PRODUCTION FLEXIBILITY REVISITED

by

Denis Lawrence and John Zeitsch*

Industries Assistance Commission
Canberra, Australia

Contributed Paper to the Thirty-third Conference of the Australian Agricultural Economics Society, Christchurch, New Zealand, 7-9 February 1989.

*Luan Tran provided valuable assistance in preparing the data as did Doreen Barnes and Roberta Wise in preparing the manuscript. The views expressed in the paper do not necessarily represent those of the Industries Assistance Commission.

1 INTRODUCTION

With the continuing secular decline in the rural sector's terms of trade and changes in relative output and input prices it is important to have a good understanding of the rural sector's flexibility in adapting to changing circumstances. Information on the ease with which the output mix can be altered, the intensity with which different outputs use the various inputs and the scope for substituting between inputs is crucial to assessing the effects of price and policy changes. Productivity improvements have also been an important means of adjustment by the rural sector to adverse price movements. Knowledge of recent productivity performance is consequently important for forecasting the future viability of the rural sector. The aim of this paper is to present information on these aspects of rural production response using a new, up-to-date data set and taking advantage of recent econometric developments.

Most early econometric studies of rural production response concentrated on either the supply of a particular output (Malecky 1975) or the relationship between various inputs (Vincent 1977; McKay, Lawrence and Vlastuin 1980). Much of the analysis of the effects of policy and price changes in Australian agriculture has been undertaken using linear programming models such as APMAA (Wicks and Dillon 1978) or the relatively large ORANI general equilibrium model (Dixon, Parmenter, Sutton and Vincent 1982). While the ORANI model allows for a large degree of disaggregation, its agricultural sector is based on the restrictive CRESH/CRETH specification (Vincent, Dixon and Powell 1980; Adams 1987). This specification allows for joint production but assumes that no input has a comparative advantage in the production of any output.

The first econometric studies of Australian agriculture to allow for flexible production relationships between outputs and inputs were the profit function studies of McKay, Lawrence and Vlastuin (1982, 1983). In these studies the parameters of translog variable profit functions were derived from BAE Australian Sheep Industry Survey data to examine the production relations between 3 outputs, 2 variable inputs and 3 fixed inputs. More recently, the BAE has developed the EMABA econometric model which attempts to separate livestock output and inventory responses (Dewbre, Shaw and Corra 1985). In spite of the differing methodologies and data sets used in these studies, a general finding is that Australian agriculture is relatively inelastic in its price responsiveness. This contrasts with recent overseas work which has found a high degree of price responsiveness in agriculture (Hertel 1988). Selected own-price elasticities from previous Australian studies are presented in Table 1.

TABLE 1 : SELECTED ESTIMATES OF OWN PRICE ELASTICITIES IN AUSTRALIAN AGRICULTURE

Study	Wool/ Sheep	Wheat/ Crops	Cattle/ Other	Labour	Materials + Services	Land	Capital	Livestock input
McKay, Lawrence and Vlastuin (1980)				-0.67	-0.98	-0.19	-1.22	-0.19
Wicks & Dillon (1978)	0.25	1.10	0.69					
Vincent, Dixon and Powell (1980)[a]	0.25	0.77	0.48					
Adams (1987)	0.46	0.74	0.70					
McKay, Lawrence and Vlastuin (1983)	0.72	0.50	0.12	-0.47	-0.10			
Dewbre, Shaw and Corra (1985)	0.39	0.92	0.34					

a Relates to the Wheat/Sheep Zone.

This paper builds on the work of McKay, Lawrence and Vlastuin (1982, 1983) and applies the techniques outlined in Lawrence (1988). A profit function model is estimated utilising pooled cross-section, time-series data derived principally from the Australian Bureau of Statistics' Agricultural Finance Survey covering 6 states and 8 years in the period 1972-73 to 1986-87. The data are discussed in detail in the Appendix. The recently developed Generalised McFadden (GM) functional form is used to estimate a variable profit function with 2 outputs (crops and livestock), 5 variable inputs (hired labour, capital, land, materials and services, and livestock) and one fixed input (operator and family labour). Use of the GM form has significant benefits in that curvature can be imposed on the estimated parameters without loss of flexibility. It also makes the use of aggregator functions more feasible to obtain a greater degree of detail. In this study an aggregator function is used to divide the materials and services category into four components (services, fertilisers and chemicals, fuel and electricity, and seed and fodder).

In the following section of the paper indices of total factor productivity are derived from the data and discussed. The profit and aggregator function methodology is then outlined in Section 3 and the results presented in Section 4. Finally, conclusions are drawn in Section 5.

2 PRODUCTIVITY CHANGES IN AUSTRALIAN AGRICULTURE

Productivity improvement has been an important means of adjustment by the rural sector to a long-term decline in its terms of trade (the ratio of prices received to prices paid). If prices paid are increasing faster than prices received then for a given production technology returns to fixed factors such as owner-operator labour will fall as will output. These effects can be compensated for by producing more output from each unit of input (ie. increasing productivity). Lawrence and McKay (1980) found that over the period 1952-53 to 1976-77 the Australian Sheep Industry increased its total productivity at an average annual rate of 2.9 per cent in the face of an average annual decline in the terms of trade of 4.1 per cent. In this section the Agricultural Finance Survey data is used to calculate indices of output and input quantities and prices from which indices of productivity and the terms of trade are derived.

Value shares of outputs and inputs are presented in Table 2. The output shares indicate that there has been a considerable change in the emphasis of production over the 15 year period examined in this study. Cropping has increased in importance from accounting for one quarter of revenues to accounting for approximately 40 per cent. Livestock revenue has conversely declined in importance. This change is reflected on the input side where the share of livestock inputs in total cost has halved over the period. The cost shares of materials and services, and land (subject to some fluctuation) have increased while those of hired labour and capital have remained relatively constant.

TABLE 2 : OUTPUT AND INPUT SHARES OF AUSTRALIAN AGRICULTURE: 1972-73 TO 1986-87

	Output Shares		Input Shares				
Year	Crops	Livestock	Hired Labour	Capital	Land	Materials & Services	Livestock
1972-73	0.25	0.75	0.13	0.06	0.19	0.44	0.18
1973-74	0.30	0.70	0.14	0.05	0.20	0.42	0.20
1974-75	0.48	0.52	0.16	0.05	0.23	0.46	0.09
1975-76	0.49	0.51	0.16	0.06	0.24	0.48	0.07
1976-77	0.48	0.52	0.14	0.07	0.24	0.47	0.08
1977-78	0.39	0.61	0.14	0.07	0.25	0.45	0.09
1980-81	0.44	0.56	0.11	0.06	0.28	0.44	0.10
1986-87	0.40	0.60	0.13	0.06	0.20	0.51	0.10

While the changes in value shares indicate that there has been considerable change in Australian agriculture over this period, in order to assess improvements in the efficiency of production it is necessary to obtain aggregated quantity measures. The Divisia index technique of the SHAZAM package (White 1978) has been used to aggregate quantities of individual outputs and inputs into the two output and five input categories utilised and across States to form indices for Australia as a whole. The advantages of the Divisia index technique are well known. Briefly, these include being based on the homogeneous translog production function (Diewert 1976), approximate consistency in aggregation and the use of moving average share weights which avoids the traditional "index number problem".

The increased production of crops is particularly evident in Table 3 where output quantity indices are presented. Crop output has doubled over the period while livestock output has remained relatively static (after a decline bottoming out in 1975-76). Total output quantity has increased over the period at an average annual rate of 3.1 per cent while total prices received have increased at a rate of 6.0 per cent.[1]

Input usage, on the other hand, has actually declined over the period (Table 4). Livestock input quantity has declined the most, followed by capital and land inputs. Hired labour, and materials and services input quantities have fluctuated but remained at approximately the same level at the end of the period as at the beginning. Overall, total input usage declined at an average annual rate of 0.3 per cent. Total prices paid, however, showed a rapid rate of increase of 10.6 per cent.

TABLE 3 : OUTPUT QUANTITY INDICES

Year	Crops	Livestock	Total Output	Total Prices received
1972-73	1.000	1.000	1.000	1.000
1973-74	0.755	0.934	0.881	1.299
1974-75	1.041	0.922	0.990	1.061
1975-76	1.190	0.888	1.036	1.067
1976-77	1.499	0.893	1.162	1.112
1977-78	1.102	0.914	1.029	1.200
1980-81	1.395	0.901	1.127	1.946
1986-87	2.061	1.103	1.493	2.250

TABLE 4 : INPUT QUANTITY INDICES

Year	Hired Labour	Capital	Land	Materials & Services	Livestock	Total Inputs	Total prices paid
1972-73	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973-74	1.098	1.012	0.989	0.992	1.018	1.012	1.185
1974-75	0.936	0.835	0.992	0.841	0.805	0.880	1.331
1975-76	0.894	0.923	0.987	0.839	0.709	0.867	1.529
1976-77	0.797	0.968	0.960	0.798	0.689	0.827	1.715
1977-78	0.768	0.982	0.955	0.756	0.736	0.808	1.895
1980-81	0.860	1.026	0.961	0.912	0.709	0.891	3.054
1986-87	0.970	0.890	0.899	1.007	0.873	0.944	4.304

1 Average annual rates of change are calculated by regressing the log of the relevant variable on a time trend.

FIGURE 1 : TOTAL OUTPUT AND INPUT QUANTITIES IN AUSTRALIAN AGRICULTURE : 1972-73 TO 1986-87

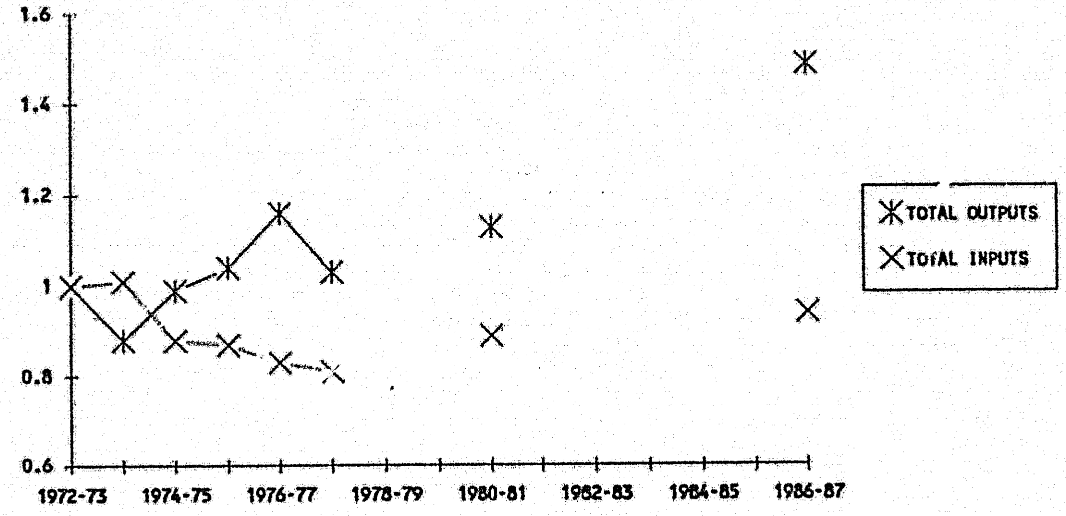


FIGURE 2 : TOTAL PRICES RECEIVED AND PRICES PAID INDICES FOR AUSTRALIAN AGRICULTURE : 1972-73 TO 1986-87

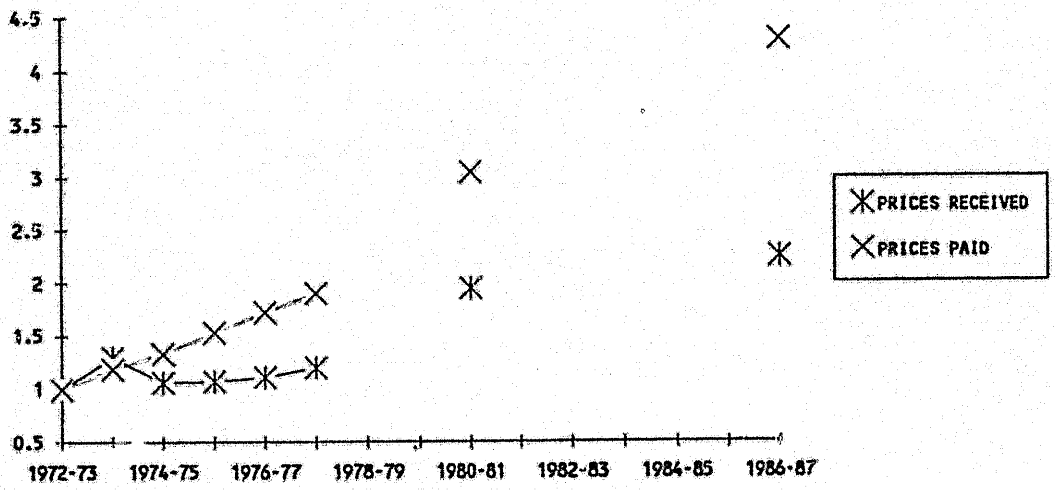
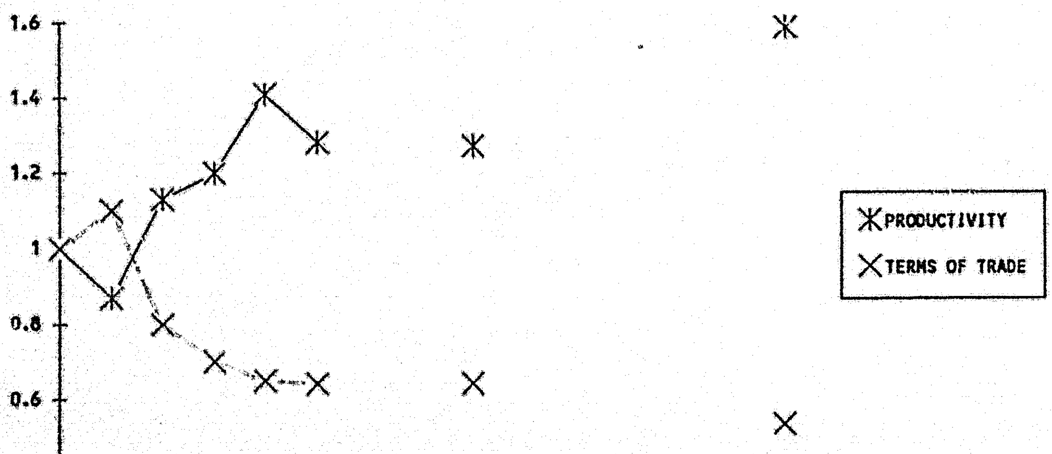


FIGURE 3 : TOTAL PRODUCTIVITY AND TERMS OF TRADE IN AUSTRALIAN AGRICULTURE : 1972-73 TO 1986-87



The indices of total output and input quantities and prices are reproduced graphically in Figures 1 and 2, respectively. The indices of total productivity and the terms of trade are presented in Figure 3 and Table 5. Total productivity has increased markedly over the period reflecting the substantial increase in output quantity combined with the decline in input usage. Productivity actually fell noticeably in 1973-74 reflecting the effect of adverse seasonal conditions on output, particularly the output of crops. Productivity was well above trend in 1976-77 reflecting the impact of favourable seasonal conditions on output. Over the 15 year period productivity increased at an average annual rate of 3.4 per cent, higher than the 2.9 per cent found by Lawrence and McKay for the 25 year period up to 1976-77. The current results not only cover a different time period but also cover all of agriculture and treat durable inputs in a different fashion compared to the earlier study. Total productivity indices for each of the 6 States are presented in Appendix Table A1.

The terms of trade for agriculture have dropped dramatically over the period (except for 1973-74) reflecting the modest increase in prices received and the steep increase in prices paid. The average annual rate of decline in the terms of trade was 4.6 per cent. This also represents an acceleration compared to Lawrence and McKay's result of 4.1 per cent.

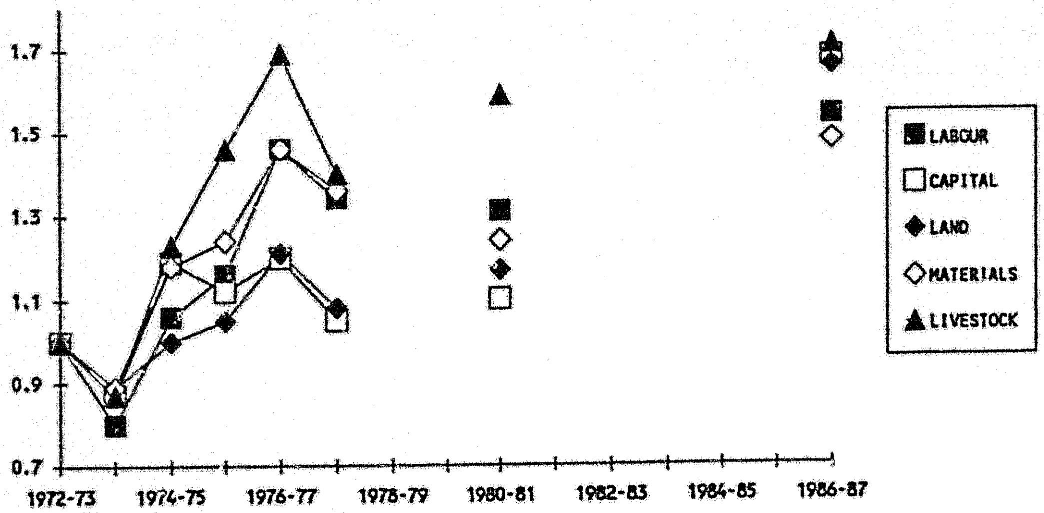
TABLE 5 : TOTAL PRODUCTIVITY AND TERMS OF TRADE

Year	Total productivity	Terms of trade
1972-73	1.000	1.000
1973-74	0.871	1.096
1974-75	1.127	0.802
1975-76	1.196	0.702
1976-77	1.406	0.652
1977-78	1.276	0.637
1980-81	1.265	0.641
1986-87	1.583	0.527

TABLE 6 : PARTIAL PRODUCTIVITY OF TOTAL OUTPUT WITH RESPECT TO INPUT GROUPS

	Partial Productivity of:				
Year	Hired labour	Capital	Land	Materials & Services	Livestock
1972-73	1.000	1.000	1.000	1.000	1.000
1973-74	0.802	0.870	0.891	0.888	0.865
1974-75	1.058	1.185	0.998	1.177	1.229
1975-76	1.159	1.122	1.049	1.235	1.460
1976-77	1.457	1.200	1.211	1.456	1.686
1977-78	1.340	1.048	1.078	1.361	1.399
1980-81	1.310	1.098	1.173	1.235	1.589
1986-87	1.540	1.679	1.660	1.484	1.712

FIGURE 4 : PARTIAL PRODUCTIVITIES IN AUSTRALIAN AGRICULTURE : 1972-73 TO 1986-87



Partial productivity indices measure the change in the ratio of total output to the quantity of a particular input. Although they help to explain the composition of changes in total productivity it should be remembered that reductions in the relative use of one input may be accompanied by increases in the use of other inputs. As expected, from Table 6 and Figure 4 livestock partial productivity has been the highest over the entire period. The partial productivity of materials and services was initially second highest but had declined in relative terms to be lowest by the end of the period. The relative performance of the labour and capital partial productivities has fluctuated while that of land has been relatively low for most of the period. Overall there is no great difference in the partial productivities or their movements reflecting the trend towards using less of all inputs.

The results of this section indicate that productivity improvement has continued to be a crucial means by which the rural sector has adjusted to declining terms of trade. Consequently, allowance for productivity improvement would be essential to any analysis of the expected effects of price and policy changes. It can also be observed that considerable change has taken place over the last 15 years in the composition of agricultural outputs and inputs. In the following section a methodology is developed for examining the price responsiveness of the two outputs and five inputs identified in this study.

3 PROFIT FUNCTION METHODOLOGY

Duality theory and the variable profit function provide a convenient and flexible framework for examining the price responsiveness of Australian agriculture. With numerous small producers each having no control over the prices they receive or pay, agriculture is well modelled by the variable profit function framework where producers vary their outputs and inputs each period to maximise profits subject to exogenous prices and fixed input quantities. Joint production is allowed, as is input substitution and the use of different inputs in varying intensities by the various outputs.

Denoting variable net output quantities by the vector x (entries positive for outputs, negative for variable inputs), net output prices by the vector $p >> 0$, fixed input quantities by the vector z, fixed input shadow prices by the vector w and the production technology set by T, the production technology can be represented by the following variable profit function:

$$(1) \qquad \Pi (p;z) = \max_x . (p^T x : (z,x) \text{ belongs to } T, p >>0)$$

The variable or restricted profit function (1) will be linearly homogenous and convex in net output prices and monotonically increasing (decreasing) in the prices of variable outputs (inputs). It will be linearly homogenous, concave and monotonically increasing in fixed input quantities.

If the variable profit function is differentiable with respect to p then the net output supply functions can be derived by applying Hotelling's (1932) Lemma:

$$(2) \qquad x (p;z) = \nabla_p \Pi (p;z).$$

The properties of variable profit functions are outlined thoroughly in Diewert (1974, 1982).

In this study, the variable profit function framework is used to estimate production response among 7 netputs and one fixed input in Australian agriculture. The netputs consist of 2 outputs (crops and livestock) and 5 variable inputs (hired labour, capital, land, materials and services, and livestock inputs). Operator and family labour is treated as the sole quasi-fixed input. Data covering 8 years in the period 1972-73 to 1986-87 is pooled across the 6 States to produce a total of 48 observations. To conserve degrees of freedom, constant returns to scale with respect to the fixed input have been imposed. This facilitates estimation of a unit profit function where profits are maximised per unit of the fixed input.

The functional form used for the variable profit function is the Generalised McFadden (GM) developed by Diewert and Wales (1987). The GM function is superior to earlier flexible forms such as the translog in that curvature conditions can be imposed on the model without loss of flexibility. Empirical implementations of the GM form in the international trade context can be found in Diewert and Morrison (1986) and Lawrence (1987).

The 7 netput GM unit variable profit function is given by:

$$(3) \qquad \Pi(p,z)/z = \tfrac{1}{2}\sum_{i=1}^{6}\sum_{j=1}^{6} b_{ij}\, p_i p_j/p_7 + \sum_{i=1}^{7} b_i p_i + \sum_{i=1}^{7} b_{it} p_i\, t + b_{tt}\left(\sum_{i=1}^{7} \gamma_i p_i\right) t^2$$

where the b_{ij} parameters are estimated subject to the following symmetry restrictions;

$$(4) \qquad b_{ij} = b_{ji} \text{ for all } i,j=1,\ldots,6;$$

t is an index of technology and the γ_i are exogenous constants set equal to the respective mean unit net output quantities to conserve degrees of freedom.

By applying Hotelling's Lemma the following set of unit net output supply equations is obtained;

$$(5) \qquad x_i/z = b_i + \sum_{j=1}^{6} b_{ij}\, p_j/p7 + b_{it}t + b_{tt}\gamma_i t^2;\ i=1,\ldots,6;$$

$$(6) \qquad x_7/z = b_7 - \tfrac{1}{2}\sum_{i=1}^{6}\sum_{j=1}^{6} b_{ij}\, p_i p_j/p_7^2 + b_{7t}t + b_{tt}\gamma_7 t^2.$$

The estimating system would normally consist of equations (5) and (6) with vectors of error terms attached and assumed to be independently distributed with a multivariate normal distribution with zero means and covariance matrix Ω. The variable profit function (3) is excluded from estimation as it adds no additional information.

In this application time-series and cross-section data are pooled and this needs to be allowed for in the estimation process as State differences in product mixes and production efficiency will make the sample non-homogenous. The theory of this situation is set out in detail in Fuss (1977). One option is to assume that the paramaters of the unit net output supply equations are State specific. Degrees of freedom considerations would limit the implementation of this to the intercept terms. The alternative is to assume that State effects are stochastic and that error terms consist of two components : a State-specific component and an overall remainder. There are two techniques for handling such a specification - covariance and error components estimators. Covariance estimation is computationally equivalent to the use of State-specific intercepts. While error components estimators have some theoretically more desirable properties than covariance estimators, Swamy and Arora (1972) show that when the sample is small and the number of States is less than 10 the covariance estimator is to be preferred. Consequently, in this study an analogous approach to Fuss (1977) is adopted. The estimating system then becomes:

$$(7) \qquad x_i/z = \sum_{k=1}^{6} d_{ki}D_k + \sum_{j=1}^{6} b_{ij}\, p_j/p_7 + b_{it}t + b_{tt}\,\gamma_i t^2 + \upsilon_i; \; i=1,\ldots,6;$$

$$(8) \qquad x_7/z = \sum_{k=1}^{6} d_{k7}D_k - \sum_{i=1}^{6} \sum_{j=1}^{6} b_{ij}p_ip_j/p_7^2 + b_{7t}t + b_{tt}\gamma_7 t^2 + \upsilon_7$$

subject to the symmetry restrictions (4). The D_k are State-specific dummy variables taking the value one for an observation in State k and zero otherwise. The error vectors are now independently multivariate normally distributed with zero means and covariance matrix Ω . The system (7) - (8) can be estimated using Zellner's (1962) iterative seemingly unrelated regressions estimator. This can be carried out using the SYSTEM command in SHAZAM (White 1978).

The technology index, t, was represented by the State-specific productivity indexes presented in Table A1. This specification was chosen as use of a simple time trend fails to capture the impact of seasonal conditions which can significantly influence output, particularly across States, and use of a seasonal conditions index fails to capture the importance of advances in productivity and technology over time.

A limitation of applied duality theory models in the past has been the failure of many models to satisfy the necessary curvature conditions. Jorgenson and Fraumeni (1981) attempted to overcome this problem by imposing semi-definiteness conditions on the matrix of second-order coefficients from translog functions. However, this procedure can introduce large biases in the estimated elasticities and hence destroys the constrained translog's flexibility (Diewert and Wales 1987). In the GM case if the matrix of estimated quadratic terms $B = [b_{ij}]$ is positive semi-definite then the variable profit function is globally convex in prices. If B is not positive semi-definite then it can be reparameterised using the Wiley, Schmidt and Bramble (1973) technique of replacing B by the product of a lower triangular matrix and its transpose:

$$(9) \qquad B = AA^T \text{ where } A = [a_{ij}];\ i,j=1,\ldots,6;\ \text{and } a_{ij} = 0 \text{ for } i<j.$$

The GM function will then be globally convex in prices without having lost its flexibility properties (Diewert 1985). The cost of this procedure is that computer-intensive non-linear regression techniques have to be used.

A criticism sometimes made of applied duality models is that they cannot accommodate a sufficiently fine level of commodity disaggregation to be of use for policy purposes. In this study the aggregator function technique of Fuss (1977) is used to further disaggregate the materials and services netput into four components (services, fertilisers and chemicals, fuel and electricity, and seed and fodder). While not new, the aggregator function technique is now more tractable with the development of functional forms such as the GM which permit imposition of curvature conditions at each stage of the estimation process.

The aggregator function procedure relies on the assumption of homogenous weak separability which implies that optimisation proceeds by a two-stage process. First, the optimal quantities of the relevant aggregates are chosen and then the composition of the aggregates is chosen. The composition of an aggregate is thus independent of both the level and the composition of all other aggregates.

The profit function can be written as:

$$(10) \quad \Pi(p,z) = \Pi\ (R,V)$$

where $R = (R_1,\ldots,R_n,\ldots)$, $V = (V_1,\ldots,V_m,\ldots)$, $R_n = R_n(p_n)$, $V_m = V_m\ (z_m)$ and p_n, z_m belong to p,z, respectively. $R_n(p_n)$ is a price index for the goods in group n and $V_m(z_m)$ is a quantity index for the fixed inputs in m. The transformation function is:

$$(11) \quad T(x,z) = T^*(Y,V) = 0$$

where $Y = (Y_1,\ldots,\ Y_n,\ldots)$ and $Y_n(x_n)$ is a quantity index assumed to be linearly homogenous. It follows that:

$$(12) \quad \max_{x_n} \left[p_n x_n : Y_n(x_n) = Y_n\right]$$

$$= Y_n \max_{x_n/Y_n} \left[p_n x_n/Y_n : Y_n(x_n/Y_n) = 1\right]$$

$$= Y_n\ R_n(p_n)$$

where $R_n(p_n)$ is an aggregator function (Woodland 1982). We then have:

$$(13) \quad \Pi(p,z) = \max.\ \left[\ \sum_n p_n x_n : T^*(Y_1(x_n),\ldots,V) = 0\right]$$

$$= \max \left[\sum_n R_n(p_n) Y_n : T^*(Y,V) = 0\right]$$

$$= \Pi^*\ (R,V).$$

In this study the following GM aggregator function is specified for materials and services:

$$(14)\quad R(p,X)/X = \sum_{i=1}^{4}\sum_{k=1}^{6} e_{ik}D_k p_i + \tfrac{1}{2}\sum_{i=1}^{3}\sum_{j=1}^{3} c_{ij}p_i p_j/p_4 + \sum_{i=1}^{4} c_{it}p_i t + c_{tt}(\sum_{i=1}^{4}\delta_i p_i)t^2$$

where D_k, p_i and t are defined as before, X denotes the aggregate quantity of materials and services, δ_i are exogenous constants set equal to the mean of the ratio of the relevant component quantity to the aggregate quantity of materials and services, and the c_{ij} have the following symmetry restriction:

$$(15)\quad c_{ij} = c_{ji} \text{ for all } i, j = 1, 2, 3.$$

Profit maximisation implies that the four component quantities per unit of total materials and services are given by:

$$(16)\quad x_i/X = \sum_{k=1}^{6} e_{ik}D_k + \sum_{j=1}^{3} c_{ij}p_j/p_4 + c_{it}t + c_{tt}\delta_i t^2 + u_i;\ i=1,2,3;$$

$$(17)\quad x_4/X = \sum_{k=1}^{6} e_{4k}D_k - \sum_{i=1}^{3}\sum_{j=1}^{3} c_{ij}p_i p_j/p_4^2 + c_{4t}t + c_{tt}\delta_4 t^2 + u_4 .$$

The quantity of aggregate materials and services (X) is obtained as a Divisia index of the four component quantities. The vectors of error terms are again assumed to be independently, multivariate normally distributed with zero means and covariance matrix Ω . If the matrix C = $[c_{ij}]$ is not positive semi-definite then price convexity can be imposed on the model by using the same technique as in (9).

While producers do not have control over the prices of the individual materials and services components, their choice of the mix of materials and services will influence the aggregate price of materials and services they face. To allow for this, an instrumental variable is needed for the aggregate price of materials and services. Following Fuss (1977) the parameters of (16) and (17) are substituted in (14) to obtain an estimate of the aggregate materials and services price. The overall estimation process thus consists of two-steps. First, the materials and services component equations (16) and (17) are estimated subject to (15). These estimates are then fed into equation (14) to obtain the estimate of the aggregate materials and services price. In the second stage this estimate of the materials and services price is used as an instrumental variable in the estimation of the system (7) and (8) subject to (4). Application of this conditional estimation procedure produces estimates which are full information maximum likelihood.

For simplicity of presentation, only the conventional net output supply elasticities are discussed in this paper. For the variable profit function the elasticities represent the change in the net supply of i with respect to a change in the price of net output j subject to the quantity of the fixed input available. They are given by:

(18) $$E_{ij} = d \ln x_i / d \ln p_j = DP_{ij} p_j / x_i; \; i,j = 1, \ldots, 7;$$

where DP_{ij} is the second-order price derivative of the variable profit function and x_i is the estimated unit net output quantity obtained from the system of equations (7) and (8). In the GM case the second-order price derivatives are given by:

(19) $$DP_{ij} = b_{ij}/p_7 \text{ for } i, j = 1, \ldots, 6;$$

(20) $$DP_{i7} = - \textstyle\sum_{j=1}^{6} b_{ij} p_j / p_7^2 = DP_{7i} \text{ for } i = 1, \ldots, 6; \text{ and}$$

(21) $$DP_{77} = \textstyle\sum_{i=1}^{6} \sum_{j=1}^{6} b_{ij} \, p_i p_j / p_7^3.$$

Two sets of elasticities are obtained for the four components of materials and services. From the first stage of estimation elasticities can be derived using formulae analogous to (18) which give the response subject to the aggregate quantity of materials and services being held fixed. By combining these elasticities with the results of the second stage of estimation a set of elasticities for the four components subject to the quantity of the fixed factor being held constant can be derived as follows:

(22) $$E_{ij}^{Z} = E_{ij}^{X} + s_j E_{XX}^{Z}$$

where E_{ij}^{X} is the cross price elasticity between components i and j given a constant quantity of aggregate materials and services, s_j is the share of component j in total materials and services, and E_{XX}^{Z} is the own-price elasticity of total materials and serivces for a given quantity of the fixed input.

4 PRODUCTION RESPONSE RESULTS

In this section results are initially presented for the second-stage of estimation, ie the profit function system. Following this the results for materials and services obtained from the first stage of estimation are discussed.

Initial estimation of the system of net output supply equations ((7) and (8) subject to (4)) produced estimates which failed to satisfy the convexity in prices property with two eigenvalues of the matrix B = $[b_{ij}]$ being negative. All of the estimated own-price elasticities from this system were, however, of the correct sign. Subsequent estimation of the system was undertaken imposing positive semi-definiteness on the B matrix using equation (9). The non-linear regression algorithm of the SHAZAM package (White 1978) was used with starting values set equal to the mean of the dependent variable for the State dummy coefficients and zero for all other coefficients. The constrained system estimates are presented in Table 7. The elasticities obtained from the constrained

TABLE 7 : ESTIMATED UNIT NET OUTPUT SUPPLY EQUATIONS[1]

Equation i	Coefficient														
	State dummy variables[2]						Second-order price terms (non-linear)						Technology Terms		Equation i
	d_{i1}	d_{i2}	d_{i3}	d_{i4}	d_{i5}	d_{i6}	a_{i1}	a_{i2}	a_{i3}	a_{i4}	a_{i5}	a_{i6}	b_{it}	b_{tt}	R^2
Crops	-28.977	-33.844	-22.218	-30.578	-22.172	-33.916	1.679	1.576	-1.274	0.245	-0.406	-1.737	47.829	-0.577	
	(-3.10)	(-6.05)	(-3.94)	(-5.35)	(-3.83)	(-6.09)	(7.81)	(2.80)	(-7.58)	(2.30)	(-1.99)	(-4.32)	(5.89)	(-3.05)	0.90
Livestock	-3.895	-11.080	-13.360	-11.449	-1.863	-7.066		-1.443	0.800	0.590	-0.326	-0.474	42.406		
	(-0.46)	(-1.33)	(-1.60)	(-1.35)	(-0.217)	(-0.85)		(-2.36)	(2.26)	(1.42)	(-0.95)	(-0.62)	(3.53)	"	0.67
Labour	2.720	4.836	2.306	3.961	2.451	2.742			-0.887	0.214	-0.284	1.605	-8.54		
	(1.33)	(2.38)	(1.14)	(1.90)	(1.15)	(1.36)			(-2.87)	(0.87)	(-0.87)	(4.00)	(-3.21)	"	0.66
Capital	-0.940	-0.043	-0.942	-0.951	-2.129	-0.168				-0.895	0.250	-0.055	-2.664		
	(-1.07)	(-0.05)	(-1.08)	(-1.06)	(-2.34)	(-0.19)				(2.41)	(0.70)	(-0.09)	(-2.28)	"	0.84
Land	-6.164	-0.881	-3.324	-3.451	-12.070	-1.286					-0.000	0.000	-14.118		
	(-1.61)	(-0.23)	(-0.87)	(-0.90)	(-3.13)	(-0.34)					(-0.00)	(0.00)	(-2.46)	"	0.93
Materials & services	-3.045	3.252	-0.025	0.672	-9.869	2.343						-0.000	-27.403		
	(-0.46)	(0.50)	(-0.00)	(0.10)	(-1.44)	(0.36)						(-0.00)	(-3.00)	"	0.72
								Symmetric							
Livestock input	-1.578	0.004	0.046	0.998	-1.494	0.007							-6.195		
	(-0.80)	(0.00)	(0.02)	(0.49)	(-0.72)	(0.00)							(-2.57)	"	0.75
System Log Likelihood			-339.78												

1 t-statistics in parentheses.

2 States 1,...,6 are NSW, Victoria, Queensland, South Australia, Western Australia and Tasmania, respectively.

estimates were only marginally different from those obtained from the unconstrained system. Most of the price terms are statistically significant as are all the technology coefficients, reflecting the superior performance of this variable relative to others tried such as simple time trends and seasonal indices.

Net output supply elasticities for Australia calculated at the means of the exogenous variables are presented in Table 8. The corresponding sets of elasticities for each of the 6 States are presented in Appendix Tables A2 to A7. The elasticities for Australia were obtained by weighting together the individual State elasticities according to shares in the mean netput quantity.

The elasticities given in Table 8 adhere largely to those that would apply to a "normal technology". That is, if production is relatively unconstrained by the availability of fixed factors (as is the case here with only family and owner-operator labour quasi-fixed), expanding one output would lower the costs of producing other outputs. Thus the following would be observed (Hertel 1984);

- gross complementarity between outputs;
- gross complementarity between inputs; and
- no regressive relationships between inputs and outputs.

As can be seen from Table 8 outputs are gross complements and, apart from the crops/capital interactions, there are no regressive relationships between inputs and outputs. On the input side however, gross substitution between inputs is more prevalent with 5 of the 10 underlying gross substitution elasticities between inputs being positive. With low output supply elasticities this result probably derives from small expansion effects being dominated by the underlying substitution effects.

Returning to the specific elasticity estimates, the notable feature of Table 8 is the general lack of price responsiveness in Australian agriculture. Both the outputs of crops and livestock have own-price

TABLE 8 : NET OUTPUT SUPPLY ELASTICITIES FOR AUSTRALIA AT MEAN EXOGENOUS VARIABLES

		With Respect to Price of:						
		Crops	Livestock	Labour	Capital	Land	Materials & Services	Livestock Input
Change in Quantity of:	Crops	0.199	0.189	-0.167	0.030	-0.038	-0.209	-0.005
	Livestock	0.104	0.186	-0.138	-0.020	-0.005	-0.081	-0.046
	Labour	0.502	0.759	-0.780	0.007	-0.094	-0.098	-0.286
	Capital	-0.257	0.313	0.020	-0.825	0.281	0.198	0.269
	Land	0.056	0.013	-0.046	0.050	-0.027	-0.033	-0.013
	Materials & services	0.165	0.116	-0.026	0.019	-0.017	-0.333	0.077
	Livestock input	0.011	0.235	-0.267	0.088	-0.023	0.281	-0.325

supply elasticities of around 0.2. The cross-elasticities between these outputs are almost as high reflecting the close relationship between cropping and livestock production. Hired labour and capital own-price demand elasticities both show more responsiveness at values of -0.8. Land input, on the other hand, shows a very inelastic own-price response at only -0.03. The inputs of aggregate materials and services, and livestock both have own-price elasticities of -0.3.

These results are broadly in line with the findings of earlier studies although output responsiveness in this study is even more inelastic, particularly in regard to crops. With the exception of McKay, Lawence and Vlastuin (1983) who found the crop supply elasticity to be 0.5, the other studies cited in Table 1 have found the crops elasticity to be closer to one. Livestock supply elasticities, on the other hand, have typically been lower ranging from 0.12 for McKay, Lawrence and Vlastuin's estimate for cattle and other outputs to their estimate of 0.72 for wool and sheep. On the input side the gross own-price elasticities of this study are similar in relative terms to the compensated cost function estimates of McKay, Lawrence and Vlastuin (1980) with the exception of materials and services which is less elastic in our case. While these comparisons provide a useful check it must be remembered that the elasticities estimated here cover all of Australian agriculture and come from a different, more recent data source than most of the other studies referred to. These elasticities are also calculated subject to a different set of conditions being held fixed, namely the quantity of operator and family labour.

Turning to the cross elasticities in Table 8, crops output responds positively to an increase in the price of livestock outputs as noted and negatively to increases in the prices of 4 of the 5 inputs. Crops output is most sensitive to increases in the price of labour, and materials and services. The positive (although near zero) elasticity between crops output and capital prices is the only apparently anomalous result in the Table. Livestock output decreases in response to increases in the price of each of the 5 inputs with this relationship being strongest for hired labour price increases. Labour and capital inputs are shown to be slight substitutes while labour is (slightly) complementary to the other 3 inputs. Capital inputs are also substitutable with land, materials and services, and livestock inputs although the cross elasticities are again typically small in magnitude. Land inputs are very unresponsive to changes in any of the netput prices reflecting land's relatively fixed supply to Australian agriculture. Materials and services inputs are weakly substitutable with livestock inputs reflecting the scope for using chemicals, drenches, etc in varying intensities. As expected, livestock input quantities also respond to increases in the price of livestock output and, in a negative way, to labour price increases.

The differences between elasticities for the 6 States were relatively minor in all cases (Tables A2 to A7). For instance, a 10 per cent increase in the price of hired labour would have led to a 8.1 per cent fall in the quantity of hired labour used in NSW, a 8.2 per cent fall in both Victoria and Queensland, a 6.9 per cent fall in SA, a 7.3 per cent fall in WA, and a 7.5 per cent fall in Tasmania. The effect of this increase in the price of hired labour would have been to reduce livestock outputs by 1.4 per cent in 4 of the 6 States with the reductions in the others being 1.2 and 1.3 per cent. The only sign changes between States were on the elasticities between crops and livestock inputs but in all cases these were close to zero.

Moving to the first stage of the estimation procedure (the materials and services aggregator function), the estimated system is presented in Table 9. In this case the matrix of price coefficients $C = [c_{ij}]$ was positive semi-definite indicating that the estimated aggregator function satisfied the property of price convexity. Furthermore, the price coefficients were strongly significant with one exception and all 4 equations fitted the data well.

The matrix of elasticities derived from the unit aggregator equations at the means of the exogenous variables are presented in Table 10. These elasticities are the response subject to the total quantity of materials and services being held constant and indicate that the fertilisers and chemicals component has an elastic response to changes in its own-price while the services, fuel and electricity, and seed and fodder components all have own-price elasticities close to -0.5. Again cross elasticities are mostly relatively small with all pairs being substitutes except for the fertilisers and chemicals, and seed and fodder components.

TABLE 9 : ESTIMATED UNIT MATERIALS AND SERVICES AGGREGATOR EQUATIONS[1]

	State dummy variables[2]						Price Terms			Technology		Equation i
Equation i	e_{i1}	e_{i2}	e_{i3}	e_{i4}	e_{i5}	e_{i6}	C_{i1}	C_{i2}	C_{i3}	C_{it}	C_{tt}	R^2
Services	-0.587 (-23.07)	-0.566 (-23.81)	-0.545 (-22.79)	-0.566 (-21.06)	-0.544 (-20.53)	-0.551 (-23.53)	0.246 (6.75)	-0.163 (-9.18)	-0.044 (-2.81)	-0.041 (-1.76)	0.000 (0.02)	0.75
Fertilisers & chemicals	-0.145 (-9.25)	-0.168 (-11.22)	-0.174 (-11.39)	-0.182 (-11.17)	-0.266 (-16.17)	-0.196 (-13.95)		0.166 (10.99)	-0.013 (-1.59)	0.020 (1.38)		0.92
Fuel & electricity	-0.119 (-10.87)	-0.142 (-13.40)	-0.145 (-13.56)	-0.133 (-11.40)	-0.113 (-9.57)	-0.123 (-12.06)			0.076 (7.91)	-0.023 (-2.17)		0.80
Seed & fodder	-0.160 (-8.62)	-0.137 (-7.85)	-0.150 (-8.34)	0.134 (-7.05)	-0.089 (-4.53)	-0.146 (-8.97)				0.037 (2.31)		0.68
System Log Likelihood			643.01									

1 t-statistics in parenthesis

2 States 1,..,6 are NSW, Victoria, Queensland, South Australia, Western Australia and Tasmania, respectively.

TABLE 10 : MATERIALS AND SERVICES ELASTICITIES SUBJECT TO A FIXED AGGREGATE QUANTITY OF MATERIALS AND SERVICES : AUSTRALIA AT MEAN EXOGENOUS VARIABLES

		With Respect to Price of:			
		Services	Fertilisers & Chemicals	Fuel & Electricity	Seed & Fodder
	Services	-0.465	0.293	0.065	0.107
Change in Quantity of:	Fertilisers & Chemicals	1.300	-1.264	0.080	-0.116
	Fuel & Electricity	0.333	0.093	-0.450	0.024
	Seed & Fodder	0.474	-0.119	0.021	-0.377

TABLE 11 : MATERIALS AND SERVICES ELASTICITIES SUBJECT TO THE FIXED INPUT OF OPERATOR AND FAMILY LABOUR : AUSTRALIA AT MEAN EXOGENOUS VARIABLES

		With Respect to Price of:			
		Services	Fertilisers & Chemicals	Fuel & Electricity	Seed & Fodder
	Services	-0.658	0.236	0.022	0.067
Change in Quantity of:	Fertilisers & Chemicals	1.108	-1.325	0.038	-0.154
	Fuel & Electricity	0.141	0.036	-0.493	-0.016
	Seed & Fodder	0.280	-0.174	-0.022	-0.419

Of more interest are the materials and services component gross elasticities which are derived using equation (22). These are presented in Table 11 and show the response subject to the quantity of the fixed input. They are thus directly comparable to the net output elasticities from the variable profit function shown in Table 9. Again fertilisers and chemicals have an elastic response to own price changes and are complementary to seed and fodder inputs. They are strongly substitutable with services inputs. Services inputs show the next highest response to own price changes and are slightly substitutable with the other 3 components. The own-price elasticity of fuel and electricity is -0.5 but this input has only a weak response to changes in the prices of the other 3 components. Likewise seed and fodder is somewhat substitutable with services and slightly complementary to the other two components.

Each of the 4 own-price elasticities for the materials and services components shown in Table 11 is larger than the own-price elasticity for aggregate materials and services shown in Table 9 due to the predominance of substitutability between the 4 components. That is, the elasticities in Table 11 show the response when only the price of one component changes whereas the aggregate response in Table 9 is equivalent to an equi-proportionate increase in the price of all 4 components. This eliminates much of the scope for substitution indicated in Table 11.

5 CONCLUSIONS

The findings of this study reinforce those of earlier papers in pointing to the continued importance to Australian agriculture of productivity improvements and agriculture's general lack of price responsiveness. The recent data set used indicates that Australian farmers have continued to achieve annual total productivity gains in excess of 3 per cent. However, over the period examined farmers' terms of trade have declined at an annual rate of well over 4 per cent. If this long-term decline in the terms of trade of agriculture continues it will be necessary for farmers to keep achieving significant productivity gains if they are to maintain a competitive return on funds invested in the agricultural sector. This suggests that agricultural research will continue to be a profitable activity for the Australian economy as a whole.

The observed importance of agricultural productivity gains also has important implications for simulations of the effects of policy and price changes. Models which simulate the effects of such changes on agriculture but which fail to allow for continued productivity gains will come up with overly pessimistic predictions of their impact on agriculture.

The lack of price responsiveness in Australian agriculture as a whole is not surprising given the absence of alternative uses for agricultural land and the degree of adjustment required to move resources in and out of agriculture. This contrasts with the United States, for instance, where much higher levels of price responsiveness in agriculture have been reported in some studies. Given the larger US economy and its more geographically diverse nature it can be expected that the transfer of resources between agriculture and the non-agricultural sector would be easier thus contributing to a higher degree of price responsiveness.

This study has also highlighted that a lack of price responsiveness at an aggregated level may mask greater price responsiveness at the more disaggregated level. By using the aggregator function procedure for materials and services more information was recovered on the response of individual components.

The development of functional forms such as the Generalised McFadden have made the use of the aggregator function framework more tractable as illustrated here. Greater application of these techniques will lead to significant increases in our knowledge of agricultural production response and provide better input to larger scale models. An obvious progression from this study would be to extend the aggregator procedure to the netputs other than materials and services thus providing an even more detailed set of elasticities characterising agricultural production response.

APPENDIX 1 : DATA SOURCES

The principal data source used in this study is the Australian Bureau of Statistics' Agricultural Finance Survey (ABS Cat. No. 7507.0). The first survey year used is 1972/73. The survey then had a sample of approximately 10 000 farms. It was then carried out on an annual basis until 1977/78 and again in 1980/81 and 1986/87. The survey presents data on the value of farm outputs and inputs. Stock values for the 3 durable inputs are presented from 1974/75 onwards. The survey value data is combined with ABARE (1988) prices received and prices paid indices to produce price and implicit quantity indices for 2 outputs and 4 input categories. A further 2 input categories are created from survey value data and ABS and ABARE quantity series. The data used here are at the aggregate level for each of the 6 States and 8 years producing a total of 48 observations.

For the components of the 2 outputs (crops and livestock) and the 2 non-durable inputs (hired labour, and materials and services) the ABARE State price indices were used along with the implicit quantities obtained by dividing the Survey values by the price indices as outlined in Appendix Table A.

For the 3 durable inputs (capital, land, and livestock inputs) a user cost value has been derived from the stock value by assuming that farmers aim to make a given rate of real return on their assets. A real opportunity cost rate of 4 per cent has thus been used along with a depreciation rate for each asset class. This approach differs from earlier studies such as Lawrence and McKay (1980) where a nominal opportunity cost was used. While the nominal opportunity cost rate varied from year to year it neglected the increasingly important role that capital gains have played. As no information was available on capital gains in this case the alternative of assuming a constant real rate of opportunity cost was opted for. This is equivalent to a

TABLE A: VALUE, PRICE AND QUANTITY SOURCES

Group	AFS Category	ABARE price index	ABS AND ABARE quantities
Crops	Sales from crops	crops	
Livestock	Sales from livestock	livestock	
	Sales from livestock products]	livestock	
	Other miscellaneous revenue]	products	
Hired Labour	Wages, salaries and supplements	wages	
	Payments to contractors	contracts	
Capital	0.09 x Value of machinery and equipment	repairs and maintenance	
Land	0.05 x Value of land and improvements		ABS area of agricultural land
Materials and Services			
Services	Marketing expenses	marketing	
	Water and drainage charges]	repairs and	
	Repairs and maintenance]	maintenance	
	Other selected expenses]		
	Rates and taxes	rates and taxes	
	Insurance payments	insurance	
	Other expenses	other expenses	
Fertiliser and Chemicals	Payments for fertiliser	fertiliser	
	Chemical and veterinary supplies	chemicals	
Fuel and Electricity	Payments for fuel	fuel	
	Payments for electricity	electricity	
Seed and fodder	Payments for seed and fodder	seed and fodder	
Livestock Inputs	0.04 x Value of livestock]	livestock	
	Purchases of livestock]		
Operator and family labour			ABARE number of operators and unpaid family helpers allocated to States by ABS proportions.

constant difference between the nominal rate of opportunity cost and the rate of capital gains. A depreciation rate of 5 per cent was assumed for capital and 1 per cent for land and improvements. The average unit of livestock was assumed not to depreciate but this required inputs in the form of livestock purchases. Consequently, the livestock input user cost consists of the real opportunity cost and the value of purchases. As no reliable land price series was available a land price index was formed by dividing the land value by the area of agricultural land in each State (ABS Cat. No. 7321.0).

No capital stock values were collected for 1972/73 or 1973/74 although capital purchase data was. The capital stocks for these years were estimated by deflating the stock for the following year after allowing for purchases and depreciation. Similarly no total livestock value was collected for 1972/73 or 1973/74. Livestock values for these years were estimated from the 1974/75 values by allowing for sales, purchases and an average rate of net natural increase observed for the rest of the sample period.

Finally, the most reliable estimates of the number of farm operators and unpaid family helpers were considered to be those of ABARE (1987, p.4). However, these are only presented for Australia as a whole. Estimates for the States were obtained by allocating this total according to the proportions observed from ABS employment data for March of each year. No value for this input was required as it was treated as being fixed. The implicit return to the input is the value of variable profit in each year. In only 9 of the 48 observations was this value non-positive.

TABLE A1: STATE TOTAL FACTOR PRODUCTIVITY INDICES

YEAR	NSW	VIC	QLD
1972-73	1.000	1.000	1.000
1973-74	0.860	0.878	0.833
1974-75	1.151	1.022	1.111
1975-76	1.189	1.109	1.165
1976-77	1.453	1.273	1.395
1977-78	1.358	1.196	1.274
1980-81	1.195	1.265	1.237
1986-87	1.546	1.543	1.472

YEAR	SA	WA	TAS
1972-73	1.000	1.000	1.000
1973-74	0.924	0.908	0.852
1974-75	1.253	1.186	1.065
1975-76	1.258	1.359	1.035
1976-77	1.350	1.573	1.175
1977-78	1.135	1.333	1.173
1980-81	1.378	1.387	1.050
1986-87	1.728	1.784	1.444

TABLE A2: NET OUTPUT SUPPLY ELASTICITIES FOR NEW SOUTH WALES AT MEAN EXOGENOUS VARIABLES

With Respect to Price of:

		Crops	L'stock	Labour	Capital	Land	M & S	L's In.
	Crops	0.201	0.190	-0.170	0.031	-0.037	-0.218	0.003
Change	L'stock	0.105	0.187	-0.141	-0.021	-0.005	-0.084	-0.041
in	Labour	0.509	0.768	-0.811	0.007	-0.093	-0.102	-0.279
Qty.	Capital	-0.263	0.319	0.021	-0.859	0.284	0.209	0.289
of:	Land	0.057	0.013	-0.047	0.051	-0.026	-0.034	-0.013
	M & S	0.167	0.117	-0.026	0.019	-0.017	-0.349	0.089
	L's In.	-0.008	0.210	-0.261	0.097	-0.024	0.326	-0.339

TABLE A3: NET OUTPUT SUPPLY ELASTICITIES FOR VICTORIA AT MEAN EXOGENOUS VARIABLES

With Respect to Price of:

		Crops	L'stock	Labour	Capital	Land	M & S	L's In.
	Crops	0.219	0.207	-0.184	0.033	-0.051	-0.225	0.000
Change	L'stock	0.105	0.188	-0.140	-0.020	-0.006	-0.080	-0.047
in	Labour	0.520	0.786	-0.820	0.007	-0.118	-0.099	-0.275
Qty.	Capital	-0.235	0.286	0.019	-0.741	0.316	0.177	0.179
of:	Land	0.056	0.013	-0.046	0.049	-0.033	-0.032	-0.007
	M & S	0.164	0.115	-0.026	0.018	-0.021	-0.326	0.075
	L's In.	-0.001	0.238	-0.250	0.064	-0.016	0.263	-0.299

TABLE A4: NET OUTPUT SUPPLY ELASTICITIES FOR QUEENSLAND AT MEAN EXOGENOUS VARIABLES

		With Respect to Price of:						
		Crops	L'stock	Labour	Capital	Land	M & S	L's In.
Change in Qty. of:	Crops	0.205	0.192	-0.176	0.031	-0.037	-0.213	-0.002
	L'stock	0.102	0.182	-0.140	-0.020	-0.004	-0.079	-0.041
	Labour	0.510	0.762	-0.823	0.007	-0.092	-0.098	-0.266
	Capital	-0.249	0.300	0.020	-0.795	0.264	0.190	0.270
	Land	0.054	0.012	-0.046	0.048	-0.025	-0.031	-0.012
	M & S	0.160	0.111	-0.026	0.018	-0.016	-0.321	0.073
	L's In.	0.004	0.202	-0.243	0.090	-0.023	0.259	-0.289

TABLE A5: NET OUTPUT SUPPLY ELASTICITIES FOR SOUTH AUSTRALIA AT MEAN EXOGENOUS VARIABLES

		With Respect to Price of:						
		Crops	L'stock	Labour	Capital	Land	M & S	L's In.
Change in Qty. of:	Crops	0.180	0.174	-0.143	0.028	-0.034	-0.190	-0.015
	L'stock	0.098	0.180	-0.125	-0.019	-0.004	-0.077	-0.053
	Labour	0.461	0.709	-0.688	0.007	-0.085	-0.090	-0.313
	Capital	-0.249	0.308	0.019	-0.801	0.273	0.193	0.258
	Land	0.055	0.013	-0.043	0.049	-0.026	-0.032	-0.016
	M & S	0.158	0.113	-0.023	0.018	-0.016	-0.320	0.071
	L's In.	0.044	0.273	-0.283	0.083	-0.028	0.249	-0.339

TABLE A6: NET OUTPUT SUPPLY ELASTICITIES FOR WESTERN AUSTRALIA AT MEAN EXOGENOUS VARIABLES

		With Respect to Price of:						
		Crops	L'stock	Labour	Capital	Land	M & S	L's In.
Change in Qty. of:	Crops	0.176	0.168	-0.143	0.027	-0.026	-0.180	-0.021
	L'stock	0.104	0.188	-0.135	-0.020	-0.004	-0.079	-0.055
	Labour	0.479	0.729	-0.732	0.007	-0.070	-0.091	-0.322
	Capital	-0.299	0.366	0.023	-0.946	0.259	0.224	0.374
	Land	0.059	0.013	-0.047	0.052	-0.022	-0.034	-0.022
	M & S	0.168	0.119	-0.025	0.019	-0.014	-0.332	0.065
	L's In.	0.073	0.302	-0.329	0.114	-0.033	0.237	-0.364

TABLE A7: NET OUTPUT SUPPLY ELASTICITIES FOR TASMANIA AT MEAN EXOGENOUS VARIABLES

		With Respect to Price of:						
		Crops	L'stock	Labour	Capital	Land	M & S	L's In.
Change in Qty. of:	Crops	0.247	0.242	-0.197	0.037	-0.050	-0.270	-0.010
	L'stock	0.107	0.199	-0.136	-0.021	-0.005	-0.087	-0.057
	Labour	0.498	0.777	-0.745	0.007	-0.098	-0.101	-0.337
	Capital	-0.241	0.303	0.018	-0.767	0.281	0.194	0.212
	Land	0.056	0.013	-0.043	0.049	-0.028	-0.033	-0.012
	M & S	0.170	0.123	-0.025	0.019	-0.019	-0.358	0.090
	L's In.	0.022	0.285	-0.295	0.073	-0.024	0.315	-0.375

REFERENCES

Adams, P.D. (1987), "Agricultural Supply Response in ORANI" Review of Marketing and Agricultural Economics 55, 213-29.

Australian Bureau of Agricultural and Resource Economics (1987), Commodity Statistical Bulletin, AGPS, Canberra.

Australian Bureau of Agricultural and Resource Economics (1988), 'Prices Received and Prices Paid Indices', mimeograph.

Australian Bureau of Statistics (various years), Agricultural Sector Part IV Financial Statistics, Cat. No. 7507.0.

Australian Bureau of Statistics (various years), Crops and Pastures, Australia, Cat. No. 7321.0.

Dewbre, J., I. Shaw, and G. Corra (1985), The EMABA Model - Structure, Specification and Some Results, BAE Occassional Paper, AGPS, Canberra.

Diewert, W.E. (1974), "Applications of Duality Theory", in M.D. Intrilligator and D.A. Kendrick (eds), Frontiers of Quantitative Economics, vol. II, North-Holland, Amsterdam, pp. 106-171.

Diewert, W.E. (1976), "Exact and Superlative Index Numbers", Journal of Econometrics 4, 115-45.

Diewert, W.E. (1982), "Duality Approaches to Microeconomic Theory", in K.J. Arrow and M.D. Intriligator (eds), Handbook of Mathematical Economics, vol. II, North-Holland, Amsterdam, pp. 535-600.

Diewert, W.E. (1985), 'The Measurement of the Economic Benefits of Infrastructure Services', Department of Economics Working Paper No. 85-11, University of British Columbia.

Diewert, W.E. and C.J. Morrison (1986), 'Export Supply and Import Demand Functions: A Production Theory Approach', Department of Economics Discussion Paper No. 86-10, University of British Columbia.

Diewert, W.E. and C.J. Morrison (1986), 'Export Supply and Import Demand Functions: A Production Theory Approach', Department of Economics Discussion Paper No. 86-10, University of British Columbia.

Diewert, W.E. and T.J. Wales (1987), "Flexible Functional Forms and Global Curvature Conditions", Econometrica 55, 43-68.

Dixon, P.B., B.R. Parmenter, J. Sutton and D.P. Vincent (1982), ORANI: A Multisectoral Model of the Australian Economy, North-Holland, Amsterdam.

Fuss, M. (1977), "The Demand for Energy in Canadian Manufacturing: An Example of the Estimation of Production Structures with Many Inputs", Journal of Econometrics 5, 89-116.

Hertel, T.W. (1984), 'Applications of Duality and Flexible Functional Forms : The Case of the Multiproduct Firm', Purdue University, Agricultural Experimental Station Research Bulletin 880.

Hertel, T.W. (1988), 'An Aggregate Technology for Modelling U.S. Agricultural Policy', Purdue University, mimeograph.

Hotelling, H. (1932), "Edgeworth's Taxation Paradox and the Nature of Demand and Supply Functions", Journal of Political Economy 40, 577-616.

Jorgenson, D.W. and B.M. Fraumeni (1981), "Relative Prices and Technical Change", in E. Berndt and B. Field (eds), Modelling and Measuring Natural Resource Substitution, MIT Press, Cambridge.

Lawrence, D.A. (1987), 'Export Supply and Import Demand Elasticities', Ph.D. thesis, University of British Columbia.

Lawrence, D.A. (1988), "Recent Developments in Applying Duality Theory", <u>Review of Marketing and Agricultural Economics</u> 56, (forthcoming).

Lawrence, D. and L. McKay (1980), "Inputs, Outputs and Productivity Change in the Australian Sheep Industry", <u>Australian Journal of Agricultural Economics</u> 24, 46-59.

Malecky, J.M. (1975), "Price Elasticity of Wool Supply", <u>Quarterly Review of Agricultural Economics</u> 28, 240-58.

McKay, L., D. Lawrence and C. Vlastuin (1980), "Input Substitution in the Australian Sheep Industry", <u>Review of Marketing and Agricultural Economics</u> 48, 57-70.

McKay, L., D. Lawrence and C. Vlastuin (1982), "Production Flexibility and Technical Change in Australia's Wheat/Sheep Zone", <u>Review of Marketing and Agricultural Economics</u> 50, 9-26.

McKay, L., D. Lawrence and C. Vlastuin (1983), "Profit, Output Supply, and Input Demand Functions for Multiproduct Firms : The Case of Australian Agriculture", <u>International Economic Review</u> 24, 323-39.

Swamy, P.A.V.B. and S. Arora (1972), "The Exact Finite Sample Properties of the Estimators of Coefficients in the Error Components Regression Models", <u>Econometrica</u> 40, 261-76.

Vincent, D.P. (1977), "Factor Substitution in Australian Agriculture", <u>Australian Journal of Agricultural Economics</u> 21, 119-29.

Vincent, D.P., P.B. Dixon and A.A. Powell (1980), "The Estimation of Supply Response in Australian Agriculture : the CRESH/CRETH Production System", <u>International Economic Review</u> 21, 221-42.

White, K.J. (1978), "A General Computer Program for Econometric Methods - SHAZAM", <u>Econometrica</u> 46, 239-40.

Wicks, J.A. and J.L. Dillon (1978), "APMAA Estimates of Supply Elasticities for Australian Wool, Beef and Wheat", Review of Marketing and Agricultural Economics 46, 48-57.

Wiley, D.E., W.H. Schmidt and W.J. Bramble (1973). "Studies of a Class of Covariance Structure Models", Journal of the American Statistical Association 68, 317-23.

Woodland, A.D. (1982), International Trade and Resource Allocation, North-Holland, Amsterdam.

Zellner, A. (1962), "An Efficient Method for Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias", Journal of the American Statistical Association 57, 348-68.