \( ID_2 \) are input-demand curves prior to an increase in productivity and after an increase in productivity, respectively. The hatched area (given certain assumptions) represents the gross welfare gains from the increase in productivity. It is the value of this area which he estimates.

Duncan specifies and estimates the input-demand functions in double-log form. He also assumes a parallel shift (of the logarithmic function, i.e. constant elasticity) in the input-demand curve from \( ID_1 \).
FIGURE 2.10

THE GAINS FROM AN INCREASE IN THE PRODUCTIVITY OF AN INPUT
to ID₂, which implies a non-parallel shift of the curve in its non-linear form.

The movement from Q₁ to Q₂ usually involves a number of years taking account of the lagged adoption of the new technology. In this time the price of product and the price of input could have been changed. For calculating purposes he strongly assumes that the shift from ID₁ to ID₂ relates to some ID curve based on an average product price for the period of the shift from Q₁ to Q₂. Also, it has to be assumed that the input price is some average of the cost of improving pastures during the period.

A single-equation regression model is formulated which is used to estimate (i) input own-price elasticity of demand, and identifies (ii) important research findings. From (ii) Duncan estimates the shift from Q₁ to Q₂. From (ii) and (i), he derives (by integration) a formula which gives an estimate of the gross value of the hatched area (see Fig. 2.10). In the model,

(a) the area of improved pastures on farms in selected areas is treated as a durable input, and

(b) the demand for the stock of improved pasture is a function of its real price and the state of pasture technology,

(c) polynomial distributed lags are fitted which helps to overcome multicollinearity and simplifies the regression to each of these independent variables in order to estimate the lags in adjustment of the stock which is associated with changes in input and product prices and the state of pasture technology.
Three dynamic aspects of the shift from $ID_1$ to $ID_2$ should be cited: firstly, the shift from $Q_1$ to $Q_2$ does not occur instantaneously. It appears, for that reason, that the long-run elasticity of input demand is the relevant one. Secondly, the improvement in technology may be lost over time due, for example, to pests, insects and diseases. Thirdly, the input demand curve can also shift with changes in product prices, and this will change the size of the hatched area for a given improvement in technology. Therefore, estimation of the discounted value of future benefits involves predictions about the price of products.

Duncan's model is a dynamic interpretation of the neoclassical theory of the demand for an input. According to the static theory of the competitive firm, every decision maker wishes to maximize his profits within a framework of input-output relationships and price ratios, instant adjustment and unlimited capital. Also, the individual's decisions for production under perfect competition have no effect on prices. Stigler (1952) points out that within such a static framework changes in demand for an input will depend on:

(i) changes in the product price;
(ii) changes in the input cost and in other inputs cost, and
(iii) changes in the productivity of the input.

Duncan assumes that there is no "money illusion" and hence the input demand function is homogeneous of degree zero. Thereby, the demand for an input is a function of real or relative prices.
Jorgenson (1963) shows that under certain assumptions the demand for the services of a durable input (such as improved pastures in this study) depends on its real price and relative price. We cannot usually measure the services of durable inputs, but, if we assume that the flow of services is a constant proportion of the stock, then we can hypothesize that the demand for the stock of a durable input is also a function of its real prices and relative prices.

Therefore, we have:

\[ K_t = f\left(\frac{P_{It}}{P_{Pt}}, \frac{P_{It}}{P_{Jt}}, R_t, U_t\right) \]

where \( K_t \) implies the level of improved pastures at time \( t \)

\( \frac{P_{It}}{P_{Pt}} \) is the input's real price at time \( t \)

\( \frac{P_{It}}{P_{Jt}} \) is the relative price of the input

\( R_t \) is a shift variable which denotes improvements in the state of pasture technology

\( U_t \) represents an error term which is assumed to be random and uncorrelated with the independent variables.

Duncan drops the relative price variable from the equation due to the problem of the high level of collinearity with the variable of real price.

Prices, particularly product prices, are not certain in the planning period; so it is assumed that producers expect the immediate past prices to hold in the future.

In order to make the model dynamic, the assumption of instant adjustment in the stock of improved pastures is relaxed. As
the results of research take time to become widely-spread, a lag in adoption due to uncertainty is expected which decreases with the increase in percentage of producers adopting the new farming practice.

Research results are included (as separate dummy variables) in the input-demand equations. A value of 1 is assigned to all years following the year in which publication of the research result is fulfilled, and a value of 0 for years before publication of research. Polynomial lags are generated on each of these variables to estimate the adoption rate.

Duncan also fits a polynomial lag structure to the real price variable. So, the equation to be estimated is equation (2) in which \( W(i) \) is considered as lag weights:

\[
(2) \quad \ln K_t = b_0 + \sum_{i=0}^{n-1} W_1(i) \ln \left( \frac{P_i}{P_{t-1}} \right) + \sum_{i=0}^{n-1} W_2(i) R_t + U_t
\]

The input-demand function is estimated with the variables expressed as logarithms. Therefore, the coefficients estimated on the price variables can be accounted as "geometric" average elasticities of demand.

As is illustrated in Fig. 2.10, the net gain to society from an increase in the productivity of improved pastures is equal to the value of the hatched area (ABCD) representing the gross welfare gains, minus research costs, and also minus any losses which arise from market distortions due to subsidies, etc. Duncan ignores the latter costs, since they are small for the wool industry. The value of the area ABCD can be estimated by the following formula which is derived by integration:
(3) \( b(Pe^{-Q_1/b} - Pe^{-Q_2/b}) - P(Q_2 - Q_1) \)

where,

\( b \) is the long-run price elasticity of demand

\( P \) is the average cost of improving pastures during the time taken to move from \( Q_1 \) to \( Q_2 \).

Duncan assumes that the shift from ID\(_1\) to ID\(_2\) is related to some input-demand curve based on an average price of product for the period which involves the movement from \( Q_1 \) to \( Q_2 \).

The major results from application of the input-demand model to three regions (Northern Tablelands, N.S.W. and Southern Tablelands, N.S.W. - both wool growing areas; and the wheat/sheep zone in Western Australia) are:

1. Internal rates of return have been estimated (on important research findings) to have been very high.
2. The adoption lags, in this study, are very short. Duncan believes that the image of the farmer as an unresponsive producer to technological change does need to be questioned.
3. Lags in adjustment of improved pastures to price change are very short too.

As there exists a high degree of collinearity between the own and cross price variables, it is not possible in general to separate the effects of the two. Thus, we cannot draw any steady conclusions concerning the role which factor substitution between land and improved pastures has played in the demand for improved pastures.
There can be two approaches to measuring adoption and adoption lags of new and improved inputs. The usual practice socio-logically is the measurement of numbers of farmers adopting overtime. This study measures the adoption of a new practice by a shift in the demand curve for the input, i.e. improved pastures. Thus it is necessary to distinguish changes along the demand curve due to price changes from changes in demand which are due to a shift in demand curve resulting from research which has increased the marginal productivity of the input.

Duncan's results on adoption lags can be compared with those obtained by Evenson (1967). Evenson estimated the aggregate research lag for U.S. agriculture, which he defined as the lag between the expenditure on research and the impact on production. This is a different formulation of the lag than that used by Duncan which was essentially the lag from publication of the results to adoption by farmers. Evenson's estimate of the average research lag for U.S. agriculture was 6 to 7½ years. For individual research findings Duncan found widely differing lags - from as short as 2 years up to 9 years.

Duncan's input-demand approach to the measurement of research benefits was novel in two important respects. First, it attempted to measure the benefits from individual projects - rather than measuring aggregate gains. Second, it measured the benefits in terms of the effect on the marginal productivity of the input concerned, rather than the change in output generated. The question which should have been raised is whether these two approaches are
compatible. The question was ultimately raised, as we shall see in the next section, though not directly in respect of measuring the gains from research.

2.4 The Appropriateness of Using Supply Analysis Versus Input-Demand Analysis

The use of the product supply curve versus the input-demand curve to measure welfare gains from research can be clarified by referring to the debate between Schmalensee (1971) and Wisecarver (1974) on the components of welfare gains.

One of the effects resulting from a shift in the supply curve is the scale effect in which, due to an input price change, there is a corresponding change in output price, producing a shift in consumer choice and changing consumer surplus.

The other change that will occur when input price is altered is in the area of input combinations used in production.

A price change will result in input substitution. It will be shown that this substitution effect is only accounted for in the measurement of welfare gains using the input-demand curve.

Schmalensee contends that the substitution effect is not a component of welfare gain (loss) and therefore advocates measurement of welfare using the shift in the product supply curve. However the Wisecarver paper argues that errors have arisen in measuring welfare costs (gains). The two errors described are (1) double counting of welfare costs, and (2) the claim that the substitution effect is not
a true social cost. These errors are avoided by the measurement of welfare costs (gains) in the input market only. Wisecarver's analysis shows that all components of social cost (benefit) will be contained in such a measurement.

(1) Source of the Double-Counting Error

There are two approaches to measuring social costs. First, the two sector (production and consumption) approach uses a shift (distortion) in the transformation function causing a movement to a lower social indifference curve and hence a loss of welfare. It clearly shows losses are due to inefficiency in production plus distortion of consumer choice. Inefficiency in production results from increased cost of a given output when one of the inputs increases in price, due to a substitution away from that input to a non-optimal combination. Distortion in consumer choice reflects loss of utility as the price of the product increases.

Second, the economic surplus method looks at welfare costs (gains) in terms of changes in areas corresponding to producers' and consumers' surplus; in this case in the input market where the price change (distortion) has occurred.

The error is to claim that the surplus measure in the input market contains only the inefficiency in production effect and that it is necessary to add the effects on consumers' and producers' surplus from the output market to obtain the total change in welfare.
This is clearly shown to be wrong by an analysis of the component areas of welfare loss (gain) between the supply and derived demand curves in the input market.

To illustrate the case simply, we assume the case of fixed proportions of inputs capital (K) and labour (L) to produce a unit of output (X). Thus, \( S_X \) is the sum of \( S_L \) and \( S_K \), i.e. \( X = \min(L,K) \).

The other relationship between the input and output market is that \( D_L \) is a derived demand from \( D_X \); that is, \( D_L = D_X - S_K \).

Hence, in Fig. 2.11 we have initially the curves \( D_X', S_X', D_L', S_L \) and \( S_K \) with equilibrium at \( E \) and \( E' \) for the output and input markets respectively.

The tax on labour, \( t = F'H' \) moves production to the point where amounts of labour \( L' \) and capital \( K' \) are used to produce \( X' \) of output.

The loss of welfare is shown by \( EFH \) and \( E'F'H' \) in the output and input markets respectively. In this case of fixed proportions these areas are equal. Let \( P, W \) and \( R \) be the prices of \( X, L \) and \( K \) respectively.

Now \( P^d_1 = W^d_1 + R^d_1 = W^s_1 + T + T^s_1 \)

and \( P^s_1 = W^s_1 + R^s_1 \)

so that \( P^d_1 - P^s_1 = T \)

and \( EFH = E'F'H' \)
FIGURE 2.11
EFFECTS OF A TAX DISTORTION IN INPUT AND OUTPUT MARKETS

To analyse the components we alter the assumptions on the shape of $D_X$ and $S_L$ and then build up the components by changing them back to their original position.

Let $D_X$ move to $D_{X^*}$ and hence $D_L$ becomes $D_{L^*}$. Let $S_L$ move to $S_{L^{**}}$, so that $S_X$ becomes $S_{X^{**}}$. Now loss of welfare is $DGM$ or $E'G'M'$ which both equal $E''JM''$ or loss of rent on capital, the untaxed factor. There is no loss of consumer surplus or loss of rent to labour. Relaxing the perfectly elastic labour supply, $S_{L^{**}}$ moves to $S_L$ and therefore $S_{X^{**}}$ to $S_X$. The increase in welfare cost $E'M'H'$ or $EMH$ is a welfare cost to labour, i.e. loss of rent on labour.

Also, as Wisecarver depicts:

$$p_d^0 - p_s^1 = G'H'$$

then,

$$EGH = E'G'H'$$

and therefore:

$$E'M'H' = EMH$$

Now we allow $D_{X^*}$ to return to $D_X$ and therefore $D_{L^*}$ to $D_L$. Now there is a loss of consumer surplus of $EFG$. But as $EFH = E'F'H'$ and $EGH = E'G'H'$, then $EFG = E'F'G'$. That is, the input market has captured the loss of consumer surplus due to the derived nature of the demand curve.

The demand for an input occurs only because it provides finished (consumer) products which have utility. Hence, the utility
or area under an input's derived demand curve is a "reflected" utility resulting from the service (product) the input finally provides. Thus changes in the "surplus" area under a derived input-demand curve includes the consumer or scale effect. Hence, double counting will result if the changes in product market "surplus area" are added to those in the input market.

(2) The Substitution Effect, Social Loss and the Advantages of the Input Market Approach

The graphical analysis above has shown that the input market and output market measures are identical where output is produced from fixed proportions of inputs, i.e. the price change has not had a substitution effect. In the variable proportions case (inputs are able to substitute for each other along an isoquant) the two markets, input and product, give different results.

Wisecarver assumes a production function homogeneous of degree one to derive an expression for the elasticity of demand for labour in terms of the elasticity of demand for the output and the elasticity of substitution (labour with capital).

Substituting this expression into the formula for the area of the welfare cost triangle resulting from the tax on labour, he obtains the result for welfare cost being the sum of the scale effect (loss of "reflected" utility due to product price distortion) plus the substitution effect (reduced output due to non-optimal input combination). Wisecarver compares this with a similar derivation for the welfare cost of the tax due to a shift in the product supply curve.
(i.e. in the product market) and finds that here welfare cost equals only the scale effect.

The output market does not measure the substitution effect. This leads to the question: Is the substitution effect a true welfare cost? Wisecarver establishes that it is a true welfare cost in three ways:

1. from the two-sector approach to welfare loss we have a part of welfare loss due to inefficiency in production. This is the substitution effect.

2. from an isoquant diagram we derive the increased costs of producing the same output (i.e. the social costs) which when expanded by the Taylor Series gives us an expression that is equal to the substitution effect.

3. by comparing tax revenue (to Government) from (a) tax, t%, on labour, and (b) a tax \( t_{XL} \)% on the product X where \( t_{XL} \) is defined as the indirect tax on X because of the tax t on labour.

The tax (b) is greater than (a) by an amount equal to the substitution effect. That is, the output market reduces the estimation of welfare loss by over-estimating the tax revenue.

Wisecarver notes that in theory we might derive the substitution loss in the output market from this tax effect but that in practice it is likely to be impossible.
Discussion

In the case of fixed input proportions, the output supply function and input demand analysis will give identical welfare gain (loss) measures. The input demand analysis does include the loss of consumer welfare due to the derived nature of the input-demand curve.

In the case of variable input proportions, output supply analysis omits the loss (gain) in welfare due to substitution of inputs in production. The substitution effect, corresponding to the inefficiency in production effect from the two-sector approach, is clearly a welfare cost.

Thus, input-demand analysis of welfare gains or losses must be regarded as being the only effective approach when dealing with a change in the price (including distortions of factor markets) of an input, except where fixed proportions can be appropriately assumed.
CHAPTER 3

DISTRIBUTION OF RELATIVE GAINS (LOSSES) FROM
RESEARCH AMONG PRODUCERS AND CONSUMERS

3.1 Introduction

Following on the earlier pioneering work by Griliches and those who used and developed his method of estimating the absolute social gains from agricultural research, attention was turned to the distribution of these benefits between producers and consumers in aggregate. The technique used was simply the extension of the Supply-Shift method to recognise changes in producers' and consumers' surplus.

In Section 3.2 Akino and Hayami (1975) estimate the distribution of returns among producers and consumers resulting from public investment in rice breeding research in Japan. They obtain results for both the self-sufficiency (no imports) case and the open-economy case. Akino and Hayami employ the special case of a supply curve which passes through the origin, and the restraints which this assumption places on the subsequent analysis and results are noted.

The study of the economic impact of investment in cotton seed research and development in Sao Paulo, Brazil, by Ayer and Schuh (1972) is reviewed in Section 3.3. As well as using the assumption that the supply curve passes through the origin, Ayer and Schuh impose a dynamic structure on quantity response to prices - in effect they assume a Cobweb response.
In Section 3.4 the work of the Industries Assistance Commission in estimating the distribution of research gains among producers and consumers for the most important of Australia's agricultural products is reviewed.

Section 3.5 compares the different assumptions made in these studies and the results obtained.

3.2 Akino and Hayami's Method

Akino and Hayami (1975) employ the approach developed by Griliches (1958), Peterson (1967), Schmitz and Seckler (1970) and Ayer and Schuh (1972) to estimate the social rate of returns to public investment in rice breeding research and the distribution of the returns between producers and consumers, both in the case of autarky (self-sufficiency) and in the case of an open economy where rice imports are allowed. Their model of estimating social returns takes, firstly, the assumption of market equilibrium in a closed economy. Later, they attempt to incorporate into their model the implications of rice imports and government policy.

They use the Marshallian concepts of social welfare and cost for the measurement of social returns to rice breeding research - in terms of changes in consumers' and producers' surpluses resulting from the shift in the supply curve of rice which corresponds to a shift in the rice production function. The above relation is depicted in Fig. 3.1. In this static model the demand curve, $dd$, and the supply curve $S_o$ represent the actual market demand and supply functions respectively, while $S_n$ "represents the supply curve that would have
FIGURE 3.1
MODEL OF ESTIMATING SOCIAL RETURNS TO RICE BREEDING RESEARCH

Source: Akino and Hayami (1975)
existed if the improved rice varieties were not developed". $P_0$ is the price of rice that the government determines to maintain and $P_n$ is the price of rice if the improved rice varieties were not developed.

By assuming an equilibrium in the market and no rice import, the shift in the supply curve from $S_n$ to $S_o$ increases the consumers' surplus by area $ABD + area \frac{BP\cdot PC}{n_0}$, and the producers' surplus by area $ACO - area \frac{BP\cdot PC}{n_0}$. Finally, the increase in social benefit is shown by area $ABC + area ACO$.

Japan, however, remained a net importer of rice during the period of analysis (1904-1950). The government regulated the rice import by tariffs and quotas to maintain basically a stable price level for rice so as to stop the urban workers' costs of living rising. If the domestic supply schedule did not shift from $S_n$ to $S_o$, the government would have manipulated policy instruments to increase rice imports by the distance $Q^O - n_0$. The producers' surplus would have been reduced (due to this policy) by area $BP\cdot PC$ without being compensated by area $ACO$.

Akino and Hayami argue that in the absence of any breeding program (which otherwise shifted domestic supply from $S_n$ to $S_o$), producers' surplus would have been smaller by area $ACO$. They define this area as the producers' gain in economic welfare from the rice breeding research on the assumption of a price stabilization policy by means of rice imports. Under this assumption, consumers' surplus remains unchanged, so the producers' gain would be equivalent to the total social benefit produced from the rice breeding programs.
Akino and Hayami's model for quantitative estimation assumes, firstly, a constant elasticity demand function as in (1).

\[ q = H P^{-\eta} \]

where \( q \) and \( P \) are the quantity and the price of rice respectively, and \( \eta \) is the price elasticity of demand. The second assumption takes a constant elasticity supply function as in (2).

\[ q = G P^\gamma \]

where \( \gamma \) is the price elasticity of supply for rice.

Akino and Hayami assume a hypothetical supply curve that would have existed if no improved varieties had been used as in (3):

\[ q = (1-h)G P^\gamma \]

where \( h \) represents the shift rate in the supply function because of varietal improvement.

They argue that in competitive equilibrium the supply function is equivalent to the marginal cost function derived from the production function. Also, as the relation between the shift rate in the marginal cost function (\( h \)) and the shift rate in the production function (\( k \)) can be approximated by (4),

\[ h \approx (1 + \gamma)k \]

then in equilibrium the following approximation formulae will hold:

\[ \text{area ABC} \approx \frac{1}{2} P \cdot q \cdot \frac{[k(1 + \gamma)]^2}{\gamma + \eta} \]
Akino and Hayami's analysis provides an interesting contrast as they assume a particular mathematical form for the supply function which passes through the origin. The actual supply function which they assume is a constant elasticity function of the form presented in equation (2). A horizontal shift in the supply function is achieved by changing the value of G. As both supply curves $S_n$ and $S_0$ (without and with the innovation) pass through the origin, Akino and Hayami implicitly assume without any supporting empirical evidence that the costs reduction at the margin is greater than (the reduction of costs) infra-marginally. Consequently, they almost without doubt reduce their estimate of returns to research, and incidentally, influence the nature of their conclusions about the effects of the distribution of the benefits of rice breeding research in Japanese agriculture as well. Recall that Duncan and Tisdell (1971) have shown how the distribution of research benefits between producers and consumers depends upon the nature of the shift in the supply curve, and on the elasticity of demand for the product. If research reduces the cost of marginal production more than for infra-marginal production, and if demand is inelastic, returns from research to producers may be negative. Akino and Hayami's empirical work in their Table 3.1 supports the theoretical analysis illustrated by Duncan and Tisdell.
## TABLE 3.1

Estimates of Average Annual Benefit in Japan From Rice Breeding Research (Million Yen in 1934-36 Constant Prices)

<table>
<thead>
<tr>
<th>Period</th>
<th>Autarky Case</th>
<th></th>
<th></th>
<th>Open Economy Case</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Producers' Gain</td>
<td>Consumers' Gain</td>
<td>Total Social Benefit</td>
<td>Total Social Benefit= Producers' Gain</td>
<td>Saving of Foreign Exchange</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3) = (1)+(2)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>Before the Assigned Experiment System</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1915-1919</td>
<td>-2.86</td>
<td>4.29</td>
<td>1.43</td>
<td>1.43</td>
<td>1.71</td>
</tr>
<tr>
<td>1920-1924</td>
<td>-26.75</td>
<td>40.48</td>
<td>13.73</td>
<td>13.49</td>
<td>16.19</td>
</tr>
<tr>
<td>1925-1929</td>
<td>-64.55</td>
<td>98.58</td>
<td>34.03</td>
<td>32.86</td>
<td>39.43</td>
</tr>
<tr>
<td>1930-1934</td>
<td>-89.86</td>
<td>138.20</td>
<td>48.34</td>
<td>46.07</td>
<td>55.27</td>
</tr>
<tr>
<td>1935-1939</td>
<td>-101.74</td>
<td>156.67</td>
<td>54.93</td>
<td>52.22</td>
<td>62.67</td>
</tr>
<tr>
<td>1940-1944</td>
<td>-90.56</td>
<td>139.29</td>
<td>48.73</td>
<td>46.43</td>
<td>55.72</td>
</tr>
<tr>
<td>1945-1949</td>
<td>-68.02</td>
<td>103.97</td>
<td>35.95</td>
<td>34.66</td>
<td>41.59</td>
</tr>
<tr>
<td>1950-1953</td>
<td>-47.94</td>
<td>72.84</td>
<td>24.90</td>
<td>24.28</td>
<td>29.14</td>
</tr>
<tr>
<td>Under the Assigned Experiment System</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1932-1934</td>
<td>-2.03</td>
<td>3.05</td>
<td>1.02</td>
<td>1.02</td>
<td>1.22</td>
</tr>
<tr>
<td>1935-1939</td>
<td>-11.56</td>
<td>17.38</td>
<td>5.82</td>
<td>5.79</td>
<td>6.95</td>
</tr>
<tr>
<td>1940-1944</td>
<td>-24.92</td>
<td>37.62</td>
<td>12.70</td>
<td>12.54</td>
<td>15.04</td>
</tr>
<tr>
<td>1945-1949</td>
<td>-41.90</td>
<td>63.58</td>
<td>21.68</td>
<td>21.19</td>
<td>25.43</td>
</tr>
<tr>
<td>1950-1954</td>
<td>-56.64</td>
<td>86.29</td>
<td>29.65</td>
<td>28.76</td>
<td>34.51</td>
</tr>
<tr>
<td>1955-1959</td>
<td>-45.27</td>
<td>68.57</td>
<td>26.30</td>
<td>22.86</td>
<td>27.42</td>
</tr>
<tr>
<td>1960-1961</td>
<td>-30.65</td>
<td>46.23</td>
<td>15.58</td>
<td>15.41</td>
<td>18.48</td>
</tr>
</tbody>
</table>

Source: Akino and Hayami (1975).
In the autarky case, the elasticity of demand is assumed as 0.2 and consumers are the sole beneficiaries of the research. On the other hand, producers are always made worse-off and disadvantaged (producer surplus falls) although the increase in consumer surplus offsets this fall. Lindner and Jarrett (1976) argue that it is only in the open economy case with infinitely elastic demand that producer surplus increases, that is, the social gain from the shift in supply would be totally captured by the producers. In this case, the increase in producer surplus is coincident with increase in total social benefit. For this reason, Lindner and Jarrett (1976) point out that the conclusions drawn by Akino and Hayami regarding the distributive effects of research, given the nature of their postulated shift in the supply function, are responsive to their demand elasticity estimates only.

In conclusion, the Akino-Hayami method is too simple and yields results which are quite unreasonable. In Table 3.1, the cumulated losses to producers in column (1) are impossible to believe. Indeed if producers were experiencing losses of this order of magnitude they would have negative incomes before the end of the period. The elasticities utilized in this analysis are not really long-run elasticities. Further, the method does not fully take into account the growing market or the possibility that supply functions themselves respond to productivity change.

3.3 Ayer and Schuh's Method

Harry W. Ayer and G. Edward Schuh (1972) used the same basic framework as used by Griliches and Peterson for the analysis of the
social rates of return on investments in cotton-research in Brazil. They assumed a positively-sloped supply function for the main analysis. Their approach is based on the concepts of consumer and producer surplus. Figure 3.2 illustrates social returns due to a supply shift as the difference between the total benefits to society (with the improved seed varieties which is the area OABC), less the production cost OAD, and the total benefits to society (with unimproved varieties which is the area OEFC), less the production cost OEG. So,

\[
\text{Social returns} = (OABC - OAD) - (OEFC - OEG)
\]

The analysis incorporated the following assumptions. The demand curve is dependent on current year prices. S is the supply curve with improved varieties of cotton, and S' is the supply of cotton when unimproved cotton varieties are used. Both supply curves pass through the origin and the case of greater reduction of costs at the margin compared with infra-marginal cost reductions holds. They postulated that the supply of cotton depends on the previous year's price. Hence, in Figure 2.3 the previous year's price (P₁) yields supply A which sells at price P₂. K is the percentage shift of S' to the left of S, and this shift is determined by the difference in yield between the unimproved and improved varieties and the proportion of each new variety planted.

In order to give the demand equation an annual basis they have "collapsed" the estimated demand equation into two dimensions defined by the price and quantity of Southern Brazil cotton fibre. So,

\[
(1) \quad \text{DCFS} : \text{PCFS} = n \frac{\text{QCFS}}{\text{PCFS}} 
\]

\[.188\]
FIGURE 3.2
SOCIAL RETURNS DUE TO SUPPLY SHIFT

Source: Ayer and Schuh (1972)
where, \( n \) includes all parameters and variables influencing demand but excluded from the above (1), by substituting the annual quantity (observed) which is \( OA \) from Fig. 3.2, and price \( (P_2) \) into equation (1). The estimation of \( n \) can be done directly and equation (1) is defined annually as \( n \) varies from year to year. They have employed the same procedure to calculate a two-dimensional supply equation on an annual basis. So,

\[
(2) \quad SCFS : QCFS = m \left( \frac{PCFS_{t-1}}{PCFS_{t-1}} \right)^{0.944}
\]

where,

- \( QCFS \) is the quantity of cotton fibre from southern Brazil
- \( PCFS_{t-1} \) is the price of cotton fibre from the south of Brazil in the previous time period
- \( m \) represents the remaining parameters and their corresponding variables influencing supply.

The parameter \( m \) (and hence the supply equation) is calculated annually by substituting the observed quantity \( (A) \) and previous years price \( (P_1) \) into equation (2) for each year and solving for \( m \).

\( K \) depends on two things: (1) changes in yield and fibre per cent; and (2) distribution of varieties. \( K \) is equal to,

\[
x \sum_{a=1}^{x} \left[ (1 - \frac{Y_F}{Y_{a}}) \cdot \frac{P_a}{Y_{a}} \right] \cdot 100 \quad \text{for any particular year}
\]

where,

- \( Y_a \) = yield of the new variety 'a'
- \( Y_u \) = average yield of the unimproved varieties
\[ F_a = \text{fibre } \% \text{ of the new variety 'a'} \]

\[ F_u = \text{average fibre } \% \text{ of the unimproved varieties} \]

\[ P_a = \text{the } \% \text{ of variety 'a' distributed} \]

\[ x = \text{the number of varieties distributed in any particular year} \]

Since \( S'CFS = (1-K).SCFS \)

Therefore,

\[ (3) \quad S'CFS : QCFS = (1-K)m \left( \frac{PCFS_{t-1}}{} \right)^{944} \]

where \( K, m, \) and \( PCFS_{t-1} \) show variation from year to year. Ayer and Schuh have shown that once equations (1), (2), and (3) are estimated for each of the years of a given time period, i.e., 1931 to 1967 in their research, the annual social returns may be determined by solving the fourth equation as follows:

Social returns = \( \int_0^A (DCFS) \ d (QCFS) \)

\[ - \int_0^A (SCFS) \ d (QCFS) \]

\[ - \int_0^E (DCFS) \ d (QCFS) \]

\[ + \int_0^E (S'CFS) \ d (QCFS) \]

Ayer and Schuh have compared the social returns with the costs of the breeding program by calculating the internal rate of return. According to them, the internal rate of return is the rate \( r \) which results in the following equality:
\[(5) \sum_{t=1}^{f} R_t (1+r)^{-t} = \sum_{t=1}^{f} C_t (1+r)^{-t} \text{ or discounted returns is equal to discounted costs.} \]

Where,

\[ t = \text{year (year 1924 is assumed to be 1)} \]

\[ f = \text{the year costs and returns end, in this study is assumed to be year 1985 (62 years after the breeding program began)} \]

\[ R_t = \text{the estimated social returns in year } t \]

\[ C_t = \text{the estimated costs of research and development in year } t \]

\[ r = \text{the internal rate of return} \]

Based on the above assumptions, the internal rate of return is calculated to be 89 per cent. Although they bias upward the estimates of costs and bias downward the estimates of returns, the return on investment is still very high.

**Sensitivity Analysis**

Ayer and Schuh mention that different assumptions about the supply and demand elasticities and the shift factor K will result in different estimates of the internal rate of return. In this study, the 89 per cent IRR is based on three basic parameters, i.e., elasticity of demand (-5.3), elasticity of supply (.944), and estimates of K. As Brazil can always sell on the export market (where it is relatively unimportant), it seems reasonable to question why the estimated price elasticity of demand for cotton fibre is -5.3, when it should have been near to infinity. Ayer and Schuh claim that the reason they have
used the estimate of -5.3 is that it has been based on empirical evidence. Also, they claim that the probable effect of limitations by the Brazilian government on cotton exports was to make the demand elasticity less than infinite. This is, in effect, a contradiction of the statement that Brazil's production is unimportant in world trade. It is likely that the econometric results are spurious.

In a similar fashion, an alternative estimate of the supply elasticity for cotton fibre, based on a longer series of data, was only about half that used in the above calculations (.449 compared with .944). Ayer and Schuh mention that it might be argued that the lower supply elasticity is more appropriate to calculate the social rate of return because the returns are generated over a long time period. Therefore, in order to test the sensitivity of the results to this elasticity, they set the supply estimates equal to both zero and 1.5. The results show that the internal rate of return is not sensitive to different price elasticities. If the supply elasticity is held unchanged and a perfectly elastic demand curve be assumed, the rate of return reduces by only two percentage points (from 89 per cent to 87 per cent). The results are shown in Table 3.2.

The internal rates of return are 89 and 80 per cent respectively, indicating a high rate of return by any standard.

Lastly, they argue that estimates of K, the supply shifter, could be subject to error. So, they recompute the internal rate of return with K assumed to be 10 per cent less and 10 per cent more than the original estimates. As it is presented in Table 3.2, again the internal rate of return is almost insensitive.
TABLE 3.2
Estimated Internal Rates of Return (Per Cent) Under Various Assumptions Concerning Elasticity of Supply and Demand and the Shift Factor K

<table>
<thead>
<tr>
<th>Elasticities</th>
<th>K nominal</th>
<th>K nominal</th>
<th>K nominal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-10%</td>
<td>+10%</td>
<td></td>
</tr>
<tr>
<td>$K_s = 0.944$</td>
<td>89%</td>
<td>86%</td>
<td>92%</td>
</tr>
<tr>
<td>$E_d = -5.3$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$E_s = 0$</td>
<td>107%</td>
<td>104%</td>
<td>110%</td>
</tr>
<tr>
<td>$E_d = \infty$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$E_s = 1.5$</td>
<td>80%</td>
<td>77%</td>
<td>82%</td>
</tr>
<tr>
<td>$E_d = \infty$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Ayer and Schuh (1972).

The above assumptions indicate that the internal rate of return to investments in cotton seed research and development has been very important (about 90 per cent). Particularly if we compare these estimates with those obtained by Griliches (35 to 40 per cent for the hybrid seed corn research), Peterson (20 to 30 per cent for poultry research), and Akino and Hayami (under the assigned experiment system,
about 74 per cent for rice breeding research), we should accept Sao Paulo's cotton seed research and development program has paid off impressively. Further aspects of this study will be discussed in Section 3.5.

3.4 Studies by the Industries Assistance Commission

In Australia the Industries Assistance Commission (I.A.C.) (1976) elaborates on the distribution of the benefits (resulting from a downward shift in the supply curve) between producers, domestic consumers and overseas consumers. The distribution of the benefits of research between the above groups depends upon how much of the fall in unit costs is in fact transmitted through to the final price of the product. This transmission is influenced by both the elasticity of supply of producers and the elasticity of demand of consumers, and by the type of shift in the supply curve. In order to estimate the distribution of benefits, the I.A.C. adopts the simplest theoretical case, namely, a parallel shift of a linear supply curve. That is, unit costs of production are reduced equally for both infra-marginal and marginal units of output. In Fig. 3.3 demand is perfectly elastic, i.e. the case where Australian production sold internationally has no effect on price OP. An increase in productivity will reduce costs of production and shift the supply curve S to $S_1$. The gain accruing to producers is equivalent to the shaded area. In this case no benefits accrue to consumers. A movement leftwards of the supply curve from $S_1$ to S illustrates the effect of a research levy on producers, in which case the producers bear the full impact of the levy. Alternatively,
FIGURE 3.3
RIGHTWARD SHIFT OF THE SUPPLY CURVE DUE TO AN INCREASE IN PRODUCTIVITY
if demand for the product is not perfectly elastic (Fig. 3.4), an increase in productivity (S to \( S_1 \)) will lower the price from \( OP \) to \( OP_1 \). The total benefits of the productivity increase are represented by the shaded area.

Consumers gain by the increase in consumer surplus brought about by the fall in price from \( OP \) to \( OP_1 \), while the producers' gain is the difference between the shaded area and the consumers' gain.

If the supply curve shifts from \( S_1 \) to \( S \) due to a research levy, producers do not bear all the costs of the levy, as part of the cost is passed on to consumers in the form of the price rise. In this case (Fig. 3.4), if some of the consumers are overseas not all the benefits from the productivity increase accrue to Australians. However, if the research is financed by a levy, overseas consumers will also bear the costs of research in the same proportion as they share in the benefits.

By using the standard model explained above, estimates of the proportional distribution of research benefits can be easily made. The consumers' share (\( \sigma \)) of the benefit of reduced production costs is determined by the ratio:\[1\]

\[
\sigma = \frac{\varepsilon}{\varepsilon - \eta} 
\]

where,

\( \varepsilon \) = the elasticity of supply

\( \eta \) = the elasticity of demand

---

1 See Greg Martin (1977) for the derivation of this formula.
FIGURE 3.4
SOCIAL GAINS RESULTING FROM AN INCREASE IN PRODUCTIVITY
Let us now take a situation where production is consumed both domestically and overseas, and given no distortions in pricing in either market (such as two-price schemes), domestic prices will be determined by export prices. So, the elasticity of world demand for Australian products rather than the elasticity of Australian (domestic) demand is the relevant elasticity; under this assumption the change in price of the product resulting from a reduction in unit costs can be estimated as follows:

$$\Delta P = \frac{e_{Sa}}{e_{D} - e_{Sa}}$$ \hspace{1cm} (2)

where,

- $e_{D}$ = the elasticity of world
- $e_{Sa}$ = the elasticity of supply in respect of Australian producers

Since consumers benefit only through a fall in prices (ignoring quality changes), the proportion of benefits flowing from the reduction in unit costs is the percentage fall in product prices.

Domestic producers, given the previous assumptions, are the only other beneficiaries and hence their proportion is (in percentage terms) 100 minus the percentage accruing to consumers.

The proportion of the total benefit flowing to consumers is divided between Australian and overseas consumers on the basis of the proportion of total production consumed by each.

The I.A.C. obtains world demand and "other country" supply elasticities from UNCTAD (1974) and in general the Australian supply elasticities are those of Gruen (1964).
According to the I.A.C. report, the elasticity of demand facing the Australian exporters (as a general proposition) is a function of the elasticity of world demand for the product, the elasticity of supply of Australian production and the elasticity of supply of other producing countries assuming a free world market, homogeneous products and arbitrage between markets. The elasticity of world demand for an Australian product \( e_{D_a} \) is determined by the world elasticity of demand \( e_D \) and the elasticity of supply of other countries \( e_{SC} \). So,

\[
e_{D_a} = e_D \frac{Q_d}{Q_a} - e_{SC} \frac{Q_c}{Q_a} \quad \ldots \quad (3)
\]

\( Q_d, Q_a \) and \( Q_c \) represent world production, Australian production and other countries' production respectively. This approach, however, assumes that Australian producers compete with all producers throughout the world, not only those who export. So, to account for self-sufficient countries and protection in importing countries, a separate model for the relevant commodities is used, where \( e_{Dr} \) is the elasticity of world demand for Australian production within the restricted free-trade area.

\[
e_{Dr} = e_D \frac{Q_{E_w}}{Q_{E_a}} - e_{Sc} \frac{Q_{E_c}}{Q_{E_a}} \quad \ldots \quad (4)
\]

The terms \( Q_{E_w}, Q_{E_a} \) and \( Q_{E_c} \) represent the quantities traded in the world, the quantity exported by Australia, and the quantity exported by other countries respectively.

The models will reduce to the following equations (5 and 6) if we use proportions rather than quantities:
eDₐ = eD \cdot \frac{100}{PPₐ} \cdot eS \frac{100-PPₐ}{PPₐ} \quad \text{(free market assumption model)} \quad \ldots \ldots (5)

where \( PPₐ \) is the proportion of world production produced in Australia.

and,

eDᵣ = eD \cdot \frac{100}{PEₐ} - eS \frac{100-PEₐ}{PEₐ} \quad \text{(protected market assumption model)} \quad \ldots \ldots (6)

where \( PEₐ \) is the world trade proportion (total exports) contributed by Australia.

The distributive estimates of direct benefits between producer and consumer can be shown in Table 3.3.

3.5 Comparison of Ayer and Schuh and I.A.C. Methodology for Analysis of Distribution of Net Social Gains to Research

Both studies use a shift in the supply curve of a commodity to look at the distribution of the benefits of research. Ayer and Schuh use the shift to represent increased productivity of new varieties of cotton, while in the I.A.C. report the shift represents a general reduction in unit costs of production for each agricultural commodity due to research. The formulation of the supply and demand models differ between the two reports. Ayer and Schuh's supply curves are exponential in form, so that a supply shift is not parallel and the reduction in costs is greater at the margin than infra-marginally. The I.A.C. uses a simple, linear model with a parallel supply shift.
### TABLE 3.3

Distribution of the Direct Benefits of Rural Research

<table>
<thead>
<tr>
<th>Product</th>
<th>Australian Producer</th>
<th>Consumer</th>
<th>Nature of Export Market</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Wool</td>
<td>85 to 88</td>
<td>s</td>
<td>11 to 15</td>
</tr>
<tr>
<td>Beef and Veal</td>
<td>74 to 88</td>
<td>6 to 13</td>
<td>6 to 13</td>
</tr>
<tr>
<td>Wheat*</td>
<td>67 to 90</td>
<td>s</td>
<td>8 to 28</td>
</tr>
<tr>
<td>Coarse Grains</td>
<td>94 to 99</td>
<td>s</td>
<td>s</td>
</tr>
<tr>
<td>Rice</td>
<td>99</td>
<td>s</td>
<td>s</td>
</tr>
<tr>
<td>Mutton and Lamb</td>
<td>58 to 68</td>
<td>25 to 32</td>
<td>7 to 10</td>
</tr>
<tr>
<td>Pig Meat</td>
<td>83</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>Manufactured Dairy Products*</td>
<td>97 to 98</td>
<td>1 to 3</td>
<td>s</td>
</tr>
<tr>
<td>Sugar*</td>
<td>91 to 93</td>
<td>s</td>
<td>5 to 7</td>
</tr>
</tbody>
</table>

s = small (less than 5%)

* = ignores effect of two price schemes, see Table 3.4 (Comparison of Ayer and Schuh and I.A.C. Methodology, Section 3.5).


Further aspects of this study will be discussed in Section 3.5.
From Duncan and Tisdell (1971) we know these cases influence benefits achieved by producers, being greater in the I.A.C. case than for Ayer and Schuh's model, given similar demand elasticity for both. A further difference in the models used is that Ayer and Schuh chose a dynamic model (Fig. 3.2), while the I.A.C. uses a static model (Figs 3.3 and 3.4) with equilibrium prices and quantity. This changes the particular areas which represent consumers' and producers' surplus. In Ayer and Schuh's case of an essentially cobweb cycle formulation the resulting yearly average size of these areas will be a function of the elasticities of the supply and demand functions and, inter alia, will depend on whether the cycle is converging or diverging.

Ayer and Schuh estimate the distribution of gains directly for both producers and consumers by integrating relevant areas under the defined curves. The I.A.C. report, however, given linear demand and supply curves derives a relationship for price fall in terms of the elasticity of supply as a ratio of the difference of demand and supply elasticities, i.e.,

$$ \Delta P = \frac{\varepsilon_s}{\varepsilon_d - \varepsilon_s} $$

This difference in distributive estimates of benefits should not be important as a fall in price represents consumer benefit, so the percentage (proportionate) price fall is taken to be the percentage (proportion) of benefit flowing to consumers. Producer benefit is then obtained by difference (compare with Ayer and Schuh's direct estimate of producer benefit).
The I.A.C. report extends its analysis to export situations with perfect and imperfect competition. According to the report, free market competition in export markets is an important factor determining the proportion of benefits accruing to Australian producers and consumers. For beef and dairy products, for example, Australia competes freely only with other exporting countries since most importing countries protect their domestic industry. According, the following equation \( \frac{eD}{eD} = eD \cdot \frac{Q_E}{Q_E} - eS \cdot \frac{Q_E}{Q_E} \) which uses trade weights is employed when calculating the elasticity of demand for Australian exports of these protected products. As was discussed earlier in Section 3.4, the terms \( Q_w, Q_a, \) and \( Q_c \) represent the quantities traded in the world, the quantity exported by Australia and the quantity exported by other countries respectively. For other products, such as wheat and wool, Australian producers compete freely against producers in both the exporting and importing countries. For these products the following equation which uses production weights is employed:

\[
e_{D_a} = eD \cdot \frac{Q_d}{Q_a} - eS \cdot \frac{Q_c}{Q_a}
\]

Recall that \( eD \) and \( eS_c \) represent the world elasticity of demand and the elasticity of supply of other countries respectively; \( Q_d, Q_a, \) and \( Q_c \) represent world production, Australian production and other countries production respectively.

Ayer and Schuh's study sees the effect on export earnings to be an important benefit of Brazil's research program on cotton. They make a rough estimate of the effect of the breeding program on
exports by estimating domestic utilization of cotton during a recent period of time and compare it with an estimate of what cotton fibre production would have been if new varieties had not been available. They argue that if production would have been less than domestic utilization, then any exports of cotton fibre is due to the new varieties having replaced the unimproved ones.

Ayer and Schuh base this analysis on data from the period 1955 to 1967 (13 years), since prior to this period stocks and exports had often violently fluctuated. Average production of southern Brazil cotton fibre within the above period has been 343 thousand tons; and average exports of southern Brazil cotton fibre for this period have been 123 thousand tons. Thus, the difference (220 thousand tons) constitutes average domestic utilization.

The average production of cotton fibre (using the old varieties) can be estimated from the above calculations of average production and the productivity factor K which is the percentage reduction in cotton fibre production if old varieties replaced the improved ones. Production with the less favourable seed would be \( (1-K) \) times the production actually obtained if the improved seed is used. \( K \), on average, has been .49 for the 13 year period and \( 1-K \) equals .51. Hence, average production using the poor varieties could have been approximately 175 thousand tons (.51 x 343,000 tons).

Since production of 175 thousand tons cannot satisfy the estimated domestic utilization of 220 thousand tons, then the implication is that Brazil would be a net importer of cotton. Alternatively,
Ayer and Schuh conclude that the cotton fibre exports from Southern Brazil which actually did occur from 1955 to 1967 may be chiefly attributed to the use of improved varieties of cotton seed.

The I.A.C. estimates presented in Table 3.3 (see Section 3.4) are subject to two practical qualifications. Firstly, in cases where bilateral trade agreements (which exclude Australia) form a significant proportion of world trade, the proportion of benefits which accrue to Australian producers is likely to be over-estimated. Exclusion of Australia from some export markets has similar implications. In other words, the effect of the trade barriers against Australian exports on the distribution of the benefits will depend partly on the form of the trade barriers. These are important in regard to sugar and dairy products. However, in the case of the wheat industry, the above estimates may be too low. The analysis presented by Alouze, Watson and Sturgess\(^1\) (1976) of Australia's role in the world wheat market suggests that Australia will face a perfectly elastic demand curve in most years. This indicates that, in the absence of two-price schemes, Australian wheat producers would receive almost 100 per cent of the benefits of research which reduces the unit costs of wheat production.

Secondly, the effect of two-price schemes (as exist for wheat, dairy products, and sugar) have been ignored. As domestic prices under such schemes are usually determined independently of export prices, then the possible price effects of unit cost reduction

are not certain when such schemes are included in the analysis. Nevertheless, it is possible that domestic consumers gain some benefits from productivity increases in the process of price-setting for the domestic market.

When the fall in price (paid by domestic consumers) equals the amount of the unit cost reduction, the distribution of research benefits which bring down the unit costs of producing wheat, dairy products and sugar is estimated to be as shown in Table 3.4.

<table>
<thead>
<tr>
<th>Nature of Export Market</th>
<th>% Australian Producers</th>
<th>% Consumer Australian</th>
<th>% Consumer Overseas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>57 to 76</td>
<td>16</td>
<td>8 to 27</td>
</tr>
<tr>
<td>Dairy Products</td>
<td>31</td>
<td>68</td>
<td>s</td>
</tr>
<tr>
<td>Sugar</td>
<td>74</td>
<td>25</td>
<td>s</td>
</tr>
</tbody>
</table>

s = small (less than 5 per cent)


Only in the case of dairy products does the presence of two-price schemes change significantly the distribution of research benefits in favour of domestic consumers. However, with the presence of two-price schemes for dairy products, the Australian consumer is
worse off to begin with (since domestic prices are higher than the prices paid by overseas consumers of Australian production). The above qualifications are important but do not change the general conclusion that Australian producers obtain more than half of the benefits from production-oriented research. Overseas consumers receive significant benefits from Australian research in the case of wool, wheat and meat.

The methodology employed in this analysis is partial, i.e. ignoring general equilibrium considerations. Research results which benefit producers and consumers of one commodity affect producers and consumers in other industries. Firstly, there will be second-round price effects. For instance, to the extent to which cost reductions lead to a fall in beef prices the price of substitutes, i.e. mutton and lamb will also fall. So, producers and consumers in those markets are affected. However, in the case of beef and sheep meats, export markets have traditionally been separate. Therefore, the degree of substitutability is likely to be low and the second-round effects small.

For products principally consumed on the domestic market, i.e., pork and poultry, the second-round effects are likely to be more significant.

In the long-run, overseas producers of rural products may also benefit if research results in Australia are transferable to them. Development of mechanised sugar cane harvesting provides an example of Australian research results which are benefiting overseas producers also.
Distribution of the benefits resulting from the cotton breeding program of Sao Paulo in Brazil may be realised by producers, consumers, or both. The proportion which goes to producers is defined as the difference in producer surplus using improved varieties versus unimproved varieties. With reference to Fig. 3.2, the change in producer surplus can be shown by \((OABP_2 - OAD) - (OEFP_3 - OEG)\). The change in consumer surplus is \(P_2BC - P_3FC\) or \(P_2BFP_3\). Estimates of these areas are based on the price elasticites of demand and supply which were -5.3 and -.944 respectively. Ayer and Schuh used the same procedure of collapsing the equations into two dimensions, price and quantity, to obtain annual estimates of the areas.

The results indicate that producers have realised the largest share of the social gains from cotton seed research. Producers received 60 per cent of total social gains in the form of producer surpluses and consumers obtained 40 per cent of total gains as consumer surpluses. Obviously, the relative price elasticities of demand and supply is the key to this division.

Ayer and Schuh argue that the "qualitative-quantitative" analysis of distribution of the producer benefits among the factors of production suggests that the large amount of the benefits of the new technology were realized, at least as first-order effects, as a producer surplus. The reason why an important part of the benefits channelled to consumers was mainly due to government restrictions on exports. On the production side, the benefits went to land owners as capital gains and to the owners of relatively insufficient entrepreneurial skills, who obtained an economic rent in the form of higher
incomes. The labour force benefited from the creation of additional employment. However, due to the labour market conditions (i.e. the large degree of unemployment) a fraction of the benefits of the new technology in increasing productivity appears to have been realized as higher real wages. Workers perhaps benefited from the reduction in the real price of cotton cloth.

The studies by Ayer and Schuh and the I.A.C. have been important in widening the scope of what has hitherto been the conventional wisdom, i.e. that, in the main, the gains from agricultural research flow to consumers. This conclusion is derived from analysis of market behaviour in the U.S. where the domestic price is directly affected by changes in supply conditions. However, in countries such as Australia and Brazil, traditional exporters of agricultural products, the "small country" assumption is generally appropriate, and in such cases producers are likely to appropriate a large share of the gains from agricultural research.

Finally, if Wisecarver's arguments are generally accepted, the analytical approach to these distributional questions will have to be made through the factor-demand functions. Use of these functions will pose questions about the specification of "appropriate" functional forms for the demand and supply curves and specification of shifts in the functions as well as estimation of the areas of surplus (loss). These are problems which are still unresolved in the use of output supply and demand curves as we will see in the next chapter.
Scobie (1976), in a summary of some of the methodology which has been used to measure relative gains of producers and consumers, notes that markedly different distributions can result from different specifications of product supply and demand curves, and the producer and consumer surplus formulations which derive from them. He examines the formulae for consumer and producer surplus used by Akino and Hayami (1975), Hertford and Schmitz (1975), Ardila (1973), and Ramalko de Castro and Schuh (1976).

Scobie points out that the formulae for consumer and producer surplus will vary depending on the nature of the supply and demand curves assumed, e.g. constant elasticity, variable elasticity, etc., and the degree of approximation used in measuring the areas of surplus.

Scobie compared the results obtained from four different mathematical formulations of consumers' and producers' surplus in response to the following questions:

(1) Under what conditions will consumers gain more than producers as a result of a technological change in production (i.e. a rightwards shift of the supply curve)?

(2) Under what conditions will the change in producers' surplus be positive?
The four sets of formulae which Scobie presented in his note have been used in published studies of the distribution of the benefits from research between consumers and producers. The answers he obtains in each case are different and in some cases, contradictory. Scobie sees that the various mathematical specifications of the consumers' and producers' surplus differ in the specification of the demand and supply curves (e.g. log linear versus linear), and in the degree of approximation used in measuring the consumers' and producers' surplus. Nevertheless, as he says, "we may expect that, despite all the differences, the same general conclusion would emerge".

In this chapter we attempt to isolate the reasons why the different formulations of the consumers' and producers' surplus give different results. This is done by developing a generalised specification of a supply and demand model and incorporating a generalised shift of the supply function to represent, in this case, reduced costs of production resulting from research. Generalised formulae for both consumers' surplus and producers' surplus are developed. The various specifications assembled by Scobie, are seen to be special cases of the generalised formulation, and the reasons for the different results from a shift of the supply curve can be isolated. However detailed reappraisal of the studies prompting Scobie's questions cannot be undertaken here because the original data bases are not available.

The reasons are, in fact, three-fold: first, the shift in the supply curve may be specified differently; second, the specification of the supply and demand functions adopted may be different; third, the approximation of the point elasticities may be different.
4.1 Rightwards Shifts in the Supply Curve

Suppose X (output) is a dependent variable, and P (price) is an independent variable. Then a supply function can be represented generally as:

\[ X_S = S(P) \]

A proportionate shift to the right in supply (in either linear or non-linear form) is defined by:

\[ X'_S = KS(P), \text{ where } K > 1 \text{ and constant.} \]

In this case, supply increases by a constant proportion for all prices.

For a parallel rightwards shift in the supply function the supply of X increases by an equal absolute amount for all prices.

For example, in a linear supply function a parallel shift is specified as follows:

\[ X_S = a + bP \]
\[ X'_S = a' + bP \text{ where } a' > a. \]

For a combination of these two kinds of shift we can postulate, for example, a rotation of a linear function, where:

\[ X_S = a + bP \]
\[ X'_S = a + b'P \text{ where } b' > b. \]

This will give the same result as in the proportionate shift case if, and only if, \( a = 0 \).
For a generalised specification of a rightwards shift in the supply function, we define

\[ X'_{S} = \{(P,X)/\forall P \ X' > X\} \]

\[ = \{(P,X)/\forall P \ S'(P) > S(P)\} \]

This can be called a "strong" shift, i.e. for all prices \( X'_{S} > X_{S} \).

If we define \( X'_{S} = \{(P,X)/\forall P \ S'(P) \geq S(P)\} \), this can be called a "semi-positive" shift, i.e. for some prices \( X'_{S} > X_{S} \).

Finally, for purposes of completeness, if we define \( X'_{S} = \{(P,X)/\forall P \ S'(P) > S(P)\} \) this can be called a "weak" shift. In this case \( X'_{S} = X_{S} \) can satisfy the "weak" inequality above.

### 4.2 Definition of Producers' Surplus

In the general case, assuming \( X_{S} \) is integrable and the inverse function \( X_{S}^{-1} \) exists (i.e. \( X_{S} \) is one-to-one and "onto"), producers' surplus (PS) will be equal to:

\[ PS = P_{0}X_{0} - \int_{0}^{X_{0}} S^{-1}(X) \, dX \]

where \( P_{0}, X_{0} \) represents any price/quantity co-ordinate on the supply function.

### 4.3 Comparative Static Effect of a Change in \( K \)

To derive the effect on producers' surplus from a shift in the supply curve we move to a market specification and assume supply and demand functions, as follows:
\[ X_\text{S} = S(P, K) \]
\[ X_\text{D} = D(P), \text{ where in equilibrium} \]
\[ X_\text{S} = X_\text{D} \]

and where, \( D(P) - S(P, K) = 0 \) ........(1)

Assuming that this equilibrium exists, and if demand and supply functions are continuously differentiable and an equilibrium price \( \bar{P} \) exists, then there is a (continuously differentiable) function \( g \) defined in some neighbourhood of \( (\bar{P}, K) \) such that:

\[ P^\ast = g(K) \] ........(2)

also, solving for \( X^\ast \) by substitution in either

demand function: \( X^\ast - D(P^\ast) = D(g(K)) \)
or supply function: \( X^\ast = S(P^\ast, K) = S(g(K), K) \)
e.g. in a linear case \( X^\ast = d + eP^\ast \)
\[
= d + e \left( \frac{d-a-cK}{b-e} \right)
\]

Now,
\[ X^\ast = S(P^\ast, K) = D(P^\ast) \] ........(3)

where \( P^\ast \) and \( X^\ast \) are equilibrium price and quantity respectively.

From the implicit function Theorem \(^2\) we find the effect on the equilibrium of a "small" change in \( K \). Equation (1) is an identity in the equilibrium values of the variable \( P^\ast \). Hence,
\[ D(P^\ast) - S(P^\ast, K) = 0 \] ........(4)

---

1 e.g. in a linear case when supply in a function of price \( P \) and a shift parameter \( K \),
\[ X_\text{S} = a + bP + CK \] and \( X_\text{D} = d + eP, \quad (e < 0) \)
Then \( X_\text{S} = X_\text{D} \)

If we substitute for \( X_\text{D} \) and \( X_\text{S} \):
\[ d + eP - (a+bP+CK) = 0, \text{ then } P^\ast = \frac{a+CK-d}{e-b} \quad \text{or} \quad = \frac{d-a-CK}{b-e} \]

2 For further details see "Mathematical Optimization and Economic Theory", 1971, pp. 499-500, by M. Intriligator.

3 The equilibrium equation (4) is an identity: (contd. over)
Now if we differentiate "implicitly" taking into account that $P^*$ (not $P$) is a function of $K$ only, because we now confine attention to equilibrium values of $P$, $X$ only.

\[
\frac{\partial d}{\partial F} \cdot \frac{dp^*}{dk} - \left( \frac{\partial S}{\partial F} \cdot \frac{dp^*}{k} + \frac{\partial S}{\partial K} \cdot \frac{dk}{k} \right) = 0
\]

or \[\frac{3D}{3F} - \frac{3S}{3F} \frac{dp^*}{k} - \frac{3S}{3K} = 0 \quad \ldots \ldots (A)\]

The derivatives of the demand and supply functions (i.e. \(\frac{3D}{3F}, \frac{3S}{3F}\) and \(\frac{3S}{3K}\)) are all evaluated at the equilibrium value $P^*$. To make this clear, let us write:

\[
\frac{3D}{3F} = D_P(P^*)
\]
\[
\frac{3S}{3F} = S_P(P^*, K)
\]
and \[\frac{3S}{3K} = S_K(P^*, K)\]

Therefore, rewriting the equation (A), we have

\[\left[ D_P(P^*) - S_P(P^*, K) \right] \cdot \frac{P^*}{K} - S_K(P^*, K) = 0 \]

this is therefore linear in \(\frac{dp^*}{dk}\)

Therefore, if we solve:

\[
\frac{dp^*}{dk} = \frac{S_K(P^*, K)}{D_P(P^*) - S_P(P^*, K)} \quad \ldots \ldots (B)
\]

($S_K$ is the partial derivative of $S$ with respect to $K$.)

\[e.g. \text{ in a linear model: } \frac{dp^*}{dk} = \frac{-c}{b-e}, \text{ directly from explicit solution for } P^*, \]

or, in equilibrium condition:

\[d + eP - (A + bP + CK) = 0\]

and \[e \quad \frac{dp^*}{dk} - (b \frac{dp^*}{dk} + C \frac{dk}{dk}) = 0 \text{ therefore, } \frac{dp^*}{dk} = \frac{-c}{e-b}\]

\[
D_P \quad S_P \quad S_K
\]
Assuming the demand and supply curves are differentiable, we differentiate (2) with respect to K which gives:

\[
\frac{dP^*}{dK} = \frac{S^*}{P^* - S^*} \tag{5}
\]

where \( \ast \) indicates evaluation at equilibrium (to save writing \( S,K(P^*,K) \) etc). If it is the case that demand is negatively related to price, supply is positively related to price (i.e. the "normal" assumption made in micro-theory); and in addition, an increase in K increases supply, then:

\[
D^*_P < 0, \quad S^*_P > 0, \quad \text{and} \quad S^*_K > 0
\]

Therefore, from (5), under these conditions:

\[
\frac{dP^*}{dK} \quad \text{is negative since the numerator in (5) is positive, and the denominator is negative. We can write result (5) in terms of elasticities if we multiply numerator and denominator by } \frac{P^*}{X^*}. \quad \text{This gives:}
\]

\[
\frac{dP^*}{dK} = \frac{P^*}{X^*} \frac{S^*}{K^*} \frac{1}{\sigma^* - \eta^*},
\]

where

\[
\sigma^* = \frac{P^*}{X^*} D^*_P \quad \text{(price elasticity of demand), and}
\]

4 For example, in the special case of proportionate shift:

\[
X_S = S(P,K) = Kh(P) \quad \text{(supply is linear in K)}
\]

Now, \( \frac{3S}{\partial P} = Kh_p(P) \quad \text{(1st derivation)} \)

\[
\frac{3S}{\partial K} = h(P)
\]

If we substitute these into (B), we will get \( \frac{dP^*}{dK} = \frac{h(P^*)}{D_p(P^*) - Kh_p(P^*)} \)
\[ \eta^* = \frac{p^*}{x^*} s^* \quad \text{(price elasticity of supply)} \]

Using these results we can now evaluate a change in producers' surplus consequent on a small change in K. If we differentiate the equation for producers' surplus above, evaluated at equilibrium, we have

\[ \frac{dPS}{dK} = p^* \frac{dx^*}{dK} + x^* \frac{dp^*}{dK} - \frac{d}{dK} \int_0^{s^*} x^* (x) dx \quad \ldots \ldots \ldots (7) \]

Theorem: Let \( f(x,t) \) satisfy the conditions for Leibnitz's rule. In addition, let \( a(t) \) and \( b(t) \) be defined and have continuous derivatives for \( t_1 < t < t_2 \). Then, for \( t_1 < t < t_2 \):

\[ \frac{d}{dt} \int_a^b f(x,t) dx = f[b(t),t] b'(t) - f[a(t),t] a'(t) + \int_a^b \frac{\partial f}{\partial t}(x,t) dx \]

If we apply the result arising from the above theorem to the last term in (7) we have:

\[ \frac{dPS}{dK} = p^* \frac{dx^*}{dK} + x^* \frac{dp^*}{dK} - \{s^* (x^*) \} \frac{dx^*}{dK} + \int_0^{s^*} x^* \frac{dS^*}{dK} (x) dx \quad \ldots \ldots \ldots (8) \]

\[ = \{p^* - s^* (x^*) \} \frac{dx^*}{dK} + \frac{x^* (p^*/x^*) S*K}{S^* - \eta^*} - \int_0^{s^*} \frac{-dp}{dK} (x) dx \quad \ldots \ldots \ldots (9) \]

\[ = (p^* - p^*) \frac{dx^*}{dK} + \frac{p^* S*K}{S^* - \eta^*} - \int_0^{s^*} \frac{-S^*}{p^*} (x) dx \quad \ldots \ldots \ldots (10) \]

\[ = \frac{p^* S*K}{S^* - \eta^*} + \int_0^{s^*} \frac{S*K}{S^*} dx \quad \ldots \ldots \ldots (11) \]

Equation (11) shows that the change in the producers' surplus as a result of a small rightwards shift of the supply curve is the net effect of:
\[
\frac{P^* S^*}{K} \frac{dP^*}{dK} = X^* \frac{dX^*}{dP^*} = X^* \frac{dP^*}{dK},
\]
which is the loss in revenue resulting from the fall in the equilibrium price due to the rightwards shift in supply; and

\[
\int_0^X \frac{X^* S^*}{SP^*} dX = \int_0^{X^*} \left(-\frac{dP}{dK}\right) dX,
\]
which is the aggregate of the reduction in marginal costs (i.e. fall in total costs) as a result of the adoption of the cost-reducing technology.

This is the familiar result, as expressed in Figure 4.1 below, that the change in producers' surplus from a shift of the supply curve is the difference between the total change in consumers' and producers' surplus $\text{ee}_1\text{fg}$ and the change in consumers' surplus $\text{pee}_1\text{p}_1$.

**FIGURE 4.1**

SOCIAL RETURN FROM A PARALLEL SUPPLY SHIFT

![Diagram of supply and demand curves showing social return from a parallel supply shift.]
4.4 Change in Consumers' Surplus

Consumers' surplus (CS) is defined as follows:

\[
CS = \int_{0}^{X^*} D^{-1}(X) \, dX - P*X^* 
\]

If we also define \( P = g(X) \, D^{-1}(X) \), then

\[
CS = \int_{0}^{X^*} g(X) \, dX - P*X^* 
\] 

\[\ldots
deadline(12)\]

Differentiating (12) with respect to \( K \), gives the change in consumers' surplus in response to a small change in \( K \), which is

\[
\frac{dCS}{dK} = g(X^*) \frac{dX^*}{dK} - P^* \frac{dX^*}{dK} - X^* \frac{dP^*}{dK} = -X^* \frac{dP^*}{dK}, \text{ since } P^* = g(X^*)
\]

and substituting (6) into the above gives:

\[
= - \frac{P*S^*}{\sigma - \eta^*} 
\] 

\[\ldots
deadline(13)\]

Equation (13) can now be compared with equation (11) to see that the change in consumers' surplus resulting from a shift of the supply curve is equal to the negative of the first term of equation (11) which is the change in producers' total revenue as a direct result of the change in price. Other familiar results can also be observed such as, for example, when \( \sigma = \infty \), \( 0 < \eta < \infty \); \( \sigma = 0 \), \( 0 < \eta < \infty \).

4.5 Comparisons with Scobie's Results

We can now provide generalised responses to the questions which Scobie posed.
(a) Under what conditions will consumers gain more than producers? i.e. when is:

\[ \frac{dCS}{dK} > \frac{dPS}{dK} \]

This will be true when:

\[ -X^* \frac{dP^*}{dK} > X^* \frac{dP^*}{dK} + \int_0^x \frac{(-\partial P)}{\partial K} \, dx \]

i.e. \[ -X^* \frac{dP^*}{dK} > \frac{1}{2} \int_0^x \frac{(-\partial P)}{\partial K} \, dx, \] which is true when the consumers' gain is more than one-half the producers' gain from the reduction in marginal costs.

(b) Under what conditions will the change in producers' surplus be positive? i.e. \[ \frac{dPS^*}{dK} \]

This will be true when:

\[ X^* \frac{dP^*}{dK} + \int_0^x \frac{(-\partial P)}{\partial K} \, dx \]

i.e. when \[ \int_0^x \frac{(-\partial P)}{\partial K} \, dx > (-X^* \frac{dP^*}{dK}), \] which is true when the producers' gain from the aggregate of the reduction in marginal costs is greater than their transfer of surplus to consumers.

This general approach to the formulation of these conditions has been carried out using exact, calculus results. It is, therefore,
difficult to reconcile these with the formulations reported by Scobie because these are mostly approximate results where, for example, point elasticities are approximated by arc elasticities.

It would be extremely difficult to reconcile these different mathematical approaches. (Moreover, the initial specifications of the functions are not available to the author). However, inspection shows that other than the difference in elasticity formulation mentioned above, the other major differences in approach between the several authors are in the specification of the shift of the supply curve (sometimes horizontal, sometimes vertical) and the different initial conditions adopted. It is therefore not obvious that the different formulations should be condemned because they give different and often contradictory results. The proper question is what is the appropriate supply and demand specification for the problem at hand? It would help however, if there was some standardisation in terms of the general approach adopted here.
CHAPTER 5

DISTRIBUTION OF THE GAINS (LOSSES) FROM RESEARCH AMONG FACTORS OF PRODUCTION

5.1 Introduction

It seems a natural progression of events that following work on the estimation of the distribution of research gains (losses) among producers and consumers that there should be interest in the distribution of the change in producers' surplus among the factors of production. In the only major analysis of its kind so far Schmitz and Seckler (1970) attempted to look at the implications for agricultural labour of the advent of the mechanical tomato harvester in the U.S..

The major implication of their analysis is to determine the value of the innovation to producers and consumers, and to see what would be the payments necessary to compensate the loser (i.e. workers).

There are a number of major aspects on which this study can be criticised. It is to be hoped that some of these criticisms point the way in which the methodology used here can be improved.

5.2 Schmitz and Seckler's Method

In the first analysis of its kind, Andrew Schmitz and David Seckler (1970) attempt to supply a framework by which "The broad social costs of technological innovation can be mapped into the framework of economic analysis". They concentrate on one of the recent
technological changes influencing agriculture - the mechanical tomato harvester, which brought about considerable social changes as well as being a scientific and engineering triumph.

Schmitz and Seckler employ "gross social returns" (GSR) as the Value to society of the reduced costs of harvesting tomatoes by the mechanical harvester.\(^1\) These returns (GSR) are defined to differ from the "net social returns" (NSR) by the value of the wage loss of the displaced workers.

Studies of the comparative costs of hand and mechanical tomato harvesting methods carried out in California are used for other tomato-producing states. It was estimated that mechanical harvesting reduced costs roughly between $5.41/ton and $7.47/ton (including amortization and 6 per cent interest charges on the machine costs).

In order to estimate GSR (as a whole), firstly, they employ as a basis the supply-shift frame-work used by Griliches, Peterson and others. Secondly, they deem it necessary to take into account the rate of adoption of the harvester.

Given the estimated total U.S. average rate of adoption and an estimated average yield of tomatoes/acre, they compute the GSR to the harvester for the United States. All estimates are carried to a definite year (being 1973) in which, by assumption, total tomato acreage mechanically harvested attains a constant amount. The annual GSR, for each year, is calculated at 6 per cent interest to 1973 (the year 1965 being the base year) and then they convert it into an annual

---

\(^1\) They neglect benefits accruing to foreign countries (e.g. Germany, the U.S.S.R.) which have imported these machines.
perpetual sum. This, together with the annual GSR in 1973 onwards, establishes the annual value of GSR to the harvester.

Rate of Return

Given the estimated benefits accruing from the tomato harvester and the research and development costs, they calculate the gross social rate of return (GSRR) to R and D costs as follows:

\[
\text{GSRR} = \frac{\text{Total annual value of gross social returns}}{\text{Research and development costs (on the tomato harvester)}} \quad (100)
\]

Gross social returns to aggregate research and development expenditures in this analysis are in the vicinity of 1000 per cent.

They follow "traditional analysis" to calculate the rates of return from an innovation in which the distributional effects are not taken into account. Then in estimating the NSRR, they relax this assumption and consider explicitly the costs incurred by workers due to the adoption of the tomato harvester.

Net Social Rate of Return (NSRR)

The formula used to compute the NSRR\(^1\) is:

\[
\text{NSRR} = \frac{\text{GSR} - C}{\text{R and D}} \quad (100), \text{where } C \text{ is the amount of compensation which is needed to offset the effect of technological change.}\]

1 They assume different employment levels for farm workers in non-agricultural industries, but in the unhelpful way of sensitivity levels ranging from 0 to 100%.

2 For detailed calculations, see Appendix to the paper "Total man-hours displaced by the tomato-harvester".
that the rates of return to R and D expenditures on the tomato harvester were considerable (even after deducting reasonable allowances for compensation). However, since compensation was not actually paid, "they believe" it cannot be true that the society as a whole has benefited from the tomato harvester.

**Purpose and Framework of Analysis**

The mechanical tomato harvester has made possible important economies in production. However, Schmitz and Seckler also see that it "has also undermined the livelihood of numerous agricultural laborers". This is a very important matter not only as far as the adoption of new technology is concerned, but generally in respect of all structural change. The assumption that labour is automatically rendered unemployed by labour displacing new technology should be questioned. Are the labourers really worse-off? Do they go on directly to unemployment relief? Or, are there other jobs they can go to? New technology does not necessarily disadvantage labour. It often leads to new and higher paid occupations.

In a survey of the employment effects of technological change in Australian manufacturing industry,¹ taken by the Department of Labour and National Service in 1971, the following results give us some interesting aspects regarding structural change:

- 73 per cent of the 2,200 responding establishments (employing more than half a million persons) introduced one or more technological

¹ National Survey of the Employment Effects of Technological Change, Department of Labour and National Service, Melbourne, 1971.
changes during the previous three years, while 60 per cent were expecting to introduce changes during the subsequent three years.\(^1\)

- of the 10,000 persons (1.8 per cent of average employment in the responding establishments) displaced by technological changes, about 7,000 were transferred to other jobs within the firm (almost invariably to positions of equal or higher status).

Further, in respect of the changing structure of occupations accompanying the technological change, 409 establishments experienced occupations declining in relative importance, 668 experienced occupations increasing in relative importance and 563 experienced the emergence of new occupations. Besides, about 6 out of every 10 establishments which displaced employees provided some sort of retraining, at the expense of the company, to make persons suitable for alternative employment within the company.

The above survey findings give us reasonable grounds to draw the following implications:

(1) Whatever the reasons for the firm adopting new technology, and supposedly it is profitable for them to do so, technological change is a very pervasive influence for change in industry (this survey understates the extent of change due to new technology because it excludes new products).

(2) Technological change is not as important a source of "retrenchment of labour" as is widely thought.

\(^1\) Technological change was defined as "the introduction of machinery, equipment, processes or sales materials of a type not used previously by the establishment".
(3) As far as labour is concerned an important consequence is the generation of new kinds of employment. This is an important point which should be borne in mind in relation to structural change as it affects labour.

(4) Firms obviously have an incentive to retrain labour of their own accord.

A more realistic framework for examining the implications of new technology for labour (or other causes of structural change) would be to think of the problem in terms of labour's expected lifetime earnings and the effect of new technology on the expected value of earnings. This approach would mean taking into account the likely occurrence of workers changing jobs several times during their working life - involving with each change the possibility of larger or smaller incomes being earned. The approach should recognise that because change is part of economic life, workers do have expectations of changing jobs. Moreover, as was argued above, technological change carries with it the high likelihood of the creation of new job opportunities. Because workers in a displaced occupation possess experience of that particular industry, it is likely that they will be chosen before others for further on-the-job training to adapt them for new occupations.

Estimation of the Effects of Technical Change on Labour

To compute the net social rate of return generated from the harvester development, Schmitz and Seckler explicitly take into account the effects of its introduction of farm workers. After analysing
the Gross Social Returns through the supply shift approach, they turn to input-demand analysis for estimating the effects in the labour market on labour demand. In Fig. 5.1, prior to mechanization the demand for tomato workers is $D_0$ and the supply is $S_0$. $D_1$ represents the demand for tomato workers when the harvester is in use. The loss of wages caused by the harvester is assumed to be equal to $W_0(Q_2 - Q_1)$. This assumption takes the following form:

(i) No possibilities of alternative employment;

(ii) The remaining employed workers receive wages at least as high as those obtained before the implementation of the harvester. This assumption does not stand up well to close analysis.

If we look to Fig. 5.1 as presented by Schmitz and Seckler, we realize that this representation actually does not make any sense. The supply curve for labour represents the opportunity cost of labour (that is, what labour could get in an alternative activity), in a free market. Only in the case where institutional wage fixing predominates may the level of labour demand move from $A$ to $B$. In this case, the wage level $W_0$ is essentially the labour supply curve. In which case the supply curve $S_0$ is inoperative. However, it should seriously be questioned whether, in the particular case they were analysing, this representation of pricing in the labour market was accurate. Even if institutional wage-fixing predominates, the labour-supply conditions must bear some influence on wages. Given a large displacement of labour in agriculture, is it not more realistic to believe that this will exert some downwards pressure on wages and hence the number of
FIGURE 5.1
EFFECT OF THE TOMATO HARVESTER ON EMPLOYMENT OF FARM WORKERS

Source: Schmitz and Seckler (1970)
workers displaced will be less? (This leaves aside the question of whether the tomato harvester in fact created opportunities for new jobs, in agriculture or elsewhere).

In Fig. 5.2, I have shown a situation such that, if $S'_0$ is the supply curve, then $CDQ^1Q^2$ will be the total area to be measured (for loss of wages). Alternatively, if $S_0$ is the supply curve (as Schmitz and Seckler have shown), then $D'Q^2Q^3C'$ should be the area for the measurement of loss of wages.

One of the many aspects of the discussion in the previous paragraph which could have borne further discussion by Schmitz and Seckler was of the effect of minimum wage fixing in general and in particular with respect to wage fixing in agriculture in the U.S..

Given an institutional wage-setting process for minimum wages, it may well set wages above what would otherwise have been sustained in a free market. Presumably the existence of such an institutional mechanism is a policy favoured, in some sense, by society. In that case, individual employers should not be expected to carry the full burden of compensation if it is to be as represented by Schmitz and Seckler in Fig. 5.1.

5.3 Minimum Wage Implications

Jacob Mincer (1976) explores the analytical and empirical differences between employment and unemployment effects of minimum wages. His discussion is relevant to Schmitz and Seckler's analysis in estimating the actual amount of unemployment caused by the implementation of the
FIGURE 5.2
EFFECTS OF THE TOMATO HARVESTER ON EMPLOYMENT OF FARM WORKERS
WITH BOTH PERFECTLY ELASTIC SUPPLY AND INELASTIC SUPPLY
tomato harvester. Since Schmitz and Seckler assume wages for the remaining employed pickers at least as high as those obtained prior to the use of the harvester, they should have gone into the discussion of problems associated with unemployment effects of minimum wages.

The theoretical analysis indicates that minimum wages generate socially wasteful labour mobility between the "covered" and non-covered sectors and between the labour market and the non-market. The direction of this mobility and of the resulting change in the non-covered sector wage are not predictable a priori contrary to (conflicting) assumptions made in the literature. The empirical analysis suggests that, in consequence of minimum wage increases, labour moves out of the covered sector into the non-covered sector and out of the labour market. In the process, wages in the uncovered sector fall. Now, given similar labour in the two sectors (there is only one before the imposition of minimum wages) and a wage $W_0$, the imposition of an above-equilibrium minimum wage ($W_m$) in the covered sector, where $W_m > W_0$, will lead to two equilibrating adjustments: in the uncovered sector, the wage changes from $W_0$ to $W_n$ in consequence of general sectoral movements of labour, and with $W_m > W_n$ a certain amount of "waiting" for jobs in the covered sector becomes worthwhile, which creates a fixed amount of unemployment.

Suppose a wage $W_m$ exceeding the equilibrium wage $W_0$ is imposed on a part of the economy, i.e. the "covered" sector, creating a differential $W_m - W_n$, where $W_n$ is the resulting wage level in the "uncovered" sector. Now in order to separate from other influences, Mincer assumes that job searchers' probability of finding a job in
the uncovered sector is equal to unity within the period. With wages above equilibrium in the covered sector, jobs in it must be rationed. Changes of success in the job search depend on the method of rationing. Mincer assumes probabilistic rationing, one in which every job searcher has an equal chance of getting a job and every employed worker an equal chance of keeping the job. This assumes that some vacancies emerge periodically in the covered sector, due to turnover. It should be noted that in probabilistic rationing search costs are implicitly assumed to consist of time costs. Becker suggests that the probability of a worker finding a job (at \( W_m \)) depends positively on the amount of time he puts into search and negatively on the amount of time put into search by everyone else. If all workers were identical, then in equilibrium all persons searching would put in an equal amount of time and have an equal probability of finding employment. The time they all put in - which essentially offsets each other - is the unemployment that is observed. Mincer argues that if we abstract from risk preferences and from search costs other than foregone earnings, equilibrium wages after imposition of \( W_m \) in the covered sector are given by:

\[
P_{m} \times W_{n} = W_{m}, \quad \text{or} \quad P = \frac{w_{n}}{w_{m}}, \quad \text{and} \quad \frac{1-P}{P} = w \quad \text{.........(1)}
\]

where \( W = \frac{(W_{m} - W_{n})}{W_{n}} \) and \( P \) is the probability of finding employment in the covered sector.

Mincer goes further into the matter and argues that in the covered sector, employment is \( E_m \) and the number of vacancies per period is \( \delta E_m \). If we abstract from growth or cycles, the rate \( \delta \) is simply a separation rate. The \( \delta E_m \) vacancies are filled as soon as they appear,
and a remaining pool of unemployed searchers of size \( U \) is observed.

As the number of vacancies (separations) is \( E_m \) and the total number of job searchers is \( U + \delta E_m \), then the probability of employment will be:

\[
P = \frac{\delta E_m}{U + \delta E_m} \quad \text{.........(2)}
\]

Define the covered sector unemployment ratio \( u'_m = U/E_m \) and the unemployment rate \( u_m = U/(E_m + U) \). Then:

\[
P = \frac{\delta}{u'_m + \delta}
\]

\[
u'_m = \frac{\delta(1-P)}{P} = \delta w \quad \text{.........(3)}
\]

and \( u_m = \frac{\delta(1-P)}{P+\delta(1-P)} = \frac{\delta w}{1+\delta w} \).

Define the proportion of employment covered \( k = E_m/(E_m + E_n) \) and the aggregate unemployment ratio \( u'_A = u'_m = u'_m \). Then

\[
u'_A = ku'_m = k\delta w \quad \text{.........(4)}
\]

and the aggregate unemployment rate \( u_A = k\delta w/(1 + k\delta w) \).

From above, it appears that the unemployment rate induced by the minimum wages imposition is proportional to the percentage wage gap \( W \) between the sectors, the separation rate \( \delta \), and the coverage ratio \( K \). The separation rate \( \delta \) has a maximum value of unity. This case of complete (100 per cent) turnover provides the highest chance
of success for job searchers, hence maximum unemployment, that is to say, $u'_m = w$ and $u'_A = kw$. The opposite extreme, zero turnover, implies no unemployment - all those without jobs having left the covered section.

5.4 Re-Employment Possibilities

Schmitz and Seckler do not attempt to estimate the actual amount of unemployment created by the harvester. Their reason for not doing so is that it would have required knowing all displaced pickers' future employments. Then they refer to Robinson (1958) who points out, "nearly four million workers were employed in 1957 in industries which did not exist or hardly existed in 1900. If we had been looking for jobs for those workers in 1900, we should never have foreseen the present number of workers in the motor industry and motor transport, in the making of gramaphones, wireless or television sets, in electricity or aviation. At any moment it is hard to foresee how those workers will ultimately be absorbed, for whose services in their former occupations there is likely to be less demand".

However, Gary S. Fields (1976) presents one specific way of estimating probabilities of future employment. This procedure (based on current data on job "accessions and terminations") regards the labour market as having two states: (a) employment, and (b) unemployment. Individuals are facing a matrix of probabilities of either remaining in or moving between these two states.

---

1 As it was discussed earlier, this resulted in over-estimation of compensation and as a consequence of that, NSRR was under-estimated.
Fields' transition matrix has the form of:

\[
P(t) = \begin{bmatrix}
P_{ee}(t) & P_{eu}(t) \\
P_{ue}(t) & P_{uu}(t)
\end{bmatrix}
\]  

where, 

\(P_{ij}(t)\) is the probability of moving from state \(i\) to state \(j\) during time \(t\). 

\(P_{ue}\) is the probability of moving from unemployment \((u)\) to employment \((s)\) during a period given that one is unemployed at the beginning of the period (and similarly for \(P_{ue}\)). 

\(P_{uu}(t), P_{ee}(t)\) are the probabilities of remaining in unemployment and employment states respectively. Fields argues that we may suppose that individuals behave as if they take the probabilities of present transition and project them into the future as though the present values will prevail forever. Now, if we assume that the components of the above matrix are constant, then the mechanism which determines the probability of employment will be a first order Markov Process. The results from Markov Chains can be used to demonstrate that:

\[
PV = \left[\begin{array}{c}
W \\
eu
\end{array}\right] \left[I - \frac{1}{1+r} P^T\right]^{-1} \begin{bmatrix}
E(0) \\
u(0)
\end{bmatrix}
\]  

---

1 The equation \(PV = f\left(\frac{W}{r}, P_{eu}, P_{ue}\right)\) (A) (as Fields mentions) simply projects today's new hire and lay-off rates into the future and would sufficiently reflect expectations of future employment probabilities. In here, \(W\) is wage and \(r\) is rate of interest. Equation (b) follows equation (A).
where,

\[ W_{eu} \] is the wage one receives if he is employed, (unemployed)

\[ I \] is the identity matrix

\[ P^T \] is the transpose of \( P \)

\( E(0) \) and \( U(0) \) are, respectively, one-zero variables denoting employment as unemployment at time zero.

If we suppose that \( U(0) = 1, E(0) = 0 \) (which means that a new labourer (migrant) is unemployed initially), and he is ineligible for unemployment compensation, or \( (W_u = 0) \). Also, if we denote the wage while employed by \( W \), equation (c) can be solved which gives an expected present value:

\[ \text{PV} = \frac{(1+r)/r}{P_{ut}/(r+P_{ue}+P_{eu})} \]  

Fields argues that this probability estimation of future employment gives better results than the fairly widely used unemployment level. The main point to be made here is that some estimate of the probability of re-employment must be made otherwise the so-called "adjustment costs" for displaced labour will be greatly over-estimated.

5.5 Compensation for Displaced Labour

A third problem in Schmitz and Seckler's analysis concerns determination of the amount of compensation. The estimated wage loss from 1965 through 1972 has been compounded forward to 1973, and then they convert it to an annual flow. The conversion to an annual flow, which makes the calculation of the NSRR possible, assumes an infinite
life for the displaced labour. This assumption, as they also believe, is "untenable". Another way of interpreting this over-estimation of compensation (which results in under-estimation of the value of NSRR), is in terms of the probability of finding a job and that probability should be taken into account due to the fact that the displaced workers will not be jobless for ever. This issue has been discussed to some extent in the previous section.

A more general part of the problem is that if society feels that it wants to get into the business of compensating people for change, then the feasibility of a general compensation policy to insure the losers from economic progress should be questioned on practical and theoretical grounds. This is the question Pasour (1973) explored.

Should persons suffering from losses because of economic growth, including government intervention, be compensated by government? That is, would a program be feasible and capable of transferring enough of the gain by taxation of the gainers in the form of government payments to the losers such that they will not incur losses and be as well-off as they would have been before? Or, should we apply what Schmitz and Seckler say in this regard: "for compensation purposes, an alternative to unionization may be a form of state intervention in which a tax is imposed on units of output. The proceeds from this tax would then be used to finance retraining, relocative, and retirement programs"?

Pasour's contention is that such programs would not be feasible. His arguments show "why a general policy of compensation to insure against losses associated with economic progress is not appropriate".
First, let us review some proposals for compensation in agriculture, then return to Pasour's arguments. Heady (1966) states: "Consumers reap a gain from the further contribution of farming to economic progress, but farmers in general have a sacrifice in the form of depressed incomes". In fact, he points out that government development policies in agriculture, e.g. research, education and the like, lead to increases in agricultural output, which benefit consumers through lower food prices, but lead to reduced farm receipts because of the inelastic demand for farm products. So, he favours "Compensation policies to provide farmers with some payoff for this contribution to the national welfare" (1967). But he does not clearly discuss the compensation problem in general, i.e. whether or not he is in favour of a full or partial compensation policy for individuals in all sectors of the economy unfavourably influenced by government action and/or economic growth.¹

T.W. Schultz (1961) proposes a general compensation policy. Ideally, the purpose of this policy is to ensure in principle that labourers and owners of resources would not be made worse off (or will not suffer losses) as a consequence of economic progress. He challenges the view that gains and losses are both necessary to induce adjustments by labour and other resources. Alternatively, Schultz contends that the incentives in a market economy can be retained by giving free reign to the unexpected gains while compensating for producers' losses because

¹ According to Pasour, "full compensation is necessary to insure against loss. Payment of partial compensation based on individual losses is subject to the same measurement problems as full compensation, however, since full compensation must be known before partial compensation can be determined".
of economic progress. He assumes that the losses are much smaller than
the gains, and, for this reason, that the net gains from economic
progress are large enough to provide an effective system of incentives.

Heady, on the other hand, compares the gains to consumers
with the losses to food producers associated with government development
policies and says that "we cannot be certain that the sum outcome is
positive". Heady suggests that adoption of a set of compensation
policies to insure that the "sum outcome is positive" could well be an
alternative in this regard.

Finally, Schmitz and Seckler's proposal is that a fraction
of the economies generated by technological innovations be allocated
out of general taxes to boost the displaced workers' mobility.

According to Pasour, "interventions of this sort would allow
social costs and benefits to fall more or less randomly on the popula-
tion as a whole and thus, in a sense, cancel each other. If this were
to occur, 'every-one' would be better off with technological change".
I quite agree with Pasour that the extent to which Schmitz and Seckler
support compensation to insure against loss is not clear. However, as
Pasour points out, the quote suggests that from a social welfare view
point, all technological change should meet the "Pareto better" welfare
criterion.

Pasour argues that a policy of compensation to insure
against losses confronts us with four problems as follows:

(1) **Measurement Problems**

We are often not able to measure losses which are associated
with economic growth. For instance, how can we separate losses (or
reduction in prices) associated with economic growth from other losses (or reduction in prices)? Or, how we can determine the extent of the loss suffered by an individual? Pasour points out how immense would be the administrative problems in determining and measuring particular losses occurring because of economic progress. For this reason, "measurement problems alone are sufficiently formidable to limit the feasibility of any program to insure against such losses".

(2) Public Choice Process

A general system of compensation to balance the direct and indirect losses resulting from government activity is not feasible because it would be contradictory with the role of government of "enhancing" various self-interests at the expense of other people. Obviously, in every action taken by government, some people may gain and some people may lose, but the important point is that specific groups of citizens use the power of the state to "enhance" their own economic interests compared with economic interests of other groups. Pasour takes as examples in the U.S., agricultural subsidies, use-value property taxation for farmers, a ban on the use of DDT, and the zoning of farmland. These examples represent choices made by government which are influenced by specific groups who virtually misuse government for the advancement of their own interests.

(3) A third reason why a general compensation policy is not feasible depends "on the fact that governmental choice is also required in

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1 "This, of course, does not preclude the possibility that certain groups might be sufficiently influential to obtain compensation for actions taken which are deleterious to their interests."
determining and adjudicating property rights between individuals in
the private sector where externalities are involved".

Pasour refers to Samuels (1971) in citing a Virginia case
of 40 years' dispute in court as an example for his third reason:
the story is about the property rights of cedar tree producers as against
the rights of apple producers whose apples were being damaged by a cedar
tree rust. This rust does not cause any damage to cedar trees, but its
life cycle involves an attacking phase on apple leaves and fruits.
This example shows, firstly, how government was forced to choose between
the interests of the two groups; and, secondly, that government in
general is an "instrument" for the accommodation of conflicting interests.

(4) Risk and Moral Hazard

There are two kinds of risks: (a) those which can be pooled
(the aggregate risk is less than the combined risk), i.e. house-burning.
In such a case, a private insurance company provides a useful function.
(b) Those which are not poolable (the individual events which combine
to form the aggregates are not independent of one another), i.e. when
the society changes its demand for skill.

Pasour points out that "moral hazard refers to the fact
that an insurance policy might have a deterrent effect on self-
protection (i.e. acts which reduce the probability of a loss) which
increases the probability of a hazardous event actually occurring".

The significance of moral hazard to the compensation issue
is that Schultz (1961) contends that gains which are associated with
economic growth are much larger than losses within the present institutional framework. Nevertheless, Pasour believes that a compensation rule would represent a pronounced institutional change. Within this proposed institutional framework, we are likely to increase risky and improper investments since we are always expecting non-positive losses.

The above shows that a general policy of compensation to insure farmers against losses, because of economic progress, does not seem to be "sound" either in practice or in theory.
This thesis has been concerned with bringing together research which has taken place over the past two decades stemming from the work of Griliches (1958) on evaluating the benefits to research. The writings surveyed have followed pretty closely a natural progression, where first the total social gains were measured; then the allocation of the gains between consumers and producers were evaluated; and most recently, concentrated on the allocation of the gains among the several factors of production.

Duncan and Tsidell (1971) have explored the implications of different assumptions about the nature of the shift in the supply curve for the distribution of research benefits between consumers and producers. The size of total benefits accruing from a research innovation will vary according to the type of shift in the supply curve (under the assumptions of a linear supply and demand schedule). Three types of shifts are considered in addition to a parallel shift—pivoted, proportional and convergent. Besides altering the total level of benefits, the type of shift will also influence the distribution of benefits between producers and consumers. Relative to a parallel shift, producers will gain more with a convergent shift and less with a pivoted or proportional shift, and vice versa for consumers.

One of the most important points for concern in this area of research is the concentration on measuring productivity gains through
shifts in the supply curve. Wisecarver has demonstrated that, except in the special case of fixed proportions, this technique will understate the gains, and that the input-demand technique gives the proper framework. In the case of variable input proportions, output supply analysis omits the loss (gain) in welfare due to substitution of inputs in production. The substitution effect, corresponding to the efficiency in production gain is obviously a welfare gain.

However, even among those workers using the supply-shift technique there has, as Scobie (1976) pointed out, been little attention to the results which may come from different specifications of the supply and demand curves and the formulae for consumers' and producers' surplus derived from them.

Scobie showed that the different formulations used give different, even contradictory, results. (It would be extremely difficult to reconcile the different mathematical approaches used by different authors.) However, inspection shows that, other than the difference in elasticity formulation mentioned above, the other major differences in approach between the several authors are in the specification of the shift of the supply curve and the different initial conditions adopted. It is not obvious (for that reason) that the different formulations should be questioned or condemned because they give different and often contradictory results. The right question is what is the appropriate supply and demand specification for the problem at hand? There is an obvious necessity for standardisation of mathematical approaches to the specification of the formulae. These same comments would apply when the input-demand approach to the measurement of gains is used.
The important point which emerges from the recent studies on the allocation of the gains between consumers and producers is that the conventional wisdom does not apply universally. It has been argued previously, mainly by reference to the situation in the U.S. market, that consumers are the primary beneficiaries of agricultural research and producers gain little. However, in countries where it is appropriate to make the "small country" assumption about exports of agricultural products, producers are shown to be the major gainers.

The study by Schmitz and Seckler on the distribution of producers' surplus among factors, in which they primarily concentrated on the returns to labour, was shown to be subject to critical comment on important parts of the study. The major area for further work in this kind of study concerns the estimation of the adjustment costs imposed on labour by technological change. It was argued that Schmitz and Seckler had taken a very extreme and simplistic view of this central part of their study.

Schmitz and Seckler estimated the amount of compensation needed to make labour as well-off as previously on the basis of a fixed, institutionally fixed wage. This assumption involves a number of other unreasonable assumptions: that labour is automatically rendered unemployed by labour-displacing innovations. It was argued that it is reasonable to expect that new forms of employment will be created in those industries and that firms will train displaced labour for these positions.

Rather than calculating compensation on the basis of the unemployed forever remaining unemployed, it was suggested that the
problem should be looked at in terms of labours' expected life-time earnings; taking into account the likely occurrence of workers changing jobs several times during their working life - involving with each change the possibility of different incomes being earned.

Finally, it should be pointed out that this whole area of work has implications for other areas of economic analysis - particularly in the area of industry protection. In this area the same problems of the distribution of gains (losses) between producers and consumers arise. So the same techniques should be applicable.
BIBLIOGRAPHY


