Australian Journal of Agricultural Economics, Vol. 31, No. 3 (December 1987), pp. 266-271

SHORT-RUN SUBSTITUTION IN THE SHEEP AND BEEF INDUSTRIES

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There has been a substantial amount of research into the effect of changes in the relative prices of factors on the mix of resources in Australian agriculture. Studies have concentrated on the changing structure of agriculture with regard to broad aggregates such as labour, land and capital (see, for example, Vincent 1977; McKay, Lawrence and Vlastuin 1980). The analysis is relevant to an understanding of developments in the rural sector and hence to certain aspects of policy. However, not all problems relating to input substitution in response to relative price changes can be handled in such a framework. Over a short time horizon such as one year, only a subset of factors can be regarded as variable or determined predominantly by current prices. For instance, rents, interest payments and expenditure on livestock and capital equipment are determined by long-run intertemporal considerations. While relative prices are the determinants of input mix in the long run, the slow speed of adjustment of such factors as land means that for the short run they can be regarded as constant.

The stimulus for this study is the involvement of the Australian Bureau of Agricultural and Resource Economics in estimation and short-term projection of farm cash costs. Estimates and projections are based on a large and complex set of information which is available to the Bureau through its own monitoring and from other agencies. This information set is combined with a set of assumptions regarding interrelationships between quantities and prices to estimate costs and their components. In the absence of reliable information on input substitution, it might seem reasonable to assume that demand for the inputs is generated by fixed input–output technology, which certainly reduces the complexity of estimation substantially. However, without the evidence from rigorous research, this assumption cannot be regarded as anything more than guesswork. An attempt is made here to fill the gap that exists in Australia regarding the relative magnitude of elasticities of demand for a particular group of inputs.

Estimates of price elasticities within a set of major variable inputs for the Australian sheep and beef industries are presented. The set was chosen to exclude those items which depend on long-run investment decisions such as land, livestock, plant and machinery. A well-known input demand system is estimated using data derived from the Bureau's surveys. The substitution parameters derived from these estimates are presented and the implications discussed.

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Methodology

Elasticities were estimated using a system of demand equations based on the work of Hanoch (1975). This approach has been widely discussed and employed in the economic literature (see, for example, Dixon 1980; Lewis 1985). The particular form employed in this paper is the constant ratio elasticity of substitution system. The popularity of this system among economic researchers is in part due to the lack of restrictions implicit in simpler specifications such as Cobb–Douglas and constant elasticity of substitution (CES). Vincent (1977) concluded that both the Cobb–Douglas and CES production function specifications for the Australian agricultural sector are inappropriate. The other major reason for the popularity of the Hanoch system is its ease of estimation and small number of parameters compared with the more general transcendental logarithmic specification (Hanoch 1975).

The constant ratio elasticity of substitution specification allows relatively easy measurement of the relevant elasticities of substitution. These are the Allen–Uzawa elasticities most commonly employed in the substitution literature (Allen 1938). They measure the change in demand for a factor relative to the change in total cost of production due to the change in price of another factor, holding output and other input prices constant. Price elasticities, holding output and other prices constant, are found by multiplying these Allen–Uzawa elasticities by the relative share of total costs attributable to each factor. These price elasticities are of most interest in our case since they show the extent to which changes in relative prices affect relative input use.

For a single output, n-input production function, a general system involves a set of equations of the form:

$$(1)\quad \log x_{it} = A_i + a_i \log(p_{it}/p_{1t}) + b_i \log q_t + (a_i/a_1)\log x_{1t} + c_i t$$

where p_i = price of i-th input;
x_i = quantity of i-th input;
q = quantity of output; and
t = time.

A_i, a_i, b_i and c_i are constants and input 1 is an arbitrarily chosen numeraire. The subscript t represents observations at a particular point in time. Time is included to take account of changes in input use over time due to such factors as technical progress and changes in resources such as capital and land. In initial specifications of the model, land and capital variables were specifically incorporated into the regression equations. Unfortunately, these variables are so highly correlated with output that individual influences were impossible to identify. Including only output and time implicitly assumes that the factors affecting input mix, other than input prices, are directly related to output or change steadily over time.

The Allen–Uzawa elasticity of substitution between any two inputs i and j is $a_i a_j / \sum_k a_k s_k$ and the corresponding price elasticity (e_{ij}) is $\sigma_{ij} s_j$, where s_j is the share of input j of total cost.

Data

The data on prices of inputs are from the relevant prices paid indexes (BAE 1984) for each state and year. The quantities used in the analysis

are derived from Bureau surveys. From individual farm data the average value of each input per farm is calculated and then deflated by the relevant price index to obtain a quantity measure. Consistent series were derived from the following surveys for different years: Australian Sheep Industry Survey, 1964–65 to 1972–73; Australian Grazing Industry Survey, 1973–74 to 1977–78; and Australian Agricultural and Grazing Industries Survey, 1978–70 to 1981–82. For the beef industry observations are from 1968–69 to 1981–82, excluding 1972–73, for all six states plus the Northern Territory. The sheep industry observations are for the six states between 1964–65 and 1981–82.

Since this study is concerned only with single output industries a subset of the total sample of farms needs to be defined. Truly single output farms are rare but it is common practice to define single output farms as ones which concentrate on a specific activity relative to others. The definitions employed in this study are as follows. Sheep farms are those carrying 200 or more sheep and fewer than 50 head of beef cattle with less than 40 ha sown to crops. Beef farms are those with 50 or more head of beef cattle, fewer than 200 sheep and less than 40 ha sown. These definitions differ from those referred to in Bureau publications. Here, more restrictive definitions are employed in order to make the observations more activity specific. The industries defined account for approximately half of all beef production and a quarter of all sheep production.

The purpose is to estimate price elasticities for the major short-run variable factors. These are hired labour, chemicals, fertiliser and fuel. The demand system included an equation for each of these inputs except the numeraire, labour. For the sheep equations all states are used in the analysis and for beef all states plus the Northern Territory.

It would be inappropriate to consider only current sales and stock increases as a measure of outputs since much of the variable input use is for maintenance and improvement of livestock for future sale. Total livestock carried is the important determinant of the demand for variable inputs. The results reported in this paper are those where closing livestock numbers are used. Several other measures of total livestock were used but made little difference to the results.

Estimation

Since the data are pooled by states and time, the covariance model with dummy variables for states is appropriate (Judge, Griffiths, Hill and Lee 1980). Labour was chosen as the numeraire. Its substitution coefficient, a_1, appears in each equation and therefore imposes restrictions both within and across equations. This restriction is that the ratio of the coefficient of relative price to that of the numeraire is equal for every equation. The restrictions imposed on the model require a full systems method of estimation. The system was estimated employing three-stage least squares.

Results

The full set of estimates is given in Tables 1 and 2. Throughout the results, the numbers in parentheses are the absolute values of the t-statistics. In both industries the coefficients of the state dummy

TABLE 1

Estimates of Parameters for the System of Input Demands: Sheep Farms[a]

Demand for	A_i	a_i	b_i	c_i	State dummies[b]					R^2
					NSW	*Vic.*	*Qld*	*WA*	*SA*	
Chemicals	−2·82	−0·30	0·20	0·02	0·45	0·27	0·45	0·20	0·24	0·68
	(1·98)	(2·49)	(0·96)	(3·11)	(3·37)	(2·23)	(2·28)	(1·86)	(1·28)	
Fertiliser	2·22	−0·48	0·10	−0·03	−0·48	0·20	−5·31	0·17	0·58	0·89
	(0·79)	(2·39)	(0·22)	(2·51)	(1·66)	(0·76)	(12·03)	(0·69)	(1·10)	
Fuel	1·13	−0·26	−0·02	0·00	0·19	0·26	0·08	0·40	0·47	0·53
	(1·27)	(2·72)	(1·08)	(0·75)	(2·02)	(3·06)	(0·56)	(5·16)	(3·19)	

[a] Figures in parentheses are the absolute values of the *t*-statistics.
[b] The excluded state is Tasmania.

TABLE 2

Estimates of Parameters for the System of Input Demands: Beef Farms[a]

Demand for	A_i	a_i	b_i	c_i	State dummies[b]						R^2
					NSW	*Vic.*	*Qld*	*WA*	*SA*	*Tas.*	
Chemicals	−1·53	−0·41	−0·03	0·03	−0·32	0·06	0·06	−0·59	−0·04	−0·31	0·67
	(0·79)	(2·34)	(0·15)	(2·75)	(0·40)	(0·07)	(0·11)	(0·87)	(0·15)	(0·36)	
Fertiliser	1·14	−0·68	−0·21	−0·04	3·20	3·73	3·09	3·33	4·24	3·38	0·64
	(0·35)	(2·93)	(0·56)	(2·11)	(2·30)	(2·52)	(3·20)	(2·81)	(4·43)	(2·27)	
Fuel	4·69	−0·23	−0·03	0·01	−1·62	−1·41	−1·14	−1·15	−1·12	−1·64	0·95
	(5·17)	(2·50)	(0·29)	(1·48)	(4·06)	(3·30)	(4·08)	(3·36)	(4·08)	(3·76)	

[a] Figures in parentheses are the absolute values of the *t*-statistics.
[b] The excluded state is the Northern Territory.

variables were significantly different, as a set, from zero. These results indicate the appropriateness of the pooling procedure adopted (see Judge et al. 1980). The goodness of fit as measured by R^2 is relatively high for pooled data. All estimates of the a_i coefficients have the expected signs and are significantly different from zero.

The output coefficient was not significant in any equation. This implies that the *mix* of inputs does not depend directly on output although, of course, the *level* of inputs depends on output. This is an important result in that it implies that only changes in relative input prices change the input mix. The mix is neutral with respect to output changes. The coefficient of time for both the beef and sheep industries indicates that over time, per unit of output, there has been increased use of chemicals, reduced use of fertiliser, and little change with respect to use of fuel, after accounting for changes due to relative price movements.

The substitution coefficients show that there is substitution between inputs due to relative price changes but that the degree of substitution is low. The substitution coefficients are all negative and significantly different from zero at the 5 per cent level. The coefficients for both the sheep and beef industries are of the same general order of magnitude.

Tables 3 and 4 show the corresponding Hicksian (output constrained) price elasticities. All are very small, even those with respect to labour, which are generally the largest. As a consequence all own-price elasticities are somewhat small and certainly less than unity. This implies that in the short run, relative price changes have little effect on the use of these inputs. The results of the study indicate that, for given output, input substitution in response to changes in input prices is low. Also, the results are similar for both the livestock industries.

TABLE 3

Price Elasticities of Demand: Sheep Farms

	Change in price of			
Change in demand for	Labour	Chemicals	Fertiliser	Fuel
Labour	−0·23	0·04	0·12	0·07
Chemicals	0·19	−0·23	0·01	0·03
Fertiliser	0·30	0·01	−0·36	0·05
Fuel	0·16	0·02	0·04	−0·22

TABLE 4

Price Elasticities of Demand: Beef Farms

	Change in price of			
Change in demand for	Labour	Chemicals	Fertiliser	Fuel
Labour	−0·37	0·06	0·19	0·12
Chemicals	0·27	−0·39	0·08	0·04
Fertiliser	0·45	0·04	−0·53	0·06
Fuel	0·20	0·01	0·04	−0·25

Conclusion

On the one hand, the evidence presented in this paper is rather reassuring to those who have been working within an input–output framework for short-run analyses since the degree of input substitution in the sheep and beef industries, according to the results reported in this paper, is low. Thus, for relatively small changes in relative prices, the bias inherent in assuming no factor substitution is most likely small. However, all the estimated equations indicate that the substitution parameters are significantly different from zero. Thus a large increase in the price of one input relative to all others would result in a significant fall in the use of that factor.

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