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SUPPLY RESPONSE WITH STOCHASTIC TECHNOLOGY AND PRICES IN AUSTRALIA'S RURAL EXPORT INDUSTRIES

by

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Introduction

Production and price risks affect the economic welfare of Australian farmers. Much of the cultivated and grassland area of the country experiences a high variability in precipitation and many regions are subject to harsh climatic conditions. Widely fluctuating yields are a frequent result. Furthermore, many rural commodities are sold for export and prices received by producers are subject to the volatility inherent in international agricultural product markets.

Seventy percent of agricultural exports from Australia are represented by beef (including veal), wheat and wool. In 1977, Australia produced only 4 percent of the world's beef but exported about one-third of her production, for over one-fifth of the world total beef exports. In the same year, beef exports from Australia formed more than 50 percent of total beef imports to the U.S. representing less than 8 percent of U.S. beef consumption. Therefore, whilst changes in U.S. beef import policies might have only marginal effect on domestic consumption, their impacts are magnified manyfold back to the Australian beef producer.

A similar assessment can be made for wheat and wool. During the period from 1974-75 to 1977-78, Australia exported between 66 and 119 percent of its total wheat production.[1] In 1977, Australia contributed almost 30 percent of total wool production in the world. Virtually all Australian wool production is exported, accounting for some 60 percent of greasy wool traded. As a result, Australia is highly vulnerable to changes in the levels of economic activity in importing countries and resultant fluctuations in wool demand. Evidence of this vulnerability occurred in 1970-71 when world wool prices plummeted to 64.7 cents per kilogram, their lowest level since the mid 1940's.

Risk and uncertainty is not limited to the demand side. In many areas of Australia the lack of surface water and potable groundwater constitutes a major limitation to agricultural activity. In general, rural production is confined to those areas with an annual rainfall greater than 200 millimeters. Some extensive beef cattle and sheep operations encroach in these arid areas, but even in zones more suitable for farming, harsh and widely fluctuating seasonal conditions give rise to high variability in yields from livestock and crop enterprises. This is a particularly important problem for major export industries such as beef, wheat and wool. A linearized estimate[2] of the price and yield risks determining the variability of export revenues during the period from 1949-1950 to 1972-73 has ascertained that for beef and veal 37.7 percent is attributable to price changes and 62.3 percent to yield changes. For wool, the respective proportions are 94.1 and 5.9 percent; for sheepmeats, 64.7 and 35.3 percent; and for wheat, 3.1 and 96.9 percent.

The Australian Grazing Industry

In order to focus the problem of price and yield risks and to facilitate its analysis, the area of study is limited to the Australian Grazing Industry (AGI), according to the definitions of the AGI Survey. The survey sample is drawn from all farms which carry at least 200 sheep and/or 50 beef cattle.[3] Thus, the industry encompasses virtually all commercial production of wool, sheepmeat, beef and veal. Production systems are relatively extensive and are typical of dryland (nonirrigated) agriculture. For descriptive and data collection purposes, the AGI is divided into three broad climatic zones as illustrated in Figure 1. They are the pastoral zone (PZ) which consists of large, specialized and extensive livestock farms in the semi-arid areas; the wheat-sheep zone (WSZ) consisting mainly of cereal cropping enterprises often operated in conjunction with complementary livestock grazing activities; and the high rainfall zone (HRZ) consisting of fairly intensive livestock grazing enterprises in wetter coastal regions.

The importance of the AGI as an export industry is illustrated in Table 1. Between 1975 and 1979, beef and veal were exported in the amount of 30-40 percent of total production, virtually all wool produced was exported and wheat exports were in the amount of 40 to 120 percent. Taken together, the three enterprises represent almost 90 percent of the value of AGI exports.

Risk, Supply Response and Policy

Production risks arise from the variability of yields and technology or, as Magnusson (1969) states, from the uncertain performance of production factors (p. 17). Price risks include both the variability of output and input prices. In the Australian context, however, agricultural decision makers typically know in advance the prices to be paid for inputs (Anderson *et al.*, 1977). Also shortage risk, reflecting aleatory factors of production, has limited relevance for Australian farmers.

Price risk in the AGI reflects the role as a price-taker of AGI in international agricultural commodity markets. As such, price risk influences agricultural decisions rather uniformily across all regions. It is convenient to refer to it as an aggregate risk. In contrast, production risk is a regional risk, since seasonal climatic conditions vary widely across Australia.

The impact of risk is of obvious importance in the determination of AGI output levels and the industry responsiveness to changes in economic stimuli. In addition, producers' attitudes toward risk, enterprise and industry expectations of commodity outlook and prices are relevant determinants of supply. Furthermore, <u>ex ante</u> supply in the AGI is modified by alternative resource use prospects, institutional aspects controlling credit availability, and foreign and domestic agricultural policies.

Describing and monitoring in detail the forces and the effects of change within the AGI is of importance for a number of policy reasons. Principal among them are the industry ability to generate export income and the establishment of permanent trade arrangements via the stabilization of export supplies. Furthermore, ramifications from the effects of AGI supply response to environmental and economic stimuli extend into farm input, processing and service sectors of the economy. In the past, when foreign demand lulled, transferring export quantities of output onto the domestic market has created substantial problems for beef producers. During the period from 1974 to 1976, retail beef prices were at record low levels and domestic per capita beef consumption rose from 40 to 65 kilograms. Thus, whilst short-term benefits were received by domestic consumers, the variability of market conditions created problems for beef producers that could lead to subsequent deleterious problems for consumers in the longer term.

The Framework for Analysis

To accommodate to a large extent the different aspects of multiple output response of the AGI outlined above, a suitable analytical framework is in the form of response surfaces associated to a mathematical programming model. Such a model allows the detailed representation of the technological structure in each AGI region, it admits the articulation of interdependent output responses; it establishes an acceptable large-scale framework for the analysis of price and production risks; it finally allows for the parametric derivation of joint response surfaces and the associated price elasticities.

The basic model of supply response is articulated in seven response surfaces for the following categories of commodities: total expected net revenue (net of risk premium) (TNR); table beef production (TB); manufacturing beef production (MB); total beef production (BEEF); wool production (WOOL); total sheepmeat production (SHMEAT); and wheat production (WHEAT).

The response of these commodities is related in a systematic way to the variation of four prices and a parameter interpreted as a coefficient of risk aversion: the price of table beef, P_{tb}; the price of manufacturing beef, P_{mb}; the price of wool, P_{wl}; the price of wheat, P_{wh}; and the Arrow-Pratt risk aversion coefficient, ϕ. Responses are conditional upon the technology matrix A chosen to represent production processes in a five-region programming model of the AGI, the variance-covariance matrices of stochastic technological coefficients, Σ_A, and prices, Σ_p, and the vector of resource availabilities, b. Thus, the general form of the response functions is

(1) $X_i = f_i(P_{tb}, P_{mb}, P_{wl}, P_{wh}, \phi | A, \Sigma_A, \Sigma_p, b)$

where X stands for the quantities supplied and i=1,...,7 is the commodity index.

It is also assumed that the collective goal of agricultural entrepreneurs in AGI can be represented by the maximization of an expected utility of money with constant risk aversion, ϕ. Finally, the constraints describing the structure of production are specified in the form of chance constraints. Thus, the programming model underlying the response structure is of the form

(2) $\max E(p)'x - \phi x' \Sigma p x/2$

subject to

(3) $\text{Prob}\ (A_i' x \leq b_i) \geq \alpha_i, \quad x \geq 0$

i=1,...,m where Prob indicates probability of (•),

b_i is the i^{th} resource level,

α_i is the probability of fulfilling the i^{th} constraint,

ϕ is a risk aversion coefficient,

E(p) and Σ_p are the mean vector and covariance matrix of prices, respectively,

A'_i is a row vector of stochastic coefficients of production assumed to be normally distributed with mean $E(A_i)$ and variance Σ_{Ai}.

Constraint (3) requires that resource use, Ax, be less than resource availability, b, with a probability greater than α. For a risk averter α is typically greater than .5. The value $(1-\alpha)$ is referred to as the risk level.

To transform the chance constraints into their deterministic equivalents it is necessary to normalize the arguments of (3) and to proceed as in Vaida (1972). The result is a computable nonlinear programming model of the form:

(4) $\max E(p)'x - \phi x'\Sigma_p x/2$

subject to

(5) $E(A'_i)x + \theta^{-1}(\alpha_i)(x'\Sigma_{Ai}x)^{1/2} \leq b_i$

$x \geq 0 \qquad i=1,\ldots,m$

where $\theta^{-1}(\alpha_i)$ denotes the point on the standard normal distribution where the i^{th} constraint will be satisfied with a probability of at least α_i. Constraints of the type (5) are nonlinear in the quantity levels, x.

The solution of the nonlinear problem (4) and (5) was achieved in an iterative way using the commercially available MINOS program. The nonlinear portion of the constraint was shifted on the right-hand side and progressively adjusted using the optimal solution of the previous cycle. With the structure of the problem at hand, convergence was always achieved in very few cycles.

A central composite second order design in incomplete blocks, as suggested by Cochran and Cox (1957), was used to select and support the parametric variations of four output prices, P_{tb}, P_{mb}, P_{wl}, P_{wh}, and the coefficient of risk aversion (block effects). The information so generated was utilized in the estimation of the response surfaces for the seven commodities. Tables 2 and 3 illustrate the layout and the codes used in the experimental design. In total, the execution of the experimental design required 30 solutions of the nonlinear program (4) and (5). For all of them convergence was achieved with less than 5 cycles.

Empirical Implementation of The Model

A five-region classification of the production environment was chosen as a basis for characterizing technological opportunities in the AGI. This choice was founded on a previous programming study by Easter and Kingma (1975).

The principal territorial division was according to the broad climatic zonal classification of the Australian Grazing Industry Survey (AGIS) into Pastoral, Wheat-sheep and High Rainfall zones. The final demarcation among these three main zones was by Local Government Area (LGA). A subsequent subdivision of the Wheat-sheep Zone (WSZ) into Northern and Southern areas was similar to that used in previous studies. For the Pastoral Zone (PZ), the boundary between the the cattle (North) and cattle and sheep (South) grazing areas was more accurately defined. The five regions and their boundaries are shown in Figure 2.

Region 1, the Northern and Central Pastoral Zone (NCPZ), is generally semi-arid and mainly supports extensively grazed beef cattle operations. Crop enterprises were limited to native pasture and a single category of moderately improved pasture. Livestock activities were selected as cattle along with steer, store, and bullock production. Heifer transfer were allowed among this zone and the Southern Pastoral (SPZ) and the Northern Wheat-sheep (NWSZ) zones. Store cattle transfers were only allowed outward to the fattening areas of the NWSZ.

Region 2, the Southern Pastoral Zone is typified by farms (stations) of extensively grazing sheep and beef cattle. The sheep are grown predominantly for wool. Relatively favorable wheat prices of recent experience have led to a notable increase in marginal wheat production. Therefore, a wheat-pasture rotation was included in this region together with sheep and cattle enterprises. Heifer transfers were defined for movements among the SPZ and both NWSZ and SWSZ. Store transfers were allowed to represent store cattle movements to fattening areas in the NWSZ and SWSZ.

Region 3 is the Northern Wheat-sheep Zone (NWSZ). While annual average rainfall is virtually the same across the Wheat-sheep Zone, its seasonality results in different patterns of pasture production. In the NWSZ rainfall occurs predominantly during summer months, significantly influencing seasonal pasture productivity and livestock fattening enterprises. The NWSZ is a mixed, livestock and cereal, cropping area. In terms of the number of enterprise possibilities it represents the most comprehensive region.

Region 4 is the Southern Wheat-sheep Zone (SWSZ). This zone is subject to a winter rainfall pattern. All activities, with the exception of wheat-sorghum rotation, are represented in the SWSZ.

Region 5, is the High Rainfall Zone (HRZ) extending to all states expect the Northern Territory. Owing to topographical features, cropping enterprises are limited. Activities in this region are centered around intensive livestock grazing, producing sheepmeats, and beef.

A schematic tableau of the model is presented in Figure 3. Submatrices 1-5 on the main diagonal represent regions. They are connected by an interregional transfer matrix which allow the movement of adult, young, and store livestock among regions. Regional outputs are fed into ten national output reconciliation rows at the base of the matrix. These outputs are then transferred to sale in the industry level activities. Within each region constraints are classified into four categories:

(i) regional resource constraints relating to land availability, feed supply and demand, livestock numbers, labor use and investment;

(ii) regional behavioral and managerial constraints limiting expansion or contraction of land types and enterprises;

(iii) regional institutional constraints on credit availability and investment;

(iv) national output reconciliation constraints.

Overall, the system of constraints includes a technology matrix A with 235 rows and 327 columns, with a density of 2.73 percent.

The Risk Components in the Model

Aggregate industry-level risk in the objective function was limited to the output prices of ten principal products of the AGI: wheat, barley, sorghum, oats, wool, mutton, lamb, lean sheepmeat, table beef, and manufacturing beef. In the objective function (4), the risk component is represented by $(\phi x'\Sigma_p x/2)$, interpreted as the risk premium associated with output price uncertainty. The variance-covariance matrix Σ_p was estimated using 11 years of observations on the ten output prices, from 1968 to 1979, deflated by the Consumer Price Index. The coefficient of risk aversion, ϕ, was determined according to a procedure suggested by Paris who shows that, under a reasonable specification, ϕ can be estimated by the relation $\phi = -\tau(x_a'\Sigma_p x_a)^{-1/2}$, where τ is a standardized normal random variable chosen to represent a risk level $(1-\beta)$ of a monetary loss to the producer, x_a is the vector of actual realized levels of production and Σ_p is the variance covariance matrix of stochastic prices. Using the available information on x_a and Σ_p and for $\beta = .95$, the implied value of ϕ is .369. Similarly, for $\beta = .90$, $\phi = .287$ and for $\beta = .995$, $\phi = .577$. These three values of ϕ correspond to the three block effects in the experimental design discussed above.

Technological risk in the system of constraints relate to pasture production, livestock fecundity and production, and crop yields. Lack of information prevented to include among the stochastic elements, feed pool input-output coefficients. Even when available, the information was not sufficient to distinguish the variability of input-output parameters on a regional basis. In total 95 coefficients involving 33 constraints were considered stochastic. The probability

α with which each of the chance constraints had to be satisfied was set at .95 for calving rates which corresponds to $\theta^{-1}(\alpha_i) = 1.645$. Since the beef cattle enterprise has a long production cycle, it was hypothesized that producers would strongly require that calving percentage be close to that expected.

The sheep enterprise (wool, mutton, and lamb) has a shorter production cycle and adjustment period, particularly for Merino sheep. Therefore, it was assumed that producers would be satisfied if the lamb reconciliations were met with a slightly lower probability, say $\alpha = 0.90$. As a result, $\theta^{-1}(\alpha_i)$ were set at 1.282 for all zones. Similarly, for wool cut per head α was set at 0.90. For cross-bred lamb and lamb (meat), where production indicates a specialization away from wool and lean sheepmeat, α was assumed at 0.95.

For cereal crops it was assumed that farmers were willing to accept greater risks. Therefore, $\alpha = 0.80$ corresponding to $\theta^{-1}(\alpha_i) = 0.842$.

Although all of the above probabilities were assumed, it would seem rather feasible to elicit the required information from AGI farmers using the sample survey structure already set up.

Aggregate Results for AGI

The results generated by the multivariate parametric analysis were summarised by a series of seven response functions as specified by equation (1) and presented in Table 4. A second degree polynomial seemed to fit the data very satisfactorily. The t-ratios reported in Table 4 do not have the usual statistical meaning since the response from the programming model cannot be considered stochastic. Yet the statistical response functions allow for a concentrated representation of the simulation experiment. With the exception of sheepmeats and wheat, the estimated functions formed good approximations to the actual response. They all show R^2 values in excess of .95. Therefore, the estimated functions form a useful basis from which supply response information can be generated and analyzed. Own-price and cross-price elasticities derived from the polynomial supply function are presented in Table 5. Except for wheat, output supplies are inelastic with respect to own-price and rather unresponsive to other prices. All commodities are competing for the available resources and, therefore, their corresponding cross-price elasticities are negative.

Because of the importance of wool production within AGI, estimates of own-price elasticity of wool supply have been discussed widely. However, medium term cross-price elasticities and own-price elasticities for several of the products considered in this analysis were not available.

In Table 6, various estimates of Australian elasticities are drawn together from the literature. Some long-, medium- and short-term estimates are presented where the specific medium-term elasticities were not available. The table serves to illustrate a range of results from studies using different estimation methods and, therefore, places the results from this analysis in proper context.

The price elasticities, with respect to beef supply estimated in this study, were lower than those from the Bureau of Agricultural Economics (BAE) model. It must be pointed out, however, that a total beef price effect was not estimated in this analysis. It is of interest that the own-price elasticities for table beef (TB) and manufacturing beef (MB) are close to the total beef elasticity of the BAE model. Similarly, the cross-price elasticity, with respect to cereal price, was the same for TB in this model as for beef in the BAE model.

For wool production, the supply elasticity is somewhat lower than that estimated by the BAE model. It is close, however, to the medium-term elasticity estimated by Gruen (1967) and fall within the range of elasticities econometrically derived by Malecky (1971) for a ten-year medium-term.

Sheepmeats' elasticities may not be strictly comparable because of the different definitions likely used in the two models. However, estimates from this analysis are not too far from those of the BAE model.

Also, wheat and cereal outputs may not be directly comparable. Wheat is the predominant crop within cereals and so may be expected to exhibit a larger (more elastic) response to wheat price then would total cereals to an index of cereal prices. Similarly, the difference between the results from the BAE model and the present study supports the proposition that the wheat component of cereal production is less responsive to changes in other prices than is cereal production in total. Compared with Gruen's (1967) estimate of medium-term own-price elasticity of wheat supply, the BAE estimate is lower while that derived in this study is higher.

An Alternative Estimate of Supply Response

The estimates of polynomial response functions presented in the previous section exhibit a considerable amount of multicollinearity.

A more economic use of prices as explanatory variables can be realized through the estimation of a translog response function for total net revenue in the form of output share equations such as

$$p_i x_i/TNR = \alpha_i + \sum_{j=1}^{4} \beta_{ij} \ln p_j + D1 + D2.$$

where j = TB, MB, WL and WH. The corresponding translog estimates presented in Table 7 seem to constitute a more suitable representation of the supply response than the polynomial specification previously discussed. In all but the wheat equation the R^2 is higher than in the polynomial specification. Furthermore, the high levels of the t-ratios indicate that the value of the corresponding coefficient may be a reliable representation of the response generated from the mathematical programming model. According to the translog formulation, the supply of all commodities decreases for an increase of every other price. Furthermore, the β coefficients of table beef, manufacturing beef and wool, with respect to the corresponding prices, form a remarkably symmetric matrix only slightly perturbed when wheat is added to the group. In summary, the translog specification may be regarded as a better representation of the multiple output supply response.

A Policy Interpretation - The Case of U.S. Beef Import

General opinion in Australia seems to be that the new U.S. policy will engender beef price destabilisation. Subjective evaluations conclude that the forecast upswing in the U.S. beef cycle in the mid-1980's would result in beef price reductions and have a direct bearing on Australian producer returns. However, no empirical estimates of beef price changes exist to confirm and quantify this evaluation. Therefore, this brief policy interpretation is conducted on the basis of assumed changes of beef prices. A 10 percent change in beef prices is considered in the following analysis using the estimated supply elasticities. Since the model was designed to estimate supply responsiveness in the AGI rather than forecast production, less importance is placed on the absolute values of revenue and output supply. Instead, the proportional changes in supply have more relevance.

The Implications for Australia in Aggregate

In the event of Australian producer expectations for a sustained 10 percent fall in beef prices over the next five years, the medium-term impacts on the AGI are shown in Table 8. Following the inception of counter-cyclical beef import measures in the U.S., Australian producer expectations with respect to beef prices, may extend to table beef (P_{tb}) or manufacturing beef (P_{mb}) alone, or to the two prices jointly. Responsiveness under all three conditions is depicted in the table. Since other studies tend to use overall beef prices, emphasis in the discussion is on the joint influence of P_{tb} and P_{mb}. The individual price effects are listed for completeness.

Table 8 shows that 84 percent of the assumed change in total beef price would be transmitted to total net revenue net of the risk premium (TNR) in the AGI. In other words, TNR would fall by 8.4 percent for a 10 percent reduction in beef prices. The underlying cause of this revenue loss was a 3.5 percent cut-back in total beef output. Offsetting the revenue effect of the negative beef supply response were positive (albeit small) impacts on the production of wool (0.1 percent), total sheepmeats (0.8 percent) and wheat (0.2 percent).

For TNR and total beef production, P_{tb} had, by far, the greatest influence on response. The fall in P_{mb} caused a fall in TNR which was less than one-quarter of the effect from the P_{tb} change. For beef output the P_{mb} change resulted in a reduction one-third the size of that from P_{tb}. Their effects on other commodities was so slight that differences between P_{tb} and P_{mb} impacts were not meaningful. In conclusion, if P_{tb} alone were reduced, owing to the change in import policy, the effects would be only a little less than if both beef prices fell. Conversely, if P_{mb} alone fell, then the model elasticity estimates demonstrate very little change in TNR and beef production in the AGI.

Concluding Remarks

From the elasticities estimated in this study a 10 percent reduction in beef prices would reduce beef supply of the aggregate grazing industry by 3.5 percent. Movement of resources from beef production to other enterprises would result in slightly increased outputs from sheep and cropping activities. The positive AGI revenue effect from the resource redeployment, however, would fall short of totally offsetting the loss in revenue caused by the fall in beef output. The resultant decrease in the industry's net revenue is estimated in 8.4 percent.

In the event that the assumed 10 percent reduction in beef price resulting from a change in U.S. beef import policy is regarded as affecting only the price of manufacturing beef, the results are similar to the "no change" situation observed by Reeves (1979). In this case, total beef production is estimated to be reduced by only 0.9 percent.

An important point for interpreting these results is that beef prices used in the model are average prices from a small sample, rather than expected prices. Therefore, the collection of further information concerning the beef price expectations of Australian producers would increase the precision of the results. The results also highlight the importance of the accuracy of information disseminated to producers. A prevailing opinion in Australia is that the countercyclical U.S. beef import policy will cause price reductions during the rising phase of the beef cycle. It seems likely that producer's expectations of price could be affected by the occurance of such a change.

A final remark relates to the representation of price risk in the model. Implicit in the foregoing analysis was the assumption of constant price variance within the risk premium component of the objective function. If, as it was conjectured, the change in U.S. beef policy engenders beef price destabilisation, then beef price variance would increase. With constant risk aversion--an explicit assumption of the model--beef enterprises would become less attractive to producers if there was no change in other price variances. Consequently, beef production might fall by a greater proportion with relatively greater shift in resources to other enterprises. With a large number of possible changes in the risk premium and zonal enterprises mixes it would be unrealistic to surmise possible revenue effects.

FOOTNOTES

[1]Exports exceed the volume produced as a result of inventory changes between years.

[2]Variances and covariances were calculated using deviations of prices and quantities from a trend as recommended by Burt and Finley (1968).

[3]But, excludes as atypical those for which study activities represent the principal source of revenue.

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FIGURE 1. AUSTRALIAN GRAZING INDUSTRY SURVEY ZONES

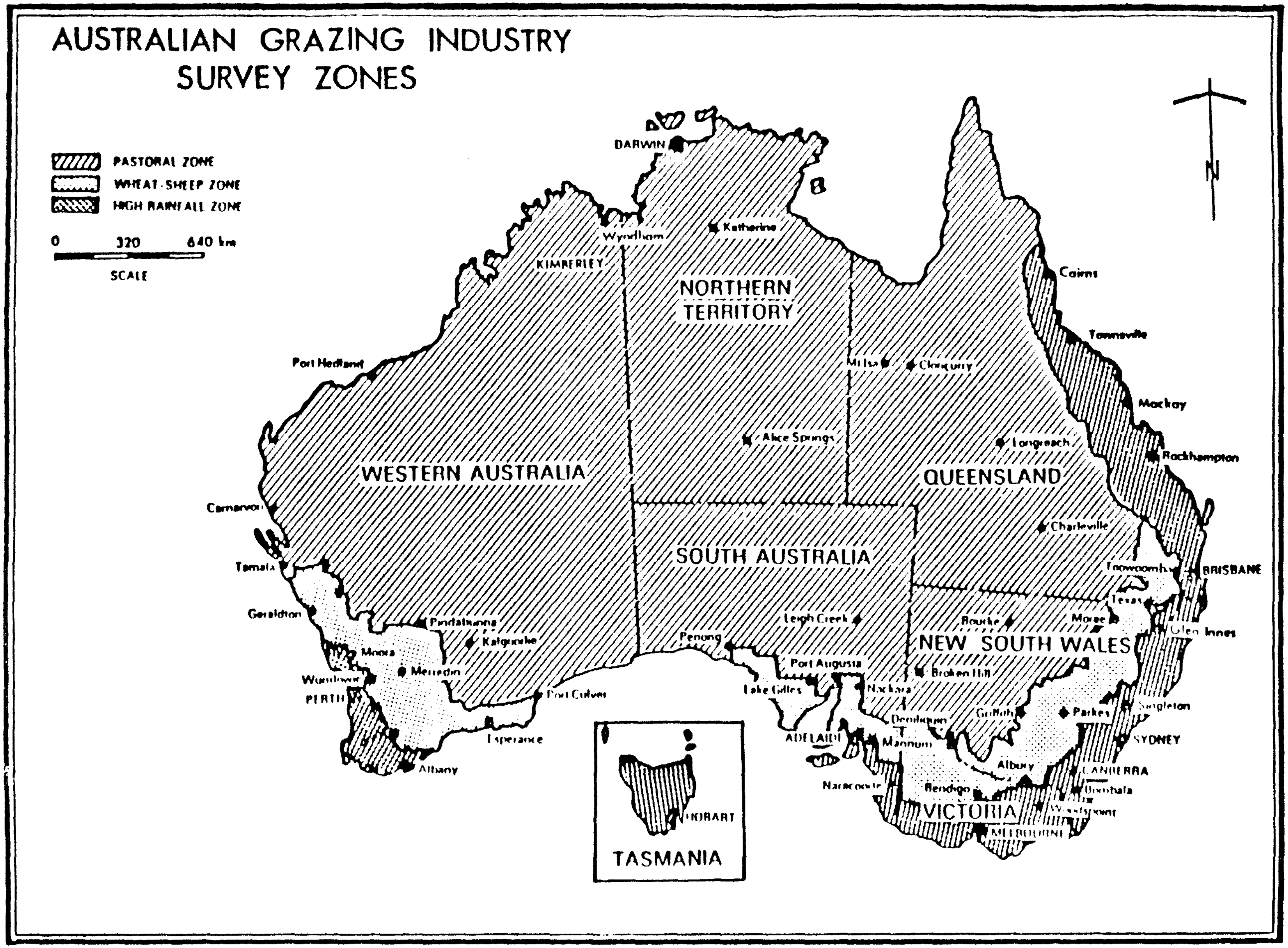
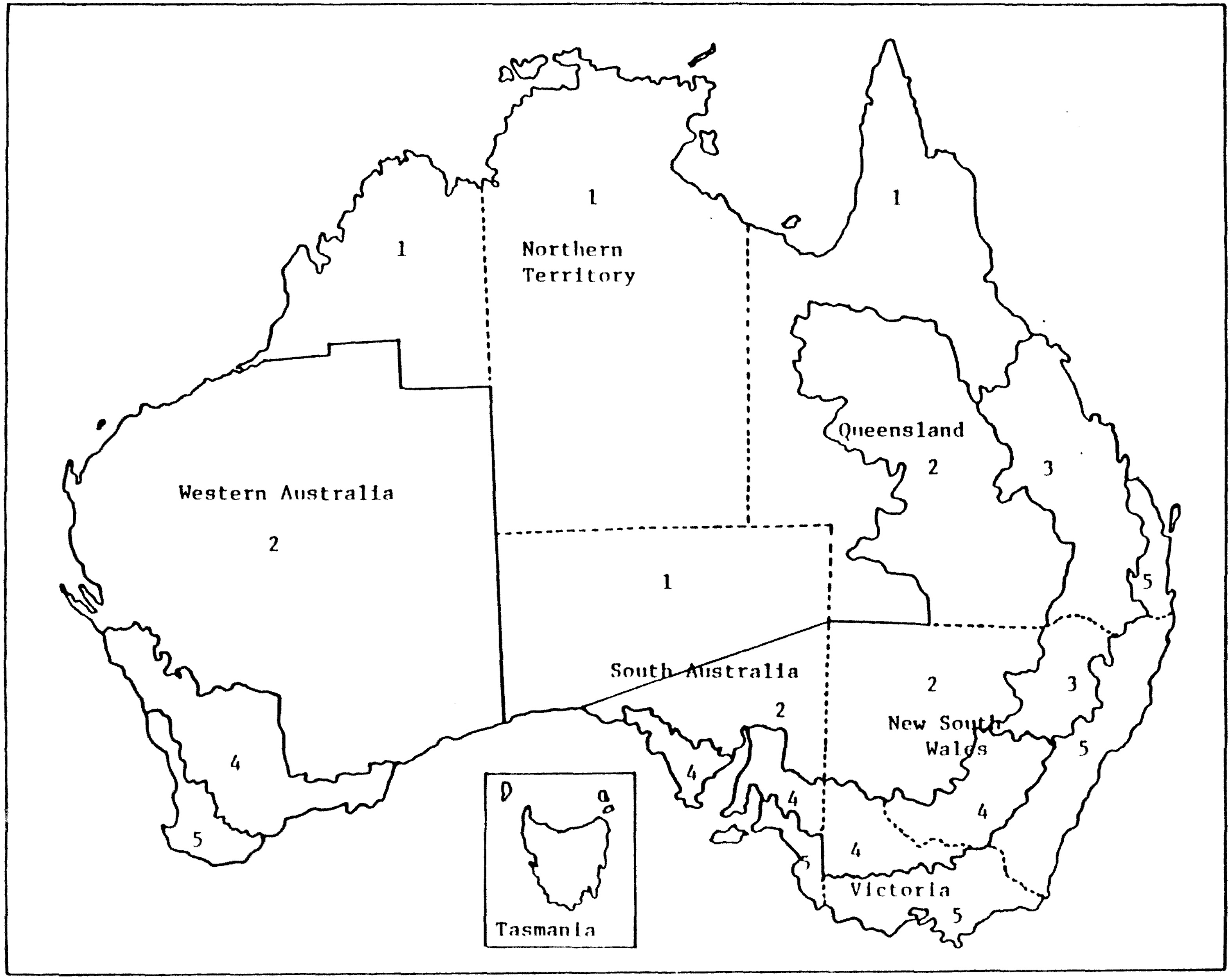
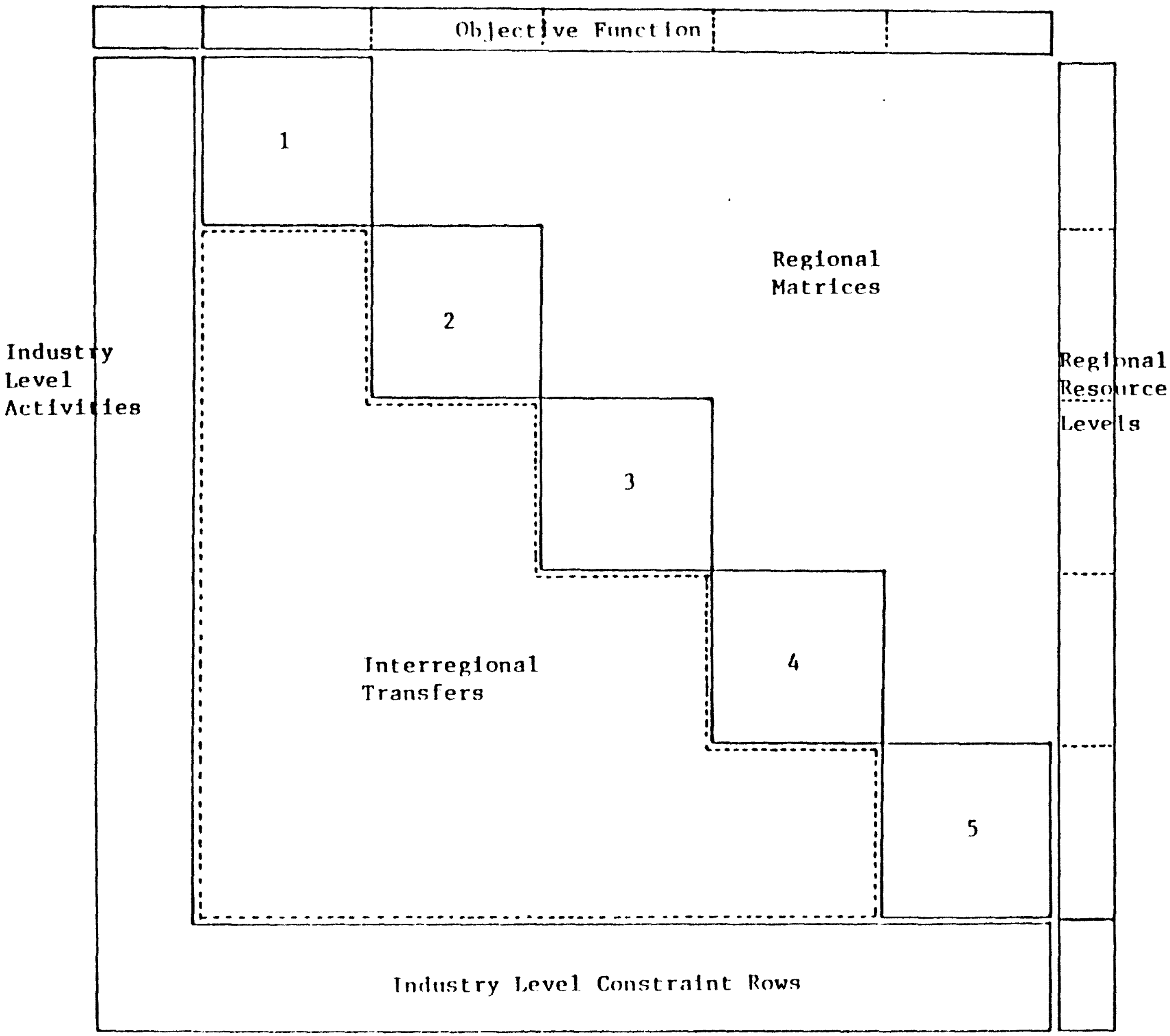


FIGURE 2. AUSTRALIA: REGIONAL BOUNDARIES FOR THE MATHEMATICAL PROGRAMMING MODEL



1. Northern and Central Pastoral Zone
2. Southern Pastoral Zone
3. Northern Wheat-sheep Zone
4. Southern Wheat-sheep Zone
5. High Rainfall Zone

FIGURE. 3 SCHEMATIC REPRESENTATION OF THE REGIONAL PROGRAMMING MATRIX



Matrix Dimensions :

Overall - 235 x 327

1. NCPZ - 26 x 45
2. SPZ - 37 x 55
3. NWSZ - 54 x 89
4. SWSZ - 54 x 76
5. HRZ - 54 x 62

TABLE 1. VOLUMES OF PRODUCTION (P) AND EXPORT (E) AND PERCENTAGE EXPORTED (%) FOR PRINCIPAL AGI COMMODITIES

Commodity		Unit	1975-76	1976-77	1977-78	1978-79
	P	kt	11,982.0	11,800.0	9,370.0	18,300
Wheat	E	kt	7,872.0	8,177.0	11,130.0	7,900
	%	%	65.7	69.3	118.8	43.2
	P	kt	3,197.0	2,847.0	2,383.0	4,000
Barley	E	kt	1,963.0	2,100.0	1,341.0	1,700
	%	%	61.7	73.8	56.3	42.5
	P	kt	1,141.0	1,072.0	990.0	1,800
Oats	E	kt	358.9	364.3	217.8	440
	%	%	31.4	34.0	22.0	24.4
	P	kt	1,134.0	956.0	714.0	920
Sorghum	E	kt	815.0	829.2	384.5	425
	%	%	72.5	86.7	53.9	46.2
	P	kt	754.0	703.0	677.0	691
Wool	E	kt	732.4	846.1	645.6	720
	%	%	97.1	120.4	95.4	104.2
	P	kt	1,840.0	1,980.0	2,184.0	2,070
Beef & Veal	E	kt	548.4	633.2	753.0	860
	%	%	29.8	31.9	34.5	41.5
	P	kt	326.0	304.0	261.0	220
Mutton	E	kt	133.9	168.2	147.6	100
	%	%	41.1	55.3	56.6	45.4
	P	kt	262.0	246.0	253.0	255
Lamb	E	kt	24.9	55.4	39.5	40
	%	%	9.5	22.5	15.6	15.7
Live Sheep	E	th	1,845	3,388	4,963	5,000

kt = kilotonnes; th = thousands.

Sources: Australian Bureau of Statistics and Bureau of Agricultural Economics.

TABLE 2. THE CENTRAL COMPOSITE SECOND ORDER DESIGN IN INCOMPLETE BLOCKS, USED TO GENERATE THE RESPONSE DATA

Treatment Number	BLOCK I				BLOCK II				BLOCK III			
	x_1	x_2	x_3	x_4	x_1	x_2	x_3	x_4	x_1	x_2	x_3	x_4
1	-1	-1	-1	-1	-1	-1	-1	1	-2	0	0	0
2	1	-1	-1	1	1	-1	-1	-1	2	0	0	0
3	-1	1	-1	1	-1	1	-1	-1	0	-2	0	0
4	1	1	-1	-1	1	1	-1	1	0	2	0	0
5	-1	-1	1	1	-1	-1	1	-1	0	0	-2	0
6	1	-1	1	-1	1	-1	1	1	0	0	2	0
7	-1	1	1	-1	-1	1	1	1	0	0	0	-2
8	1	1	1	1	1	1	1	-1	0	0	0	2
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0

Source: Cochran and Cox, Plan 8A.5, p. 373.

TABLE 3. OUTPUT PRICES USED IN THE ESTIMATION OF RESPONSE DATA

Price	Experimental Design Code +2	+1	0	−1	−2
$P_{tb} = x_3$	1.1715	1.03092	0.9372	0.84348	0.7029
$P_{mb} = x_4$	0.785875	0.69157	0.6287	0.56583	0.471525
$P_{wl} = x_2$	2.2875	2.013	1.830	1.647	1.3725
$P_{wh} = x_1$	114.0375	100.353	91.230	82.107	68.4225

TABLE 4. POLYNOMIAL RESPONSE FUNCTIONS FOR AGI

Coefficient	TNR	TB	MB	Beef	WOOL	SHMEAT	WHEAT
Constant	-2965.48	-302.01	411.87	109.85	299.76	1810.42	-160.40
	(-1.34)	(-0.32)	(0.70)	(0.13)	(1.13)	(2.13)	(-1.73)
P_{tb}	1191.62	1688.30	-688.59	1019.79	21.13	35.84	49.27
	(0.71)	(2.37)	(-1.49)	(1.65)	(0.10)	(0.05)	(0.70)
P_{mb}	1639.40	699.68	-195.51	504.11	225.36	81.58	69.75
	(0.65)	(0.65)	(-0.29)	(0.55)	(0.75)	(0.08)	(0.66)
P_{wl}	733.56	-129.46	307.05	177.59	30.00	-740.60	40.08
	(0.85)	(-0.35)	(1.33)	(0.56)	(0.29)	(-2.22)	(1.11)
P_{wh}	15.93	0.67	-1.45	-0.78	1.23	-14.80	1.77
	(0.92)	(0.09)	(-0.31)	(-0.12)	(0.60)	(-2.22)	(2.44)
$(P_{tb})^2$	-375.56	-979.32	-31.45	-1010.77	23.57	48.11	-23.09
	(-0.79)	(-4.86)	(-0.25)	(-5.78)	(0.41)	(-0.26)	(-1.16)
$(P_{mb})^2$	-916.44	257.39	-80.93	176.46	-264.41	-115.32	-51.01
	(-0.60)	(0.57)	(-0.29)	(0.45)	(-2.09)	(-0.28)	(-1.15)
$(P_{wl})^2$	-75.14	-38.59	55.46	16.87	-12.85	123.54	-8.20
	(-0.60)	(-0.73)	(1.66)	(0.37)	(-0.86)	(2.56)	(-1.57)
$(P_{wh})^2$	-0.03	-0.07	-0.01	-0.06	-0.002	0.04	-0.01
	(-0.65)	(3.46)	(0.83)	(-3.39)	(-0.33)	(1.91)	(-3.47)
$P_{tb}*P_{mb}$	-200.95	-1217.49	1417.06	199.57	56.10	86.29	5.89
	(-0.15)	(-2.20)	(4.05)	(0.42)	(0.36)	(0.17)	(0.11)
$P_{tb}*P_{wl}$	3.98	152.72	-118.42	34.30	-80.80	-137.83	-2.02
	(0.01)	(0.80)	(-0.99)	(0.20)	(-1.50)	(-0.79)	(-0.11)
$P_{tb}*P_{wh}$	3.99	11.13	-0.73	10.40	0.39	0.59	-0.07
	(0.44)	(2.91)	(-0.30)	(3.14)	(0.36)	(0.17)	(-0.18)
$P_{mb}*P_{wl}$	-21.25	29.00	-558.23	-529.23	198.00	129.35	-3.01
	(-0.01)	(0.10)	(-3.12)	(-2.15)	(2.47)	(0.49)	(-0.11)
$P_{mb}*P_{wh}$	-0.15	-0.58	2.62	2.04	-3.92	-3.22	-0.06
	(-0.01)	(-0.10)	(0.73)	(0.41)	(-2.44)	(-0.62)	(-0.10)
$P_{wl}*P_{wh}$	0.39	1.02	-0.82	-0.20	0.26	4.68	-0.06
	(0.08)	(0.52)	(-0.67)	(-0.12)	(0.47)	(2.62)	(-0.33)
D1	-34.07	-0.53	-2.50	-3.04	-2.67	-9.78	-0.09
	(-2.48)	(-0.09)	(0.68)	(-0.60)	(-1.62)	(1.83)	(-0.15)
D2	-87.79	-0.81	-7.62	-8.43	-9.21	-31.71	1.70
	(-5.97)	(-0.13)	(-1.93)	(-1.56)	(-5.23)	(-5.57)	(2.76)
R^2	0.987	0.957	0.939	0.950	0.958	0.901	0.868

TABLE 5. OUTPUT PRICE ELASTICITIES OF SUPPLY

Commodity	Price			
	P_{tb}	P_{mb}	P_{wl}	P_{wh}
TNR	0.69	0.15	0.89	1.30
TB	0.51	-0.10	-0.04	-0.12
MB	-0.45	0.62	-0.20	-0.39
BEEF	0.26	0.09	-0.08	-0.08
WOOL	-0.02	-0.06	0.21	-0.01
SHMEAT	-0.03	-0.05	0.33	-0.17
WHEAT	-0.01	-0.01	0.13	1.73

TABLE 6. ALTERNATIVE ESTIMATES OF SUPPLY RESPONSE ELASTICITIES

Commodity and Source of Estimate[a]	Term[b]	Price			
		Beef[c]	Wool	Wheat	Cereal[d]
Beef:[e]					
Gruen	SR	0.16	0	0	-
BAE	MR	0.69	-0.18	-	-0.12
Wool:					
Dahlberg	SR	-	0.08	-	-
Dalton & Lee	SR	-	0.08-0.09	-	-
Gruen	SR	0	0.05	-0.04	-
Malecky	SR	-	0.05-0.17	-	-
BAE	MR	-0.24	0.32	-	-0.13
Gruen	MR	-	0.25	-	-
Malecky	MR	-	0.35	-	-
Malecky	MR[f]	-	0.16-0.71	-	-
Gruen	LR	-	3.59	-	-
Malecky	LR	-	3.94-4.70	-	-
Sheepmeat:[g]					
BAE	MR	-0.23	0.18	-	-0.01
Lamb:					
Gruen	SR	0	-0.05	0	-
Wheat:					
Gruen	SR	0	-0.11	0.18	-
Gruen	MR	-	-	0.82	-
Gruen	LR	-	-	3.82	-
Cereals:[h]					
BAE	MR	-0.10	-0.06	-	0.35

For footnotes to the table, see the next page.

Footnotes to Table 6

- indicates that the particular elasticity was not estimated

(a) Sources of the estimates were as follows:

BAE derived from the BAE nonstochastic regional programming model. The results were from an analysis, described by Hall (1979), using the model and were reported in Longmire et al. (1979, Table 5.3: 74).

Dahlberg from Dahlberg (1964). The period covered was 1949 to 1961.

Dalton & Lee from Dalton and Lee (1975: 236). The unusual SR wool price elasticity of supply of 5.09 was not reported in the above table but is discussed in the text. The period covered was 1956-57 to 1973-74.

Gruen from Gruen et al (1967, Table 6.3.4 and 6.3.5: 177-178). The period covered was 1947-48 to 1964-1975.

Malecky from Malecky (1971, Part IV: 76-79) and Malecky (1974, Table 6: 255). In general lower elasticity estimates were reported in the 1971 study. Also short-run estimates from a constant elasticity model were smaller than short-run annual estimates derived from a variable elasticity model. The periods covered were 1946-47 to 1964-65 (1971) and 1946-47 to 1974-75 (1975).

(b) The term codes refer to: SR (short-run) 1 year; MR (medium-run) 5 years, except where specified; and LR (long-run) an infinite time horizon.

(c) Beef price was an amalgam of all beef prices.

(d) Cereals price referred to an (unspecified) range of cereal crops.

(e) Beef refers to total beef production.

(f) In this case Malecky's (1975) MR relates to a 10-year period.

(g) It is not known whether sheepmeats specified in the Hall (1977) results included the lean sheepmeat component specified in the IAQP model. It is possible that this latter commodity may have been termed live sheep exports, in which case sheepmeat would refer to mutton and lamb, only.

(h) Cereals refer to an (unspecified) amalgam of grain outputs.

TABLE 7. TRANSLOG ESTIMATES OF SUPPLY RESPONSE FUNCTIONS

	α_i	$\beta_{i,Ptb}$	$\beta_{i,Pmb}$	$\beta_{i,Pwl}$	$\beta_{i,Pwh}$	D_1	D_2	R^2
TB	5.6796	0.5283	-0.1935	-0.7022	-1.0310	0.0229	0.0602	0.966
	(22.66)	(9.56)	(-3.53)	(-12.82)	(-18.83)	(1.72)	(4.54)	
MB	1.4398	-0.1945	0.2376	-0.1984	-0.2350	0.0033	0.0130	0.956
	(15.95)	(-9.86)	(12.05)	(-10.06)	(-11.92)	(0.70)	(2.72)	
BEEF	7.1194	0.3339	0.0440	-0.9006	-1.2660	0.0262	0.0732	0.966
	(24.48)	(5.25)	(0.69)	(-14.17)	(-19.93)	(1.70)	(4.76)	
WOOL	6.6282	-0.7189	-0.2098	0.2406	-1.3338	0.0275	0.0703	0.972
	(25.74)	(-12.78)	(-3.73)	(4.28)	(-23.71)	(2.02)	(5.16)	
SHMEAT	7.8574	-0.7722	-0.2065	0.3471	-1.6019	0.0174	0.0405	0.948
	(19.20)	(-8.64)	(-2.31)	(3.88)	(-17.92)	(0.81)	(1.87)	
WHEAT	-5.4838	-0.8346	-0.1620	-0.9683	1.5418	0.0276	0.2333	0.849
	(-6.00)	(-4.18)	(-0.81)	(-4.85)	(7.72)	(0.57)	(4.82)	

TABLE 8. AUSTRALIA: MEDIUM-TERM IMPACTS ON REVENUE AND PRODUCTION LEVELS OF A 10 PERCENT REDUCTION IN BEEF PRICES

Revenue/ Commodity Supplied	Estimated Percentage Impact of:		
	P_{tb} - 10 Percent	P_{mb} - 10 Percent	P_{tb} and P_{mb} - 10 percent
	percent		
TNR	-6.9	-1.5	-8.4
BEEF	-2.6	-0.9	-3.5
WOOL	+0.2	-0.1	+0.1
SHMEAT	+0.3	+0.5	+0.8
WHEAT	+0.1	+0.1	+0.2