The Impact Of Technological Change On the Scarcity Of Land[*]

by

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Abstract

The relationship between productivity growth and the price of land is analysed to provide evidence on how new technology influences the level of land degradation and the scarcity of land. It is found that the impact that technological change has on land prices depends critically on the factor bias in the change and the price elasticity of demand for the output. With an inelastic output demand curve and/or a substantial land saving bias, technological change can depress land prices, produce long run losses for farmers and increase the likelihood of higher rates of land degradation.

1. Introduction

The literature surrounding the controversy of what productivity growth actually means has, in the main, failed to address fundamental questions about the source of measured productivity growth and its implications for long-run stocks of environmental resources and the well-being of society as a whole. Specifically, there has been little analysis of the extent to which the achievement of short run productivity growth in agriculture is, and has been, at the expense of the stock of environmental resources. This issue is potentially implicated in adverse environmental consequences such as dry land salinity, toxic chemical residues and broadacre erosion.

Although some recent economic growth/development literature dealing with developed countries has focused on the relationship between technical change and the environment (for example see Coxhead and Jayasuriya (1992) and Ehui and Spencer (1990)) the issue has hardly been addressed in the economics literature in Australia at all.

Where productivity and the environment have been considered in the Australian literature, it has generally been in the context of the relative impacts of environmental degradation and productivity growth on actual and potential production. For example Clarke et al (1990) evaluated the extent to which soil degradation had reduced the value of agricultural output and the degree to which these reductions were offset by productivity growth. While they found that the value of productivity growth far out-weighed the value of soil degradation in Australian agriculture they did not explicitly consider the extent to which productivity growth had been associated with the aggravation or amelioration of soil degradation. Similarly, little consideration was given to whether the extent of the degradation was justified or optimal in a social welfare sense.

One way of analysing the issue of how productivity growth effects the soil degradation is to examine the relationship between productivity growth and land prices. Land prices are a key indicator of the incentive farmers have to conserve or degrade soil because the physical area of land and soil quality (measured in terms of productive potential) are alternative inputs in the production process. In the long run the costs of expanding output through land purchase and improvements in soil quality will be equated at the margin.

Increases in land prices, due to factors other than soil quality, act as a positive incentive for farmers to improve soil quality. In this case farmers at the margin will find it more profitable to improve soil quality rather than expand the area of land. Similarly, if land prices fall the profitability of improving soil quality will fall in comparison with the option of purchasing more land. The expected outcome would be a reduction in the incentive for farmers to improve soil quality.

Changes in land prices are also an important indicator of the actual implications of soil degradation because they reflect trends in the economic scarcity of soil. The notions of natural resource scarcity analysed by Barnett and Morse (1968) and Smith (1980) can be applied to agricultural land and soil as well as minerals and forestry resources. In the area of soil degradation however, there has been a concentration on physical scarcity rather than economic scarcity. This gives a potentially misleading picture of the economic implications of soil degradation as there is no reason why reductions in physical availability of soil due to degradation should be matched by an increase in the economic scarcity of soil.

In the face of soil degradation the economic scarcity of soil could rise, fall or remain unchanged depending on what happens to the demand for soil. Discussions of soil degradation in terms of the cost of repair, the value of lost production and inches of soil lost focus on the supply side of the issue. An analysis of changes in the economic scarcity of soil involves an examination of both the demand and supply side of the soil market. As such it shows the extent to which the level of soil is a constraint on society's agricultural production ambitions.

An analysis of the relationship between productivity growth and land prices is also potentially useful because it should provide an indication of the overall return to land owners (mainly farmers) from research and development in the long run.

In the second section of this paper a general analytical model of the relationship between the stock and quality of agricultural land and the pattern and the extent of technological change is developed. The implications of assumptions concerning the values of basic market parameters such as the price elasticities of supply and demand for agricultural output are also investigated. The model is used to explore the impact of neutral and biased technological change on land prices in sections 3 and 4.

The implications of the degree of substitutability between land area and soil quality are briefly analysed in Section 5 while the policy implications of this study are addressed in the final section.

2. Analytical Model Of The Relationship Between Technological Change And Soil Degradation

2.1 Conceptual Framework

The relationship between productivity growth and soil degradation in the wool industry is multi-faceted. It is a complex relationship with productivity growth reflecting the interaction between technological change and all production inputs, including soil, within the production process.

Lopez (1988) has shown that the fruits of technological change in agriculture will ultimately be reflected in lower output prices and/or changes in land prices. Rising land prices represent gains to the owners of agricultural land while falling output prices represent gains to the consumers of agricultural products. In a study of the impact of technological change in USA agriculture for the period 1950 to 1980 Lopez (1988) found that technological change had reduced the intensity with which land was used relative to the other production inputs. The net effect of this technological change, measured in a one-product model, was to depress both land and farm output prices.

In the large country case, land saving technological change is associated with falling output prices while land using change tends to produce higher land prices. In Lopez's terms, land using technological change results in the share of land in the total value of output rising. It involves the direct quantity effect plus an induced price effect.

This view of biased change is consistent with the change in factor market equilibrium that results from technological change. In terms of a conventional isoquant diagram (see Figure 1) the direct quantity effect is represented by a non-parallel, downward shift in any production isoquant from I to I*. Note that L* indicates the fixed level of land available to the industry.

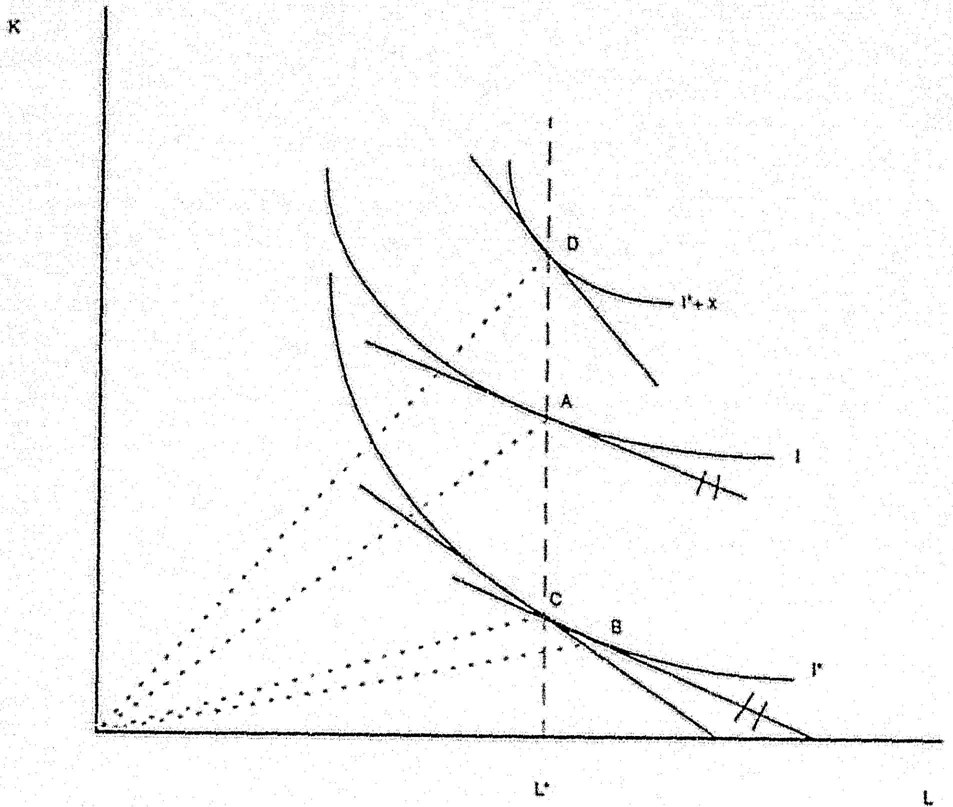
The case portrayed is consistent with land using technological change as it is conventionally defined in a Hicksian sense with the downward shift on the land axis being greater than the shift on the other input axis. In the absence of any changes in output levels or factor prices the optimal production point would tend to shift from A to B. The intensity with which land is used in the production process would be higher as reflected in the flatter factor ray (OB compared with OA).

The Lopez price effect depends on two impacts. The first is the extent to which technological change shifts the factor demand curves and the responsiveness of factor demand and supply to the resulting factor price changes. (The shift from B to C in Figure 1.) The second is the extent to which the technological change results in lower output prices and higher output levels. (The shift from C to D.) This is determined by the elasticity of demand for output.

The direct quantity effect and price effect need not be in the same direction. Consequently, a direct change which is land saving could be more than offset by the price effect, producing a net increase in the share of land in the value of total output. In this case the initial impetus towards an increase in the intensity with which land is used (A to B) has induced further changes in factor intensity through changes in the output and factor markets (B to C plus C to D). The net effect is that a change that is land using in the conventional sense has resulted in a decline in the intensity with which land is used in the production process.

Lopez's model is important for two reasons. Firstly, it highlights the importance of looking beyond the direct or partial impact of a change to consider the total equilibrium impacts. Secondly, it demonstrates the critical role that technological change can have in land markets, and by implication, soil management decisions.

To avoid confusion Lopez's definition of bias in technological change will not be used in this study. Bias in technological change will be defined in the conventional Hicksian sense.



A to B direct effect

B to C Increase in Price of L due to fixed L

C to D Increase in Price of L due to increase in output

Figure 1

Impact of Technological Change on the Price of Land: Land Supply Fixed

2.2 A Comparative Static Model

A simple analytical model can be used to cast some intuitive light on the relationships Lopez has highlighted. For the purposes of exposition the markets involved in the system are assumed to be perfectly competitive and output is assumed to be measured by one aggregative variable. The price (P) and quantity of agricultural output (Q) are determined by solving the following demand and inverse supply equations.

$$Q_D = f + d * P \quad (1)$$

$$P = b + c * Q_S \quad (2)$$

The parameter b in the inverse supply equation represents an exogenous shift in the industry cost function. In this analysis the shift is assumed to be a reflection of cost reducing technological change. The slope coefficient in the demand equation (d) is assumed to be negative, while the supply equation slope coefficient (c) is assumed to be positive.

Three inputs, land (L), soil quality (SQ) and other inputs (K), can be combined to produce one output (Q) in the following production function which will be assumed to be homogenous.

$$Q = Q(K, SQ, L) \quad (3)$$

The three input model was specified to maximise the insight into the land management decision while keeping the model within the bounds of tractability and comprehension. The quantity of land used in agriculture is assumed to be less than perfectly elastic while the supply of K is assumed to be perfectly elastic. Changes in the level of soil quality reflect changes in the level of soil degradation. Improvements in soil quality are equivalent to reductions in soil degradation. Finally, SQ and L are assumed to be complementary inputs. (The implications of this last assumption are discussed later in Section 5)

The marginal products of the three inputs are derived from the underlying production function.

$$\frac{dQ}{dL} = MP_L \quad (4)$$

$$\frac{dQ}{dK} = MP_K \qquad (5)$$

$$\frac{dQ}{dSQ} = MP_{SQ} \qquad (6)$$

The input and output markets are in equilibrium and the following conditions hold.

$$MP_L * P = P_L \qquad (7)$$

$$MP_X * P = P_K \qquad (8)$$

$$MP_{SQ} * P = P_{SQ} \qquad (9)$$

$$P = MC \qquad (10)$$

Where: P_L = price of land
P_X = price of other inputs
P_{SQ} = shadow price of soil quality
MC = marginal cost

The price of land and soil quality, the level of soil quality, the quantity of other inputs and the price and quantity of output are all assumed to be endogenous. The exogenous parameters are the price of other inputs (P_X) and level of land which are held constant, and the rate of cost reducing technological change.

The competitive equilibrium position is characterised by the following marginal condition.

$$\frac{MP_L}{P_L} = \frac{MP_{SQ}}{P_{SQ}} = \frac{MP_X}{P_K} = \frac{1}{MC} = \frac{1}{P} \qquad (11)$$

The simple diagrammatic representation of this conceptual model is presented in Figure 2. Part (a) represents a segment of the production surface while Part (b) shows the product market. The factor markets are summarised in Parts (c), (d) and (e).

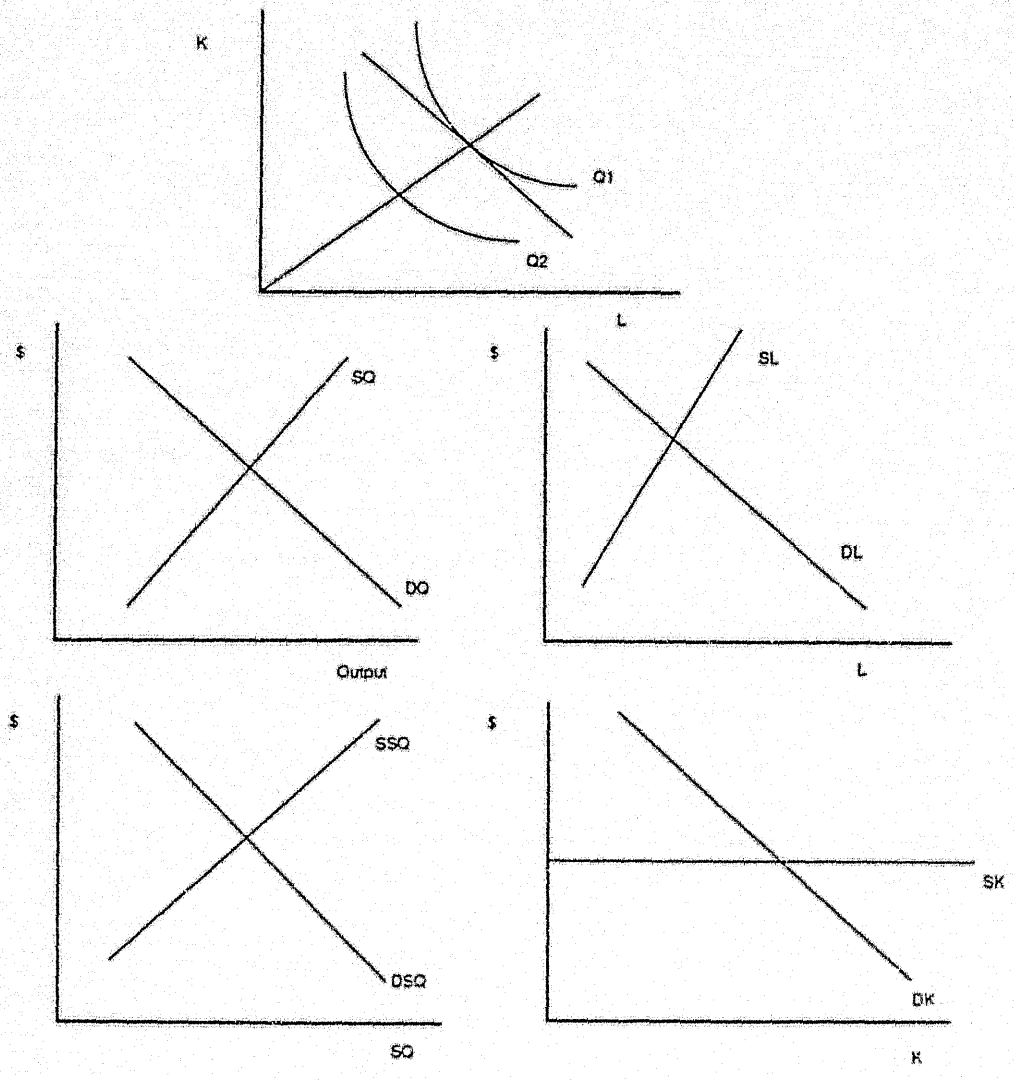


Figure 2
A Factor Market Based Model

This model allows the relationship between productivity growth and the stock of environmental assets used in wool production to be positive, negative or neutral. Similarly, the impact of the process of soil degradation (or conservation) on production is not constrained in any one direction. Soil degradation could increase, decrease or have no effect on wool production depending on the particular conditions being considered.

It is explicitly assumed that changes in the level of soil quality is the net result of soil degradation and conservation processes within the industry. (For purposes of clarity of exposition the production surface is represented in Panel A in terms of two rather than three inputs. This is consistent with the third input (SQ) being used in fixed proportions with L. This simplification relates to the diagrams only and is not imposed on the analysis in the following sections.)

3 Neutral Technological Change

Hicks neutral technological change would result in an equi-proportional increase in the marginal products of all production inputs. This form of technological change would include a substantial part of the technology that is embodied in improved managerial capability. As such it is dependent on the level of public and private investment in farm management training.

The case is illustrated in Figure 3. Prior to the introduction of the new technology firms were operating at point A on the Q unit isoquant. The new neutral technology effectively shifts the isoquant back to Q'. In the absence of any changes in P_L/P_K if firms choose to continue to produce Q output they will now find it optimal to operate at B, using less of all inputs. However, as a result of the technological change the profit maximising level of output is likely to change.

If production is held constant, proportional increases in the marginal products of the inputs would lead to a proportional fall in the level of marginal cost, no change in P and a reduction in the use of L, SQ and K. If c and d are non-zero and of the expected sign, these changes will result in the following disequilibrium.

$$\frac{MP_L}{P_L}=\frac{MP_K}{P_K}=\frac{MP_{SQ}}{P_{SQ}}=\frac{1}{MC}>\frac{1}{P} \qquad (12)$$

To bring the system back into equilibrium, and maximise profits,

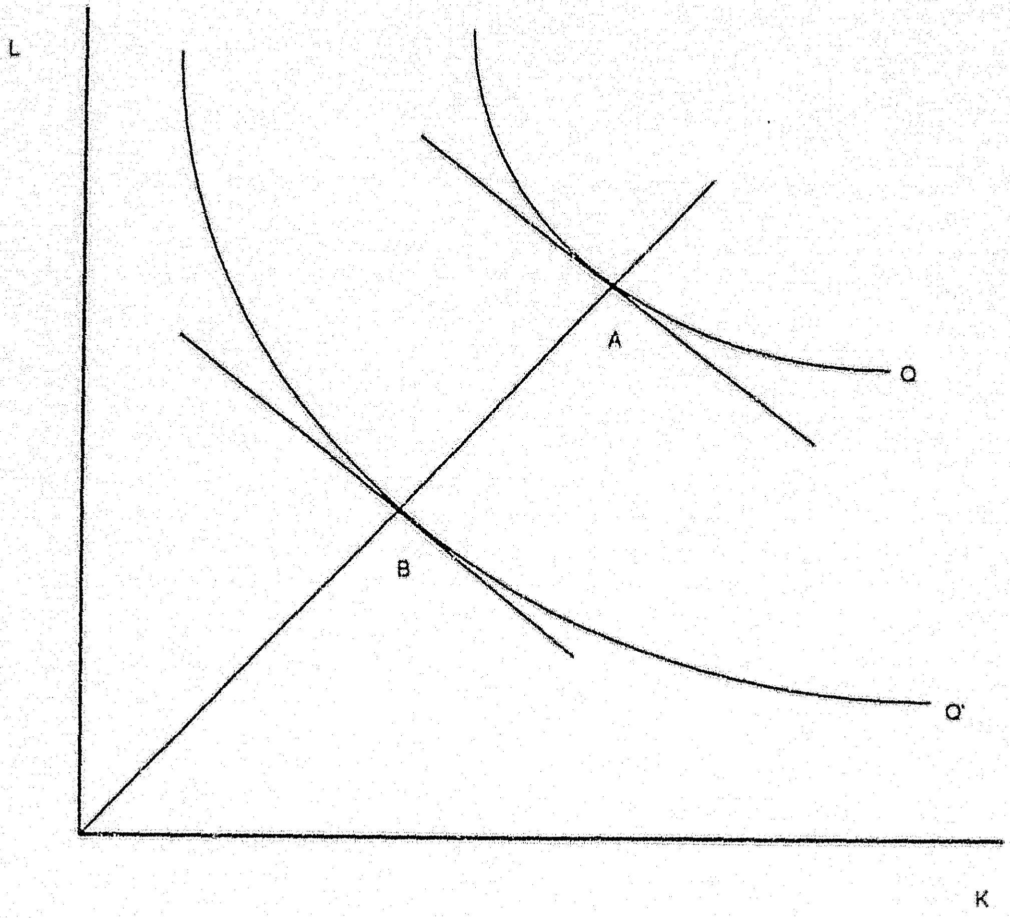


Figure 3

Neutral Technological Change With A Fixed Output producers will expand production, and therefore the demand for all inputs. The price of output will fall, the marginal product of K will fall, the marginal products of L and SQ will fall and/or the prices will increase, and the marginal cost will increase, moving the market back towards equilibrium.

Whether the use of L and SQ will be higher as a result of the technological change depends on the relative magnitudes of the first round reduction in L and SQ and the subsequent expansion in factor demand as output is increased to the new equilibrium level. Given that the reduction in costs between A and B in Figure 3 will be directly proportional to the reduction in inputs the issue effectively reduces to two empirical questions. The first concerns the size of the percentage fall in costs due to the new technology relative to the resultant percentage increase in equilibrium agricultural output while the other involves the returns to scale exhibited by the production process.

Cost Elasticity of Output

The responsiveness of output to changes in production costs can be expressed in general terms through manipulation of Equations 1 and 2. In the case where the cost reductions result in a parallel shift in the industry supply schedule, the responsiveness can be measured as the elasticity of equilibrium quantity with respect to the intercept term of the supply curve.

$$\frac{dQ}{db} = \frac{-1}{c+d'} \qquad (13)$$

Where $d' = 1/d$

From 13 the following elasticity can be derived.

$$\frac{dQ}{db} \cdot \frac{b}{Q} = -\left[\frac{a}{Q(c+d')}\right] \qquad (14)$$

Equation 14 can be rearranged to yield the general condition of the elasticity in terms of supply and demand elasticities.

$$E_b = -\left[\frac{\frac{b}{P}}{\left(\frac{1}{E_S}+\frac{1}{E_D}\right)}\right] \qquad (15)$$

The terms E_S and E_D refer to the price elasticities of supply and demand for output respectively. Equation 15 confirms the intuitive expectation that the greater the sum of the supply and demand elasticities and the higher the value of P relative to Q, the more likely it is that a reduction in the intercept term will result in an expansion in the demand for the factors of production.

If the output demand curve is perfectly inelastic, the denominator approaches infinity and the value of E_b approximates zero. At the other extreme, a perfectly elastic output demand curve would mean that E_b can be further reduced to the following.

$$E_b = \frac{b}{Q} \times \frac{dQ}{dP} \qquad (16)$$

Equation 16 shows that with a perfectly elastic demand curve the value of E_b is dependent on the basic properties of the product supply schedule.

Where the technology is characterised by a pivotal shift in the supply curve the responsiveness of output to changes in technology can be measured as the elasticity of equilibrium quantity with respect to changes in the equilibrium marginal cost (or output price). Using equations 1 and 2 it is possible to derive terms for dQ/dc and dP/dc. Dividing the first term by the second term, multiplying the result by P/Q and multiplying the numerator and denominator by 1/P, yields the following term for the cost elasticity of output.

$$E_b = -\left[\frac{1}{\frac{1}{E_S} + \frac{1}{E_D}}\right] \qquad (17)$$

The notion that the impact technology will have on farmers is dependent on the extent to which the resultant cost reductions translate into higher output levels is certainly not new. For example, in evaluating the impact of pasture improvement on the wool industry Gruen (1960) drew a distinction between output expanding and cost reducing technology. His two categories can be interpreted as referring to cases where E_b is greater than one and less than one respectively.

Returns to Scale

The relationship between returns to scale, cost elasticity and the demand for land following cost-reducing technological change is summarised in Table 1. If the production system is characterised by constant returns to scale the impact of neutral technological change on the demand for factor inputs can be derived directly from the value of the cost elasticity of output. If the elasticity is less than one the technology will reduce the demand for inputs. The reduction in factor demand due to lower

Table 1

Short Run Impact Of Neutral Technological Change On The Demand For Land

		Value of Cost Elasticity of Output		
		<1	1	>1
Returns To Scale	Decreasing	?	+ve	+ve
	Constant	-ve	-	+ve
	Increasing	-ve	-ve	?

costs will more than outweigh the demand expanding influence of increased output. If the elasticity is greater than one the change will tend to increase demand for inputs while factor demand will not change if the elasticity is equal to 1.

In general terms the lower the returns to scale and the higher the cost elasticity of output the more likely it is that cost reducing technological change will increase the demand for the factors of production. For example, when the cost elasticity is greater than 1, the demand for factors will increase following neutral technological change as long as the production system is characterised by decreasing or constant returns to scale. If convexity is assumed to hold for the system of equations (which in part implies that the returns to scale are non-increasing) the demand for inputs will not fall unless the cost elasticity is less than 1.

Where the effective quantity of land can be varied, the net short run effect of neutral technological change will be changes in both land prices and levels of the land input. If land is held fixed the impact on land would be completely reflected in changes in land prices. The impact on soil quality could be expected to be reflected in changes in both the shadow price and equilibrium level of soil quality and, under the assumptions made, the changes would be consistent with the impact of technology on the demand for land.

4 Biased Technological Change

4.1 Land Saving Technological Change

If the marginal product of K rises relative to the marginal product of L and SQ the technological change can be classified as land saving. An improvement in crop and pasture species would be an example of this form of technological change while the production of superfine wool from sheep the are permanently housed would be the extreme version of land saving technology in the wool industry.

The general case with exogenous factor prices is illustrated in Figure 4 (SQ is again excluded from the diagram for expositional purposes). The Q unit isoquant shifts from Q to Q'. In the absence of a change in relative input prices there will be a tendency for the L/K and SQ/K ratios to decline, with L and SQ falling relative to K. Reductions in the level of L and SQ will tend to increase MP_L/P_L and MP_{SQ}/P_{SQ}. The levels of L and SQ would fall until a point of tangency is achieved on the relevant isoquant. That is, until the change in MP_L/P_L and MP_{SQ}/P_{SQ} is equal to the technology induced change in MP_K. If the level of L is fixed the increase in MP_L/P_L would be achieved entirely through

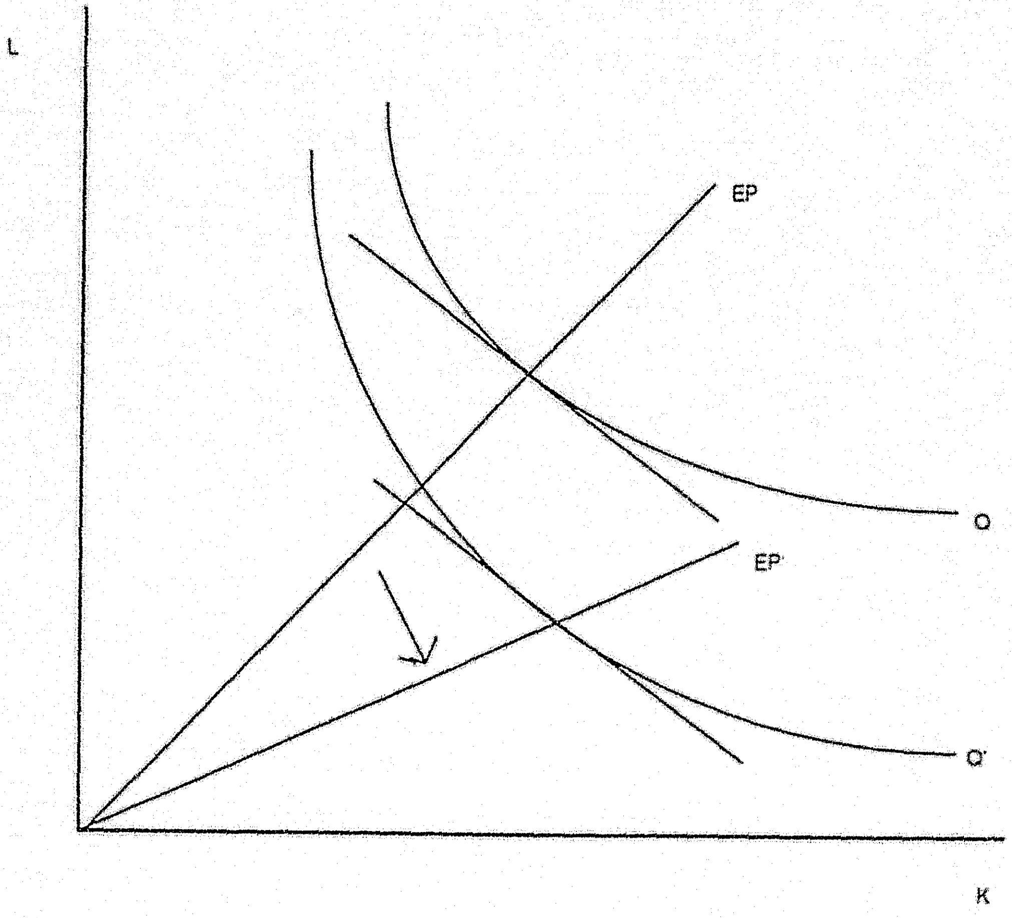


Figure 4

Land Saving Technological Change With A Fixed Output reductions in the price of land. These input changes would place the market in the following disequilibrium.

$$\frac{1}{P} < \frac{1}{MC} = \frac{MP_K}{P_K} = \frac{MP_L}{P_L} = \frac{MP_{SQ}}{P_{SQ}} \qquad (18)$$

Profit maximising behaviour will result in an expansion in output and a resultant second round increase in the use of all factors. The expansion in output would tend to reduce P, MP_L/P_L, MP_{SQ}/P_{SQ} and MP_K/P_K and increase MC, bringing the market back into equilibrium.

Therefore, land saving rather than neutral technological change, increases the likelihood that technological change will decrease demand for land due to the presence of the initial substitution of K for L and SQ. Where the values of the elasticities and returns to scale were consistent with negative results under neutral change, land saving change can be expected to accentuate that tendency. If the parameter values were consistent with a positive land demand response with neutral change , land saving change would result in an indeterminant impact. Finally, if the production system exhibited constant returns to scale and both the cost and price elasticities were unitary, the introduction of land saving technological change would tend to reduce the demand for land.

The demand for K will tend to increase more with land saving technological change than with neutral technological change.

4.2 Land Using Technological Change

Technological change is land and soil quality using if it results in the marginal products of land and soil quality rising faster than the marginal product of other inputs. Land using technology would include new technology that is embodied in other factors of production that are complementary with land such as the introduction of large scale cultivation equipment in the cropping industry.

The impact of this type of change on the demand for L and SQ is the same as the impact of land saving change on the demand for K. Where the returns to scale are non-increasing and the cost and price elasticities are both non-negative, the demand for L and SQ will increase.

This case is illustrated in constant output terms in Figure 1. The introduction of the new technology shifts the isoquant from I to I'. In the absence of any change in the factor markets the least cost production point will tend to shift from A to B. However, point B is in an infeasible region as it involves the use of more L than is available to the industry. The tendency towards increased use of L will be translated into a higher level of demand for L which in turn will be totally reflected in higher land prices if the level of L is fixed. The new feasible least cost production point will be equivalent to point C.

5 Substitutability Between Land and Soil Quality

In the preceding analysis it was assumed that land and soil quality are complementary inputs in the sense that the marginal product of one input is positively related to the level of the other input. Under this assumption a change which increases the demand for land will also increase the demand for soil quality and so result in soil improvement. However, this need not be the case. Technological change can change the L/SQ ratio just as it can change the L/K ratio.

Land using\soil quality saving change would involve an extensification of production with stock being run on larger properties at lower stocking rates with less labour inputs. This is consistent with a move towards a low input grazing system.

On the other hand, a soil quality using\land saving change represents an intensification of production. It could take the form of technology that increases the returns from any given level of soil quality. This would improve the attractiveness of soil improvement as opposed to land purchase as a means of expanding production. The current research into high phosphate-high stocking rate sheep grazing systems for sheep production in high rainfall zones is an example of this form of technology (see Saul and Cayley 1992).

With soil quality using\land saving change, the demand for soil quality and the level of soil quality will tend to be higher than with a neutral change while the demand for land will tend to be lower. The opposite will be the case with land using\soil quality saving change. This type of technological change would tend to increase the likelihood of soil degradation occurring.

6. Concluding Comments

The impact that technological change will have on agricultural land depends on the nature of the technology involved and values of the cost elasticity of output, the price elasticity of demand

and the nature of returns to scale.

Technological change could lead to conservation or degradation depending on the impact it has on the demand for soil quality. The short run impact could be reinforced or offset by longer run adjustments to normal profit levels.

It was found that the magnitude of the price elasticity of demand for output was a critical factor in determining the direction of the impact of technological change on land prices. When the technological change was Hicks neutral, it could generally be to expected depress land prices when the price elasticity of demand for output was less than one. The exception to this is when the function coefficient is substantially greater than one.

This conclusion did not hold when the assumption of Hicks neutrality was relaxed. It was found that with land using technological change, land prices could increase even if the industry was characterised by an inelastic demand for their output.

The sensitivity of the land market to technological change was found to be negatively related to both the magnitude of the elasticity of substitution between the factors of production and the price elasticity of supply for the land input.

Overall these results suggest all research and development has the potential to have an impact on the incentive farmers have to conserve and improve land. Moreover, it would appear that it is possible for research agencies to identify the general nature of the impact given knowledge of the basic features of the industry concerned and the nature of the factor bias engendered in the proposed technology. This is potentially important because funding agencies and Government are becoming increasing concerned with the environmental impact of both their funding initiatives and farm management practises.

The results of this analysis also suggest that research agencies need to interpret analyses of the benefits of research that are based on the summation of changes in short run producer and consumer surplus values with some caution. These analyses generally assume parallel shifts in supply schedules and so exclude the possibility that farmers in general can lose from the introduction of new technology. It would appear that in industries such as the wool industry, grower representatives on funding committees should be cautious in endorsing new research that is likely to lead land saving technological change.

Furthermore, woolgrowers should be concerned by Lopez's findings on the overall impact of agricultural research in the USA. If Lopez is correct many of the gains claimed by research and extension agencies may be only short term in nature and could be eroded substantially market forces in the longer term.

The analysis in this paper did not explicitly extend to technology that takes the form of changes in conservation practices or tools to ameliorate the impact of soil degradation. A consideration of this form of technology would require an even more disaggregated factor market model than has been proposed here. In particular, the supply and demand for soil quality would need to be explicitly modelled. The supply function for soil quality would represent the marginal cost of conservation while the demand function reflects the value of marginal damage costs. Empirical information on the nature of these areas is even more scarce than information on the nature of the aggregate land market.

Finally, the value of basic market parameters such as the price elasticity of demand for output are critical in understanding the impact of technology on the price of land in the grazing industry. In the case of wool, the value of these parameters are far from clear. Despite decades of research on elasticities of demand there is no consensus on the general magnitude of price elasticity of demand for wool in the long run. The analysis in this paper highlights the need for further work in clarifying the value of basic market parameters.

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