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ESTIMATION OF SUPPLY RESPONSE IN AUSTRALIAN BROADACRE
AGRICULTURE: THE MULTI-PRODUCT APPROACH

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In this paper the duality approach is applied to modelling supply response in Australian broadacre agriculture. The aim is to estimate supply elasticities for broadacre agriculture taking account of the substitution possibilities between these activities. To achieve this aim, Australian broadacre agriculture is disaggregated by individual states, which appear to be relatively homogenous in their substitution possibilities between crops and livestock. Supply elasticities at the aggregate level for wheat, wool and beef cattle are estimated. The Symmetric Generalised McFadden (SGM) functional form is used, imposing the condition of price convexity, in the context of variable profit estimation. The use of the SGM function enables the imposition of the correct curvature conditions without the loss of the flexibility properties underlying the profit function approach.

The assumption that technology is joint, and that decisions on each output are made according to a multi-output production function, is upheld. For this reason, any policies directed at a single output should be considered carefully. The empirical results from the study suggest that such policies may affect all production decisions, not only those regarding the commodity targeted.

Introduction and Background

An understanding of the role of supply response in Australian broadacre agriculture, and measurements of these responses, are both important for forecasting and policy purposes. Because of the nature of Australian broadacre farming, a multi-product approach is needed in modelling supply response. Sheep, cattle and grain crops are the main broadacre agriculture enterprises in Australia, and farms are often of a multiple enterprise type - mainly combining wheat, coarse grains and livestock products.

Australian broadacre production conditions have for some time been categorised into three zones: pastoral, wheat/sheep and high rainfall zones.

The pastoral zone is the largest in area. It includes the whole of the Northern Territory and portions of all the mainland states except Victoria. It comprises all of the arid and most of the semi-arid parts of Australia. The property areas in this zone are very large and livestock are generally grazed extensively on native pastures.

The wheat/sheep and high rainfall zones extend into all mainland states. The wheat/sheep zone accounts for nearly half the national sheep flock and well over half of the sheep properties. Cattle output has also become important in this zone over the last few years. The wheat/sheep zone forms a classic example of a multi-product agriculture production region.

The high rainfall zone lies in the south-east and south-west extremities of Australia and along its south and east coasts from Kangaroo Island in South Australia to Mossman in northern Queensland. The whole of Tasmania is in this zone. Sheep numbers per unit area are highest in this zone; mixed farming is dominant, and a large proportion of farms combine wool and prime lamb production.

Grain production is dominant in the wheat/sheep zone and to a lesser extent in the high rainfall zone. Six main types of cereal grains are produced in Australia: wheat, barley, oats, sorghum, maize and triticale. Sorghum and maize are summer crops; wheat, barley, oats and triticale are winter crops. There are various alternatives in the production of grain crops in Australian farms. For example, wheat is often grown on farms that also produce some combination of oats, barley, sorghum, maize, or other coarse grains and various types of livestock (such as sheep and cattle).

Farms in all of the states produce grains. The diversity of climatic and geographical conditions causes variation in growing seasons and in the amount and type of grains grown. For example, sorghum, a summer crop, is grown largely in northern New South Wales and southern Queensland. Wheat is the most important of the grain crops grown in Australia, being produced in all states. However, its protein quality varies across states, with higher protein wheat generally produced in the more northerly areas.

From the above facts, two main implications can be drawn for supply analysis. One is that, because there are different sets of competing products in each state, efficiency of estimation of supply response can be improved by statewide disaggregation. Disaggregation will also allow for transportation costs and differences in state government policies, such as marketing arrangements. The other implication is that, on farms that engage in multiple enterprises a farmer can easily adjust to changing market prices by adjusting the crop mix. Supply elasticities for multiple output farms would be expected to be larger than where the farmer has few production

options. These implications have influenced the approach used in the modelling of supply response in this study.

The main aim of the study is to estimate supply elasticities of use in evaluating policies pertaining to the broadacre industries. The study takes advantage of recent econometric developments in modelling multi-output production response, which enable the use of a more reliable survey data set than in the past. A review of some of the relevant past studies is presented in the next section, followed by a discussion of the advantages of using the duality approach in modelling supply response in Australian agriculture. The profit function used for the study, the estimated supply elasticities, a discussion of the results and, finally, the conclusions of the study are then presented. The data and methodology are shown in the Appendix.

Previous Issues and Research

In modelling supply response the researcher is faced with a variety of choices concerning model structure, data structure and behavioural equations. The data structure could be time-series, cross-section or both combined. The model structure could involve either a single equation or a system of equations. Most of the econometric models in the literature on Australian agriculture have used either single-equation production function models or single-equation output supply response models. Concentration on a single output response can lead to specification error in the model, because production decisions about one output in Australian broadacre agriculture are likely to be related to those about other outputs. Attempts which have been made to accommodate multiple output production explicitly in the model specification include Vincent, Dixon and Powell (1980), McKay, Lawrence and Vlastuin (1982 and 1983), Wall and Fisher (1987), and Lawrence and Mitsch (1989).

Estimation of agricultural supply response requires a number of somewhat arbitrary assumptions about the appropriate behavioural equations. The first choice is that of the dependent variable, which has to be a measure of supply. In the majority of analyses, crop supply has been measured as quantity produced, although in more recent studies supply has been measured as the area sown to the crop¹. This latter measure seems preferable, since it avoids the large effect that random, uncontrollable, post-planting effects such as weather can have on quantity produced. Moreover, it is most likely that the farmer's primary decision variable is area sown rather than quantity produced. However, it can be argued that in the long run farmers do have a perception of the quantity produced from a given unit area. For livestock, supply is usually measured in head; for wool, numbers of bales is more appropriate. However, some studies use weights instead, in both cases.

The second choice concerns the explanatory variables. The most usual are own prices, prices of alternative products, prices of inputs and 'technological change'. Lag structures on price, such as geometric and polynomial lags, and simple moving averages of past prices, have been used in an attempt to model price expectations. The common proxy for technological change has been time.

¹ In instances where economic theory does not allow for area to be the dependent variable, production is used. This applies mainly to the profit function approach to modelling supply responses.

TABLE 1

Own- and Cross-Price Supply Elasticities in Australian
Broadacre Agriculture

Study and data period	Elasticity of supply of:	<u>with respect to price of :</u>			Response time
		Crops/ wheat	Sheep/ wool	Cattle/ other	
Vincent, Dixon and Powell 1952-53 to 1973-74 (Annual)	Wheat	0.77	-0.25	-0.11	Short run
	Wool	-0.20	0.25	-0.18	
	Beef	-0.27	-0.08	0.48	
McKay, Lawrence and Vlastuin (1983) 1952-53 to 1976-77 (Annual)	Crops	0.50(b)	-0.42	0.43	Short run
	Sheep/wool	0.15	0.72	0.08	
	Beef	-0.48	0.25	0.12	
Dewbre, Shaw and Corra (1985) 1959-60 to 1982-83 (Annual)	Wheat	0.40	-0.09	-0.03	Medium run
	Wool	-0.06	0.31	-0.24	
	Beef	-0.17	-0.12	0.29	
Hall, Fraser and Purtill (1988) 1983-1984	Wheat	1.4	0.00	0.20	Long run
	Wool	-0.20	2.50	-2.30	
	Beef	0.10	-1.90	2.40	
<u>Livestock</u>					
Lawrence and Zeitsch (1989) 1972-73 to 1977-78, 1980-81 and 1986-87	Crops	0.20		0.19(c)	Short run
	Livestock	0.10		0.19	

(a) Wheat/sheep zone. (b) Using composite price of crops. (c) Using livestock price.

Studies of Australian broadacre supply response provide interesting contrasts in methodologies, underlying assumptions, data and estimation techniques; and the elasticities obtained vary widely (Table 1). Vincent et al. (1980) used a 'constant ratio of elasticity of substitution homothetic/constant ratio of elasticity of transformation homothetic' (CRESH/CRETH) system of multi-product supplies. For the period 1952-3 to 1973-4, they estimated short run supply elasticities of 0.77 for wheat, 0.50 for barley, 0.25 for wool/sheep and 0.48 for cattle, supplies being measured as quantity produced.

McKay et al. (1983) relied on cross-parameter constraints derived from a translog variable profit function to estimate a short run elasticity for total crop supply of 0.50, with cross-price elasticities of -0.42 and 0.43 with respect to beef and sheep products, respectively. They measured output as quantity of grain sold. In contrast to other studies, these elasticity estimates imply a significant complementarity between the crop and sheep industries on the Australia-wide scale.

The Econometric Model of Australian Broadacre Agriculture (EMABA) constructed by Dewbre, Shaw, Corra and Harris (1985) measured output response in terms of area sown, and a land area share model was employed to determine the share of total cultivable land available to crops and livestock. The broadacre 'allocation' decisions were viewed as hierarchical and as each being determined by relative expected profitabilities. The period of estimation was 1957-58 to 1981-82 and the data observations were annual. Supply elasticities were calculated for one year and for long and medium run. The estimated medium run (greater than five years) own-price supply elasticities included 0.40 for wheat, 0.31 for wool and 0.29 for beef. The cross-price elasticities were very close to zero.

Wall and Fisher (1987) used profit function models to study production decisions in the Australian sheep industry over the period 1967-68 to 1980-81. Own-price elasticity estimates were highest for wheat and other crops, with the wool estimate usually the lowest. Except for wheat produced in the pastoral zone, all own- and cross-price elasticity estimates were - like those above - less than unity.

Hall, Fraser and Purtil (1988) employed the Bureau's regional linear programming model. They estimated long run supply elasticities of greater than one for wool, sheep meat, beef and crops. In the long run, wool and sheep meat were clearly complements, and beef cattle and crops appeared to be complementary to a limited degree. Wool price had no effect on crop production, and the effect of crop price on wool production was negative.

Lawrence and Zeitsch (1989) estimated a profit function model using pooled cross-section, time series data covering six states and eight years, derived mainly from the Australia Bureau of Statistics' Agricultural Finance Survey. They estimated short run supply elasticities of 0.20 for crops and livestock. Their estimated cross-price elasticities were 0.20 for crops supply with respect to livestock prices and 0.10 for the converse. Their findings generally indicated a lack of price responsiveness in Australian agriculture, and the continued importance of productivity improvements in accounting for output change. In general, own-price elasticities from past studies in Australia also indicated a lack of price responsiveness in Australian agriculture (Table 1).

The Duality Approach to Modelling Supply Response

There are two modelling approaches to estimating supply response, the primal and dual approaches. In the primal approach the boundary of a production transformation set is estimated directly. In the dual approach, profit, cost or revenue functions are instead estimated. The use of a profit or cost function framework makes it possible to model producers' response to market conditions given only the constraint of certain fixed inputs within each time period. With the amount of the fixed input given, the model represents the producers' choice of quantities of outputs and variable inputs to maximise their profit each period. Wall and Fisher (1987) indicate that the dual approach has the following advantages over the primal approach for studying production decisions:

- In the dual approach prices are specified as the exogenous variables, whereas in the primal approach input quantities are specified as exogenous. It follows that there are likely to be fewer statistical problems with the dual approach.

- . The estimates of output supply, input demand and price elasticities are more easily derived in the dual than in the primal approach. In addition, monotonicity, convexity, homogeneity and symmetry restrictions can be easily imposed and tested statistically in the output supply and input demand functions.
- . The dual approach is more flexible for modelling multiple-output systems. In most cases a production function is not an adequate specification of a multiple-output production technology, because either non-jointness or input-output separability (defined below) has to be assumed.
- . The hypothesis of non-jointness of outputs can be statistically tested in the dual approach.

Just, Zilberman and Hochman (1983), presenting a recent development in estimation of multi-crop production functions, considered whether separability or non-jointness is the better approach for attaining tractability in such functions. Non-jointness - that is, each input usable for the production of a single output only - is the stronger assumption. It clearly does not hold for Australian broadacre agriculture. The weaker assumption, separability, is essentially that the choices of input and output mixes are made independent of each other. Just et al. (1983) indicated that if a farmer grows several crops, the allocation of inputs among crops is not necessarily recorded nor available. This is true in the Australian case. Nevertheless, their approach to supply response is based on the assumption of non-jointness. Their multiple-output production technology is described by a system of independent production functions subject to variable and fixed input allocation equations.

Wall and Fisher (1987), on the other hand, found that in the wheat/sheep and high rainfall zones of Australia, non-jointness cannot be used to simplify economic models of the production technology. Neither does this approach provide an adequate measure of the differences in land quality. Shumway, Pope and Nash (1984) concluded in their study that various approaches are needed depending on the source of jointness. They suggested that allocable fixed inputs are an important source of jointness and showed that where input allocation equations are required, the primal approach such as that of Just et al. (1983) has to be used.

In addition to the advantages stated above, the dual approach can also make full use of the detailed information on input usage obtained in the surveys carried out by the Bureau. As Wall and Fisher indicated, in much of the previous empirical work - especially the single-output supply equation models - it was not possible to fully accommodate the multiple-output production nature of Australian agriculture because of the lack of a theory of multiple-output production. The method employed in the present study, and the sources of data used, are explained in detail in the Appendix. The derivation of relationships from an explicitly specified profit function implies certain symmetries between input price effects on output supply and output price effects on input demand. Even if input demand is not estimated, the incorporation of the input usage in the analysis will certainly improve the estimation of supply relationships.

Profit Function

A restricted expected variable-profit function is used which will permit the derivation of functional forms for output supply and variable input

demand via the duality theory. Denoting the production technology by T , variable net output quantities by the vector x (positive for outputs, negative for variable inputs), fixed quantities of inputs by the vector z , and net output prices by the vector p , the restricted expected profit function can be expressed as:

$$(1) \quad \Pi(p; z) = \max_x (p' x : (z; x) \text{ belong to } T, p \geq 0)$$

T is assumed to be a non-empty, compact, and convex set. Under this assumption, $\Pi(p; z)$ is homogenous of degree one in variable input and output prices and in fixed input quantities, convex in net output prices, and concave in quantities (Diewert 1974). Detailed properties on the variable profit function can be found in Diewert (1974, 1982). If $\Pi(p; z)$ is differentiable the net output supply function can be derived by applying Hotelling's lemma,

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

where $x(p; z)$ is the profit maximising level of net output supply (or input demand) if i is an output (or variable input) (Hotelling 1932). Therefore, $\Pi(p; z)$ is assumed twice continuously differentiable.

One of the problems encountered by applied economists when using flexible functional forms in the producer or consumer context is that the theoretical curvature conditions (concavity, convexity, or quasi-concavity) implied by economic theory are frequently not satisfied by the estimated cost, profit, or indirect utility function (Diewert and Wales 1987). Earlier studies of supply response in Australia by McKay et al. (1983) and Wall and Fisher (1987) using the translog, quadratic and Generalised Leontief flexible functions failed to satisfy the convexity property. The translog and quadratic variable profit functions were used in this study and also failed to satisfy the convexity property. An earlier attempt to overcome this problem was by imposing curvature on the translog function (Jorgenson and Fraumeni 1981, cited by Lawrence 1988). However, loss of flexibility and biases in the estimated elasticities can result (Diewert and Wales 1987).

A major recent thrust of the theory of duality has been to find ways of imposing the convexity conditions that were rejected by estimated models. The rejection of these conditions amounts to rejection of the assumption of profit maximisation, which is the foundation on which the dual theory is based. The functional form used in this study is the symmetrised form (SGM) of the Generalised McFadden (GM) form developed by Diewert and Wales (1987). Curvature conditions can be imposed on this functional form without the loss of flexibility (Lawrence 1988). However, nonlinear regression techniques then have to be used. Past empirical studies using the GM form include Lawrence and Zeitsch (1989), Lawrence (1987) and Diewert and Morrison (1986). The present study uses the technique employed by Diewert and Wales (1987) and Lawrence (1988) and builds on the work of Lawrence and Zeitsch (1989) (though using an altogether different set of data).

Dynamic supply responses are not uncommon in agriculture. In past studies using single equations, dynamics have been represented by various means, such as Nerlove's partial adjustment model. It is much more difficult to incorporate dynamics into flexible functional forms like the SGM, and it has not been done in this study (though output prices have been lagged empirically). It is expected that, in future studies, the inclusion of dynamics while maintaining consistency with the theoretical base of duality will enhance our knowledge of supply response.

The study uses data from ABARE's Australian Agriculture and Grazing Industries Survey (AAGIS). Data covering the period 1978 to 1987 are pooled across five states, producing 50 observations. Four netputs and one quasi-fixed input are used. Three of the netputs are outputs: wheat, wool and cattle. (Sheep was originally included as a separate netput, but later excluded because it failed to show any appreciable or statistically significant supply responses.) The remaining netput is an aggregation of the four inputs hired labour, capital, livestock input, and materials and services. Aggregation of inputs was possible because the study is mainly concerned with supply, rather than demand, elasticities. Farm family labour is treated as a quasi-fixed input - that is, as fixed in any given year. To conserve degrees of freedom, constant returns to scale with respect to the quasi-fixed input are imposed. Empirically, the output prices are lagged one year in the case of wheat, two years for wool and three years for cattle. The data used and the methodology employed are discussed in detail in the Appendix.

The GM functional form for the four netputs is as follows:

$$(3) \quad \Pi(p;z)/z = 1/2 \sum_{i=1}^3 \sum_{j=1}^3 b_{ij} p_i p_j / p_4 + \sum_{i=1}^4 b_i p_i \\ + \sum_{i=1}^4 b_{it} p_i t + b_{tt} \left(\sum_{i=1}^4 \gamma_i p_i \right) t^2$$

where symmetry restrictions are imposed on the b_{ij} , ie:

$$(4) \quad b_{ij} = b_{ji} \text{ for all } i, j = 1, 2, 3$$

The expression is divided by the quasi-fixed input z to reduce heteroscedasticity in the estimated equations derived from it. The subscripts i and j denote wheat, wool, cattle and the aggregate input (1, 2, 3 and 4 respectively); t is an index of technology and the γ_i are exogenous constants set equal to the respective mean unit output quantities to conserve degree of freedom.

Applying Hotelling's lemma, the following set of unit net output supply equations is obtained

$$(5) \quad x_i/z = b_i + \sum_{j=1}^3 b_{ij} p_j / p_4 + b_{it} t + b_{tt} \gamma_i t^2; \quad i = 1, 2, 3;$$

$$(6) \quad x_4/z = b_4 - 1/2 \sum_{i=1}^3 \sum_{j=1}^3 b_{ij} p_i p_j / p_4^2 + b_{4t} t + b_{tt} \gamma_4 t^2$$

The estimating system consists of equations (5) and (6) with vectors of error terms attached which are assumed to be independently distributed with a multivariate normal distribution with zero means and general covariance matrix. The theory of the application of time-series and cross-section data are described in Fuss (1977) and Swamy and Arora (1972). Since the data are

pooled by states and time, the covariance model with dummy variables for states is appropriate (Judge, Griffiths, Hill, Lutkepohl and Lee 19^a). State dummy variables S_k were therefore used to allow for differences in product mixes and production efficiency between states, as in Lawrence and Zeitsch (1989).

The estimating system is therefore:

$$(7) \quad x_i/z = \sum_{k=1}^5 d_{ki} S_k + b_1 \sum_{j=1}^3 b_{ij} p_i p_j / p_4 + b_{it} t + b_{tt} \gamma_i t^2 + u_i;$$

$$i = 1, 2, 3;$$

$$(8) \quad x_4/z = \sum_{k=1}^5 d_{k4} S_k - 1/2 \sum_{i=1}^3 \sum_{j=1}^3 b_{ij} p_i p_j / p_4^2$$

$$+ b_{4t} t + b_{tt} \gamma_4 t^2 + u_4$$

with symmetry restrictions imposed.

Productivity indices derived from the data themselves were used as the technology index t . A simple time trend would have failed to capture the seasonal climatic conditions which undoubtedly can influence output quantities. On the other hand, a seasonal climatic index alone would have failed to capture the effects of advances in technology. To use both would have increased the degrees of freedom impracticably.

The above system can be estimated using either Zellner's iterative Seemingly Unrelated Regressions (SUR) estimator or some other iterative algorithm procedure to obtain maximum likelihood estimates. The SUR procedure in the SAS econometric package was in fact used for the model estimation.

As mentioned earlier, a limitation of duality theory has been the failure of the models to satisfy the curvature conditions. With the GM function, if the matrix of the estimated quadratic terms, $B = (b_{ij})$, is positive semi-definite then the profit function is globally convex in prices. If B does not satisfy the positive semi-definite condition then it can be reparametrised. Lawrence and Zeitsch (1989) used the Wiley, Schmidt and Bramble (1973) technique of imposing positive semi-definiteness conditions on the matrix of second-order coefficients from the GM function. This technique replaces B by the product of the lower triangular matrix and its transpose which is:

$$(9) \quad B = AA' \quad \text{where } A = (a_{ij}); i, j = 1, 2, 3; \text{ and } a_{ij} = 0 \text{ for } i < j$$

When the above is done the GM function will be globally convex in prices without having lost its flexibility properties (Lawrence and Zeitsch 1989; Diewert 1985). The reparametrised system, imposing curvature, can be estimated by using nonlinear regression techniques.

Supply Elasticities

In the case of a variable profit function the supply elasticities represent a change in the net supply of i in response to a change in the price of the net output j , subject to the quantity of the fixed input variable. The elasticities derived will indicate the characteristics of the production technology and net output responses. The netput supply elasticities are given by:

$$(10) \quad E_{ij} = d \ln x_i / d \ln p_j = Dp_{ij} p_j / x_i; \quad i, j = 1, 2, 3, 4$$

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

$$(11) \quad Dp_{ij} = b_{ij} / p_4 \quad \text{for } i, j = 1, 2, 3;$$

$$(12) \quad Dp_{i4} = - \sum_{j=1}^3 b_{ij} p_j / p_4^2 = Dp_{4i} \quad \text{for } i = 1, 2, 3; \text{ and}$$

$$(13) \quad Dp_{44} = \sum_{i=1}^3 \sum_{j=1}^3 b_{ij} p_i p_j / p_4^3$$

Discussion of Results

Parameter estimates obtained by estimating the specified system of equations (7 and 8) failed to satisfy the curvature criteria which required that the estimated functions be convex with respect to output and input prices. As has been mentioned, these criteria can be imposed by reparametrising the B matrix using equation (9). The nonlinear regression algorithm of SYNLIN and SIMNLIN of the SAS package was used to estimate the system of equations and supply elasticities.

Since the main objective of this analysis was to obtain output price elasticities only the output supply elasticities are presented and discussed. Short to medium run output price supply elasticities, calculated at the means of the exogenous variables, are presented for the five mainland states in Tables 2, 3, 4, 5 and 6. The elasticities for Australia (in this case, the five mainland states) are presented in Table 7. The Australian elasticities were obtained by weighting the state elasticities by the state shares in the mean output quantities.

The figures in parentheses in the tables of supply elasticities are standard errors. The standard errors were calculated using Monte Carlo simulations (in which the parameter estimates are perturbed by amounts taken from a distribution given by the variance-covariance matrix of the estimates). The estimates of wool and cattle own-price supply elasticities are statistically significant at the 5 percent level, while those for wheat are not quite significant at the 10 percent level. The cross-price

TABLE 2

Net Output Supply Elasticities (Mean Values 1978-87) for
New South Wales at Means of Exogenous Variables

Elasticity of supply of:	with respect to price of:		
	Wheat	Wool	Cattle
Wheat	0.441 (0.373)	0.278 (0.334)	0.100 (0.100)
Wool	0.226 (0.204)	0.991 (0.500)	0.172 (0.183)
Cattle	0.065 (0.091)	0.152 (0.240)	0.866 (0.217)

Figures in parentheses are standard errors.

TABLE 3

Net Output Supply Elasticities (Mean Values 1978-1987)
for Victoria at Means of Exogenous Variables

Elasticity of supply of:	with respect to price of:		
	Wheat	Wool	Cattle
Wheat	0.384 (0.335)	0.341 (0.566)	0.101 (0.103)
Wool	0.195 (0.175)	0.887 (0.487)	0.161 (0.125)
Cattle	0.063 (0.092)	0.185 (0.220)	0.806 (0.245)

Figures in parentheses are standard errors.

TABLE 4

Net Output Supply Elasticities (Mean Values 1978-1987)
for Queensland at Means of Exogenous Variables

Elasticity of supply of:	with respect to price of:		
	Wheat	Wool	Cattle
Wheat	0.223 (0.160)	0.185 (0.213)	0.062 (0.040)
Wool	0.287 (0.279)	1.224 (0.702)	0.236 (0.190)
Cattle	0.064 (0.122)	0.156 (0.591)	0.866 (0.482)

Figures in parentheses are standard errors.

TABLE 5

Net Output Supply Elasticities (Mean Values 1978-1987)
for South Australia at Means of Exogenous Variables

Elasticity of supply of:	with respect to price of:		
	Wheat	Wool	Cattle
Wheat	0.143 (0.092)	0.118 (0.113)	0.037 (0.100)
Wool	0.191 (0.159)	0.848 (0.418)	0.162 (0.140)
Cattle	0.078 (0.133)	0.220 (0.316)	0.844 (0.272)

Figures in parentheses are standard errors.

TABLE 6

Net Output Supply Elasticities (Mean Values 1978-1987)
for Western Australia at Means of Exogenous Variables

Elasticity of supply of:	with respect to price of:		
	Wheat	Wool	Cattle
Wheat	0.366 (0.899)	0.217 (0.845)	0.087 (0.234)
Wool	0.225 (0.219)	0.991 (0.504)	0.178 (0.172)
Cattle	0.060 (0.103)	0.156 (0.256)	0.839 (0.246)

Figures in parentheses are standard errors.

TABLE 7

Net Output Supply Elasticities (Mean Values 1978-1987)
for Australia at Means of Exogenous Variables(a)

Elasticity of supply of:	with respect to price of:		
	Wheat	Wool	Cattle
Wheat	0.262	0.196	0.067
Wool	0.213	0.938	0.172
Cattle	0.060	0.161	0.790

(a) For the five mainland states.

elasticity estimates are not statistically significant. The Australian estimates in Table 7 indicate that output price responses for wheat, wool and cattle are inelastic.

The own-price supply elasticities all have the expected sign, but the six cross-price elasticities (though none is individually significant) all indicate that the relationships between wheat, wool and cattle are complementary. Evidence of short run complementarity in Australian broadacre agriculture has also been found by Lawrence and Zeitch (1989) and Hall, Fraser and Purtill (1985). These complementarity results may not be regarded as consistent with a priori expectations from economic theory, but in fact a mixed farmer may find it profitable to expand all activities when the price of one of the outputs goes up. Note that the largest increase is always seen to be in the area where the price increase has occurred. According to Lawrence and Zeitsch (1989), if production is unconstrained by the availability of fixed resources such as land or family labour (including farm operators), the expansion of one output would lower the costs of producing other outputs. In other words, as economies of scale and size increase, costs per unit output are reduced and there is a gross complementary relationship between outputs and inputs. Such complementarity can be expected if family labour can be changed from year to year; if there are opportunities to expand the productive land base; if farmers are over-using their resources; or if greater intensity of farming is practised when output prices rise together.

The estimates of elasticities were generally consistent with those of other studies in the literature. The estimated elasticities are short to medium run (1-3 years). Because of the relatively long biological lags in livestock production, livestock outputs will exhibit a lagged adjustment to output prices. The lag structures of output supply were not readily amenable to estimation in the study because of the functional form which was used to accommodate the multi-product theoretical approach. Because of the dynamic nature of livestock production, lagged output prices were used in the model estimation, which produced higher estimates for own-price elasticities than when lags were not used. It appears that, for long run elasticities to be estimated, profit functions should take account of the dynamic nature of supply response in terms of production and output prices.

Because of the weak complementary relationships between broadacre industries - which may be one factor underlying the appreciable own-price responsiveness - implications for policy formulation need careful consideration. For example, knowledge regarding producers' behavioural characteristics with respect to choices among enterprises and decisions on the expansion and intensity of input use (especially of the quasi-fixed inputs) is central to policy decisions affecting prices of outputs, such as the guaranteed minimum price for wheat and the minimum reserve price for wool. The price elasticities indicate that there is little short term fluctuation in output due to price changes, and therefore that a large price variation will considerably affect farm incomes.

Conclusions

In this study the SGM functional form, with global convexity imposed, was used to estimate short to medium run supply response in Australian broadacre agriculture. The estimates were derived from survey data on a state basis. In a number of previous studies, simpler models and different data sets have been used. Nevertheless, the main findings of those studies

was confirmed, in that short to medium term supply response was found to be inelastic. Some evidence for complementarity was found, as in several other studies, although the relevant coefficient estimates were not statistically significant.

The method chosen here to model supply response was justified on the ground that it accommodates the multi-product nature of Australian broadacre agriculture. On the other hand, the exclusion of dynamics from this specification means that further investigations would be needed to establish the magnitude of the supply response, as well as the nature of cross-product relationships, in the longer run. The incorporation of dynamics into profit functions would make them a more rigorous and attractive approach to modelling supply response in Australian agriculture.

APPENDIX

Data Sources and Methodology

The main source of data used in this study was the ABARE Australian Agriculture and Grazing Industries Survey (AAGIS) and the relevant prices paid and received indices (ABARE 1989) for each state and year. The values and quantities used in the analysis were derived from AAGIS. The period of the study was 1978 to 1987. The data were aggregated to the state level over the ten years, producing 50 observations from the five states, New South Wales, Victoria, Queensland, South Australia and Western Australia; Tasmania was omitted because of lack of data for some of the variables in some periods of the survey. In extracting the data set, the constraint of 200 or more sheep per farm was imposed; this constraint improves the representation of the production mix of the three outputs of the study and their substitution possibilities.

The AAGIS value data were combined with the ABARE prices paid and received indices to produce Divisia price and implicit quantity indices for all the categories of output and input. The Divisia index technique is based on the homogeneous translog production function, which approximates consistency in aggregation. Four netputs and one fixed (or quasi-fixed) input were used in the study. The netputs were three outputs (wheat, wool and cattle) and aggregated farm inputs excluding farm family labour. The data for all the netputs were weighted averages for the AAGIS sample farms on a state basis.

The aggregated farm inputs comprised two non-durable inputs (hired labour, material and services), and two durable inputs (capital and livestock input). For capital, a real opportunity cost of 4 per cent and a depreciation value of 5 per cent were used. Capital was assumed to consist of all farm machinery, motor vehicles, workshop and livestock equipment. Land, for which there was no consistent and accurate value or price series, was omitted from the estimating variables. (Although relative prices are expected to be the principal determinants of input and output mix in the long run, the slow speed of adjustment of such factors as land means that for the medium run of one to three years they can be regarded as constant.) From the stock value, a user cost value was derived assuming that farmers aim to make a specific rate of real return on their assets. A real opportunity cost of 4 per cent of the livestock stock value was added to sheep and cattle purchases. Sheep purchases were attributed to wool production and meat production in the ratio 4:1, based on the shares of revenue from sheep and wool over the period of the study.

For operator and farm family labour, no value was required as it was treated as quasi-fixed.

Output prices used in the estimation were lagged variously. It was assumed that agricultural producers normally make their production decisions before actual output prices are known, and respond to expected prices which in fact are past years' prices. The lag periods were chosen to maximise statistical significance, using OLS. Output prices were lagged one year for wheat, two years for wool and three years for cattle.

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