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SUPPLY RESPONSE IN BROADACRE AGRICULTURE

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This paper describes a mathematical programming model of broadacre agriculture in Australia and presents estimates of national and regional supply responses made with it. Own-price and cross-price supply elasticities are presented for wool, sheep meat, beef and crops and the results compared with those of two other major models of Australian agriculture. It is shown that long term supply responses for the commodities studied are substantially greater than 1 as are cross-price elasticities in a number of cases. It is also shown that supply responses differ substantially between regions.

Introduction

Farmers respond to changing output and input prices by adjusting their enterprise mix and pattern of input use. The size and direction of these adjustments is of major importance in determining both responses to policy changes and estimating the effects of changing market prices and price relativities. In the present situation where grain prices are depressed and wool and meat prices relatively high, Australian farming is adjusting away from cropping and into livestock enterprises. The area sown to wheat has fallen from a peak of about 13 million ha in 1983-84 to just under 9 million ha in 1987-88, while sheep numbers are forecast to be 164 million in 1988 compared with 139 million in 1984. Beef cattle numbers are expected to be 21 million in 1988, up from 19 million in 1984 (ABARE 1987). If these trends continue they will have an important influence on the rest of the economy, the exchange rate and prices of certain products such as wool.

This paper presents estimates of supply responses to output price changes for major commodities in Australia both at the national and regional levels. These have been derived using a mathematical programming model. The different approaches to modelling supply responses using positive or normative models were discussed by Hall and Menz (1985) who used an earlier version of the model used in this paper to make estimates of supply elasticities. The methodology of this paper is similar to that in Hall and Menz, but it has been extended by presenting regional results and further extended by using a new long term version of the original model which has been fully updated.

An alternative approach to the method used in this paper involves using positive models based on time series data. In general, these are econometric models, often with simulation components as in the Bureau's EMABA model (Dewbre, Shaw, Corra and Harris 1985). It is to be expected that different types of model will produce different estimates because of their different aims and methods.

The Regional Programming Model

The first version of the regional programming model was completed in 1977. This model is described in Longmire, Brideoake, Blanks and Hall (1979) and modelled the situation in Australian agriculture in the early 1970s. The new version of the model is similar in general concept but has been completely updated to 1983-84 coefficients. Full documentation of this model is expected to be available later in 1988. A discussion of the philosophy behind this version of the model is presented in Hall, Quiggin, Fraser and Purtill (1987).

The regional programming model represents the Australian broadacre industries which together account for 65 per cent of commercial farms in Australia and produce about 60 per cent of the total value of agricultural output. These farms produce sheep, beef cattle and crops (predominantly wheat). The major industries not covered by this model are horticultural industries, the dairy industry and the intensive livestock industries such as pigs and poultry.

The model comprises a single large matrix which is optimised using linear programming. This matrix is made up of 13 submatrixes, each representing a single region. Each submatrix represents an appropriate choice of enterprises to allow it to simulate the production pattern in the region. The objective function maximises the excess of returns over costs, taking no account of farmers' reactions to risk either in prices or production. The model thus represents a profit maximising response. This is

consistent with the findings of Bond and Wonder (1980) that, although farmers are on average risk averse, the average degree of risk aversion is relatively small.

The model regions are delineated on the basis of climatic and agronomic studies so that each region is as homogeneous as is feasible with the available information. The main basis of the delineation is the Bureau's agricultural and grazing industries survey of the pastoral, wheat-sheep and high rainfall zones. Within these zones, Tasmania and Western Australia are separated and the wheat-sheep zone in the eastern states is divided into a northern summer rainfall area (Queensland and northern New South Wales) and a southern winter rainfall area (South Australia, Victoria and southern New South Wales). Data for the model were derived predominantly from the farm surveys carried out by the Bureau (BAE 1987), with additional information from other sources including state departments responsible for agriculture and the CSIRO.

All the supply elasticity estimates presented in this paper abstract from considerations of demand. In reality, market prices are determined by the interaction of the quantities supplied and demanded. Where adjustment is instantaneous or at least proceeds at the same rate for supply and demand, price is determined in a simultaneous system. Where there are adjustment lags in either supply or demand, then price cycles can be set up (Ezekiel 1938). The 'true' supply responses from models such as the regional programming model therefore cannot be used directly to predict the future course of supply but can be used in the context of a systematic model incorporating both supply and demand. The role of an analysis such as this one is to clarify the workings of the supply side of agriculture and in particular the substitution relationships between one product and another.

Experimental method

The regional programming model is used in this analysis to estimate the output responses of broadacre agriculture to changes in major product prices. This is done by changing prices according to a systematic design and estimating supply responses to prices by fitting production surfaces to the results. It is these production surfaces, which express the output of each product as a quadratic function of output prices, that are used to calculate the elasticities presented in this paper.

A central composite design is used for these experimental treatments (Cochran and Cox 1957). This is an efficient way of exploring variations in production because of price changes because it provides estimates of the responses to five levels of four commodity prices with only 25 separate treatments. (The design is presented in the appendix which is based on Hall and Menz 1985.)

The observations of the variables are deterministic so that the regression model does not conform to the assumptions generally associated with regression models. On this basis, the t-values can be regarded as having little meaning (Candler and Cartwright 1969). In regressions estimated from stochastic data it is common to omit from the final model those variables not demonstrated to be statistically significant by t-tests. However, in the case of a designed experiment using a model of this type, any variation which is expressed is a real effect and should not be disregarded. Hence, the elasticities are calculated from the supply functions when all the variables are included. The $\bar{R}^2$ in these models

TABLE 1

Prices Used in the Experiment: In 1983-84 dollars

Price level	Differences from the base price in standard deviations	Wool (greasy)	Sheep meat (dressed weight lamb)	Beef (dressed weight all cattle)	Crops
		$/kg	$/kg	$/kg	$/t
Highest price	1.4	3.40	1.50	2.45	193
High price	1.0	3.31	1.37	2.26	185
Base price	0.0	3.09	1.05	1.81	164
Low price	1.0	2.87	0.73	1.36	143
Lowest price	1.4	2.78	0.60	1.17	134
1987-88 price		3.17	0.96	1.83	112

indicates the goodness of fit of the estimated function to the data. This fit is quite satisfactory for all four functions.

The prices used are presented in Table 1. The base prices are 1983-84 prices, and the variations around these are based on the observed variations in real prices for the sixteen years 1970-1985. It was considered that these ranges were fair approximations of the range of prices which could be expected on the basis of past experience (but crop prices in 1987-88 are expected to be below the lowest level in the experiment). The elasticities calculated are point estimates calculated at 1983-84 prices and at 1983-84 levels of output estimated from the model.

Australia Level Results

Two sets of supply elasticities are presented in Table 2. The long term elasticities are based on the core version of the model in which supply response is constrained only by area of land and technical coefficients. They represent a response to expectations that prices will remain constant in real terms for a period longer than ten years.

The medium term elasticities were estimated from a constrained version of the base model in which total numbers of ewes and beef cows were constrained to remain within one standard deviation of numbers in 1983-84. The standard deviations were calculated over five and ten year periods ending in 1985-86. There was little difference between them, and the five year range was used. This type of constraint, introduced by Day (1963) and extensively used in recursive programming models since then, simulates the effects of the factors working against change which modify instantaneous profit maximisation. The constraints are arbitrary and assume equal flexibility in increasing and decreasing stock numbers. Crop areas were not constrained because substantial changes to crop areas can be made in one season whereas livestock numbers are slow to adjust. These assumptions could be refined (see, for example, Miller 1972) but they are considered adequate to give an indication of the effects of constrained optimisation as an approximation to medium term supply response.

TABLE 2

Price Elasticities of Supply in the Regional Programming Model: 1983-84 Prices

Product	Response due to change in the price of			
	Wool	Sheep meat	Beef	Crops
Long term				
Wool	2.5	0.5	-2.3	-0.2
Sheep meat	1.2	1.5	-3.0	-0.4
Beef	-1.9	-0.5	2.4	0.3
Crops	0	0	0.2	1.4
Medium term				
Wool	0.6	0	-0.2	0
Sheep meat	-0.4	0.3	-0.2	0
Beef	-0.1	-0.1	0.5	0.1
Crops	0	0	0.1	1.1

In this paper the main discussion is based on the base (long term) model, with the constrained medium term elasticities being presented to assist comparison with other models.

The long term elasticities of output response to product prices at the Australia level and at 1983-84 prices and outputs are presented in Table 2; they are derived using the design in the appendix with the unconstrained base version of the regional programming model. In all cases the own-price elasticities are greater than 1 - approximately 1.5 and 1.4 for sheep meat and crops, 2.4 for beef, and 2.5 for wool. These estimates are much larger than those obtained from earlier versions of the model (Hall and Menz 1985). This reflects the greater flexibility of this model because of its longer term orientation. The estimates are also larger than those produced by econometric methods, a reflection of the difference in technique and the longer time period of this model.

The signs of the estimated cross-price elasticities indicate the extent to which the various products are complementary or competitive. In the long term, wool and sheep meat clearly complement each other but compete with crops and beef cattle. Beef cattle and crops appear to be complementary to a limited degree. The relationship between wool and crops, however, is more complex. The price of wool has no effect on crop production but a rise in the crop price causes a small fall in wool production.

The medium term elasticities are much smaller than the long term elasticities, as would be expected; they are derived by using the experimental design in the appendix with the constrained version of the model. The own-price supply elasticity of wool is 0.6 in the medium term and 2.5 in the long term, suggesting that wool production is unlikely to change significantly in the medium term without a large change in price. The most interesting change is that sheep meat and wool, which are complementary in the long term, are competitive in the medium term. This can be explained as follows. In the long term, sheep numbers can be increased in response to

price increases for wool or sheep meat. Where sheep numbers are limited, however, the only way of increasing either wool or sheep meat production in the medium term is by changing flock composition and utilisation. In the short and medium term, flock size is limited by breeding capacity and so this competitive relationship is not unexpected. However, it should be borne in mind that the constraining process for obtaining medium term elasticities is somewhat simplistic and allows some breed substitution as well as the intended end use substitution.

The long term elasticities from the model are generally higher than those estimated econometrically. Table 3 presents supply elasticities from the EMABA and ORANI models for comparison with those estimated in this study. A qualification to these comparisons, which are based on estimates at different price levels, is presented in a later section. The long term own-price elasticities for wool and sheep meat from the EMABA model are notably less than those from the regional programming model. The more appropriate comparison, however, is of medium term elasticities.

These three models represent three approaches to supply analysis in agriculture. Although EMABA is a model of demand as well as supply, only the supply sector is considered here.

The ORANI model is based on work by Vincent, Dixon and Powell (1980) which develops the approach of Powell and Gruen (1968). The basis of this work was a fixed production possibility frontier given by the fixity of inputs in a given period. The supply problem is then a question of choosing a position on the frontier. Vincent et al. developed this insight into a system in two joint processes. The CRESH (constant ratio of elasticities of substitution homothetic) production function determines the aggregate production frontier while the CRETH (constant ratio of elasticities of transformation homothetic) function allocates the output between the products. The system can be solved to give the direct and cross-price elasticities for both product supply and input demand. The major assumptions involve dynamics, relative supply responses between products and the absence of product specificity of inputs.

TABLE 3

Supply Elasticities with Respect to Own Price from Different Models

	EMABA(a)			Regional Programming Model	
Product	Medium term(b)	Long term(c)	ORANI (d)	Medium term	Long term
Wool	0.4	1.0	0.5	0.6	2.5
Sheep meat	0.5	0.6	0.3	0.3	1.5
Beef	0.3	2.0	0.6	0.5	2.4
Crops	0.8	1.3	0.7	1.1	1.4

(a) Dewbre, Shaw, Corra and Harris (1985). (b) Five year response. (c) Twenty year response. (d) Adams (1985).

The elasticities generated from the ORANI model are static because there are no dynamic processes in the model. They can be regarded as short run responses since capital is fixed. Given that the dynamics are not modelled, the description 'short run' implies that the period is the same for all products. Insofar as this assumption is questionable there is a possibility of distorting the relative elasticities (Colman 1983).

A further major assumption is that inputs are not product specific. Vincent et al. justify this on the basis that highly aggregated inputs such as 'all land' are not specific. This appears to be a very strong assumption to make, given the comparative advantage of certain areas in soil types for certain products. For example, the pastoral areas of the Northern Territory are almost totally specialised in beef production for climatic reasons.

The system used to derive these elasticities is a very elegant method of extracting the maximum information from the data. The elasticities generated are essentially for the short run and hence could be expected to be substantially lower than those for the longer term from the regional programming model and similar to its medium term estimates.

The EMABA elasticities are derived from Dewbre et al. (1985). The approach in EMABA is different from that in ORANI where the data are made to produce a lot of information by applying economic theory and strong assumptions. In EMABA an alternative approach has been adopted - 'direct specification of supply and demand equations as unknown functions of variables which the logic of demand or production theory dictates as important' (Dewbre et al. 1985, p.6). The major considerations in this decision were data limitations and the complexities of attempting to model dynamics, particularly the dynamics of livestock production.

The production responses of EMABA can be considered in two groups: crops and livestock. The total crop area response, corresponding to the crop output response of the regional programming model, is represented directly by a single equation which distributes land between crops and grazing. The coefficients estimated imply a short run elasticity of crop area with respect to crop prices of 0.2 and a corresponding long run elasticity of 1.3 with a six year mean adjustment lag. This implies that the five year elasticity will be about 0.8.

The long run elasticity of crop area from EMABA is similar to that from the regional programming model. Two sets of EMABA estimates of elasticities are presented, one for five years, corresponding to the medium term elasticities from the regional programming model and to ORANI estimates, and one set of twenty year estimates which correspond to the long term estimates from the regional programming model.

The livestock sector of EMABA is complex, built up of a series of behavioural relationships determining slaughter and retentions and a series of identities describing inventory dynamics. The elasticities quoted were derived for five and twenty year time horizons, with exogenous prices and all market clearing prices fixed. Each product price was varied in turn to obtain the supply responses. The five year elasticities estimated are similar in size to those from the ORANI model and the medium term estimates from the regional programming model, while the twenty year elasticities are similar to the long term elasticities from the programming model for beef and crops but not for wool and sheep meat.

There are a number of reasons why a programming model can be expected to indicate more responsiveness to price change than an econometric model. These differences reflect principally the level of detail and disaggregation used in a programming model. For example, in this model there are two types of land available in each region, giving a total of 26 land classes. In addition, there are five levels of crop fertility on the cropping lands. In the real world, every paddock is different and even within paddocks there are often differences in the productivity of crops and livestock. The effect of this modelling simplification is to treat larger areas as qualitatively uniform in programming models than is possible in the real world.

Another factor producing different responses between programming and econometric models is the extent of lags and friction in the real world. In the programming model any change in price which produces a new optimum can be immediately met. Thus, each solution of the model represents an optimum at that price. In the real world, however, lags of several years in the adjustment process are not uncommon. Lembit and Hall (1987) found that, in the dairy industry, lags in adjusting cow numbers following a price change average about five years. Similar lags may well occur in broadacre industries, particularly where changes involve major investments and substantial outlays of capital. It has been shown that farm investment is closely related to farm income (Lewis, Hall and Kingston 1986); hence, in periods of low farm income the rate of adjustment may well be below the optimum or desired rate.

A third factor restricting supply responses to price changes in the real world is uncertainty and the discounting of actual price changes to subjective expected price changes by decision makers. This both slows response, as farmers await confirmation that a change in price is likely to last long enough to make investment worthwhile, and reduces the level of response as farmers adjust their production only in response to their subjectively discounted price. This price is below the market price when prices are rising, but in periods of falling prices may well be above the market price.

Elasticities at different price levels

The own-price supply elasticities estimated from the regional programming model, unlike those from EMABA and ORANI, are different at different price levels. The supply elasticities for wool, beef, crops and sheep meat production with respect to their own prices are shown in Figure 1, which is derived by re-estimating the long term elasticities with all prices at 1983-84 levels except for the relevant price for each commodity. The prices used are the same as those in Table 1 based on the variation observed in each price between 1970 and 1985. For each commodity, 100 in the index represents the 1983-84 base price.

In all cases, the supply elasticity decreases as the price increases. This reflects increasing competition for resources as the production of each commodity is expanded in response to higher prices. For example, it is relatively easy to expand wool production from low levels, but the greater the expansion the more likely it is that the most suitable resources are already being used for wool production and the more costly the increased production becomes. The figure indicates that the responsiveness of supply to own price is most marked for beef, with the supply elasticity ranging from 2 at high prices to 9 at low prices. The crops elasticity also shows a wide range - from 0.5 at high prices to 4 at low prices. Sheep meat and wool both have narrower ranges of elasticity, indicating lower responsiveness of

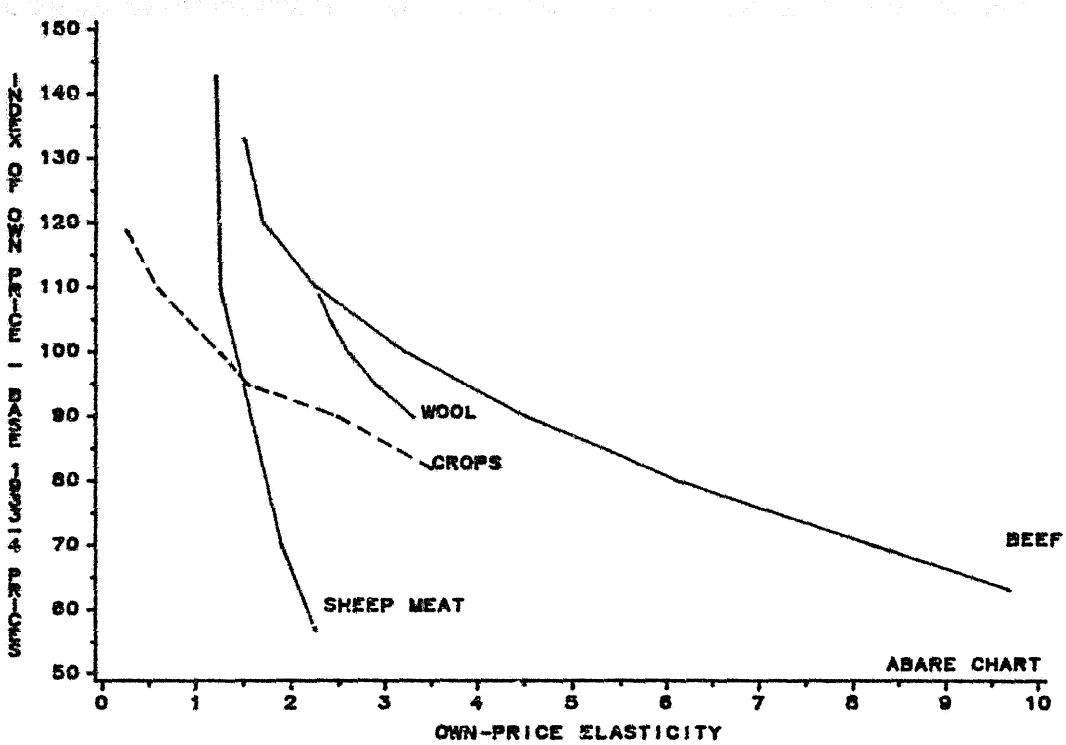

FIGURE 1 - The Relationship of Own-Price Supply Elasticities to Own Prices.

supply to price. The wool supply elasticity ranges from 2 to just over 3, and the elasticity for sheep meat ranges from 1 to 2.5.

The supply responses to price changes as indicated in Figure 1 are generally greater at lower prices. This will affect comparisons between elasticity estimates based on different periods and different prices. It would be a very complex process to compensate fully for these differences, but a simple indication of the general effect can be obtained by estimating regional model elasticities at general prices appropriate to each period. EMABA elasticities were estimated using the averages of prices in the period 1970-85. These were about 10 per cent above 1983-84 prices. This means that elasticities from the regional programming model would have been smaller than those quoted in Table 3. For example, using the EMABA prices the beef supply elasticity from the programming model would be closer to 2 than to the 2.4 estimated at 1983-84 prices. ORANI elasticities are based on a thirteen year period ended 1979-80 in which average prices were approximately 27 per cent above prices in 1983-84. At these price levels Figure 1 suggests that the crop supply elasticity from the programming model would be less than 1 and similar to that from ORANI. However, the livestock supply elasticities from the programming model would still be higher than those estimated using ORANI even at these higher prices.

Regional Estimates

The regions of the regional programming model (Hall et al. 1987) are named in Table 4, which presents regional elasticities of supply with respect to price. The regions can be grouped as follows:

TABLE 4

Key Regional Supply Elasticities

Region	Wool	Sheep meat	Beef	Crops
	%	%	%	%
		With respect to wool price		
1. Western high rainfall	3.0	1.3	-1.7	-
2. Western wheat-sheep	2.2	1.1	-	0.7
4. Southern high rainfall	-	-	-2.5	0
5. Southern wheat-sheep	2.5	1.1	-4.0	-0.2
7. New South Wales high rainfall	-	-	-0.5	0
8. Northern wheat-sheep	1.3	1.3	-7.9	-0.4
13. Tasmania	22.6	9.0	-0.6	-
		With respect to sheep meat price		
1. Western high rainfall	0.8	4.9	-0.7	-
2. Western wheat-sheep	0.3	0.6	-	0.1
3. Western pastoral	-	-	0	-0.1
4. Southern high rainfall	-	-	-0.5	-0.4
5. Southern wheat-sheep	0.4	0.8	-0.8	-0.1
7. New South Wales high rainfall	-	-	-0.1	0
8. Northern wheat-sheep	0.5	0.5	-2.9	-0.1
13. Tasmania	4.5	7.7	-0.4	-
		With respect to beef price		
1. Western high rainfall	-3.8	-10.9	3.1	-
2. Western wheat-sheep	-0.7	-0.4	-	0.1
3. Western pastoral	-	-	1.8	0.4
4. Southern high rainfall	-	-	1.8	-0.8
5. Southern wheat-sheep	-2.4	-2.2	4.5	0.1
7. New South Wales high rainfall	-	-	1.4	-1.3
8. Northern wheat-sheep	-2.5	-2.5	14.6	0.6
9. Queensland high rainfall	-	-	0.5	-
10. Central Queensland	-	-	1.3	-
13. Tasmania	-13.3	-10.2	2.0	-
		With respect to crop price		
1. Western high rainfall	-0.4	-0.9	0.2	-
2. Western wheat-sheep	0.8	0.5	-	1.2
3. Western pastoral	-	-	0.1	3.9
4. Southern high rainfall	-	-	-0.1	2.1
5. Southern wheat-sheep	0	-0.1	0.7	1.2
7. New South Wales high rainfall	-	-	0	2.3
8. Northern wheat-sheep	-1.2	-1.2	6.8	2.6
13. Tasmania	-0.8	-0.9	0.1	-

Note: A dash (-) indicates either none of the commodity was produced at base level prices or this commodity is not able to be produced in the region.

- **high rainfall regions** - Western Australia, Victoria and South Australia, Tasmania, New South Wales and Queensland;

- **wheat-sheep or cropping regions** - Western Australia, southern winter rainfall area (South Australia, Victoria and southern New South Wales) and northern summer rainfall area (northern New South Wales and Queensland); and

- **pastoral regions** - Western Australia (excluding the Kimberleys), central Australia stretching from the Kimberleys through to the New South Wales border, the monsoonal region in Arnhem Land and Cape York, Central Queensland, and a southern pastoral region in New South Wales and South Australia.

The regional own-price elasticity of wool with respect to the wool price is close to the national average for both the western high rainfall and wheat-sheep regions but not for Tasmania where it is particularly high. The pastoral regions have both zero own-price and cross-price elasticities for wool. This is due to the limited opportunities to change the enterprise mix in these regions. Inspection of the cross elasticities indicates that wool production is highly competitive with beef production in the southern and northern wheat-sheep regions and to a lesser extent in the high rainfall regions. It is competitive with crop production to only a very limited extent, indicating that mixed farming is the optimum land use throughout most of the wheat-sheep regions.

The highest own-price elasticities for sheep meat are in the western high rainfall and Tasmanian regions. All other regions have low price elasticities for sheep meat. Sheep meat production is competitive with beef production in the high rainfall and wheat-sheep regions other than the western wheat-sheep region.

The largest own-price elasticities for beef are in the western high rainfall and southern and northern wheat-sheep regions. Sheep meat and wool production are competitive with beef production in the western high rainfall, western wheat-sheep, southern wheat-sheep, northern wheat-sheep and Tasmanian regions. In both the southern and New South Wales high rainfall regions, beef production competes with cropping, whereas in other regions it is slightly complementary. Throughout the northern pastoral areas, the supply response of beef shown by the model is very low, reflecting the lack of alternative and competitive enterprises. In most of these pastoral areas, increased production can come only from increases in turnoff from the existing areas and resources.

Only three regions are of importance in terms of the regional supply responses with respect to the crop price. These are western wheat-sheep, southern wheat-sheep and northern wheat-sheep which together produce 90 per cent of all crops in the model. Crops compete with wool and sheep meat production in the western high rainfall, northern wheat-sheep and Tasmanian regions but are complementary in the western wheat-sheep region. Beef production is slightly complementary to cropping in a number of regions, the most notable being northern wheat-sheep.

Conclusions

The regional programming model is a general purpose tool widely used in Bureau research. This paper presents and discusses some of the supply

responses of this model. These responses underlie the results obtained in other analyses employing it. The results indicate that the model is broadly consistent with other major models of the sector and that differences can be explained in terms of economic logic.

Supply elasticity estimates made at the national level for wool, sheep meat, beef and crops indicate large long term supply responses for all four products with respect to their own prices and a number of major cross-price responses. Medium term supply responses are smaller, as expected.

The elasticities from the regional programming model were generally higher than those from two other major agricultural models used in Australia. The elasticities estimated were also shown to be sensitive to price levels. In general, elasticities were greater at lower price levels, particularly for beef and crops. This might reflect increasing competition for resources as production of any given product is increased in response to increased prices.

The elasticity estimates for the thirteen regions of the model for all four products show considerable differences in supply responses between regions.

APPENDIX A

Experimental Design

The types of production examined were crops (wheat, oats, barley and sorghum), sheep meat (including the meat equivalent of live exports), beef (table and manufactured) and wool (cross-bred and merino). The prices varied were those appropriate to the four types of output. All crop prices and the price of each category of sheep meat, beef and wool were varied equiproportionately.

The prices of each treatment were set in a designed experiment in order to bring out the effects of own prices and cross prices on the output of each product. This allowed for the interactions between, for example, wool prices and beef production, as well as the direct effects of wool prices on wool production and beef prices on beef production.

A full factorial design for the experiment reported here with four prices and with five levels of each price would have required 625 treatments (5 x 5 x 5 x 5). This is expensive in terms of the money cost of solving the programming models and in terms of the work needed to analyse the results. A more efficient design described by Cochrane and Cox (1957) is the central composite design, which requires only 31 treatments to cover four prices at five levels. There is some loss of information compared with that from a full factorial design, but this is compensated for by much lower costs of obtaining the solutions and of analysing the experiment. A central composite design was used in this study.

The design is illustrated in Figure A.1, which shows a design with two independent variables. This allows for a simple graphical presentation, which is impossible with four variables.

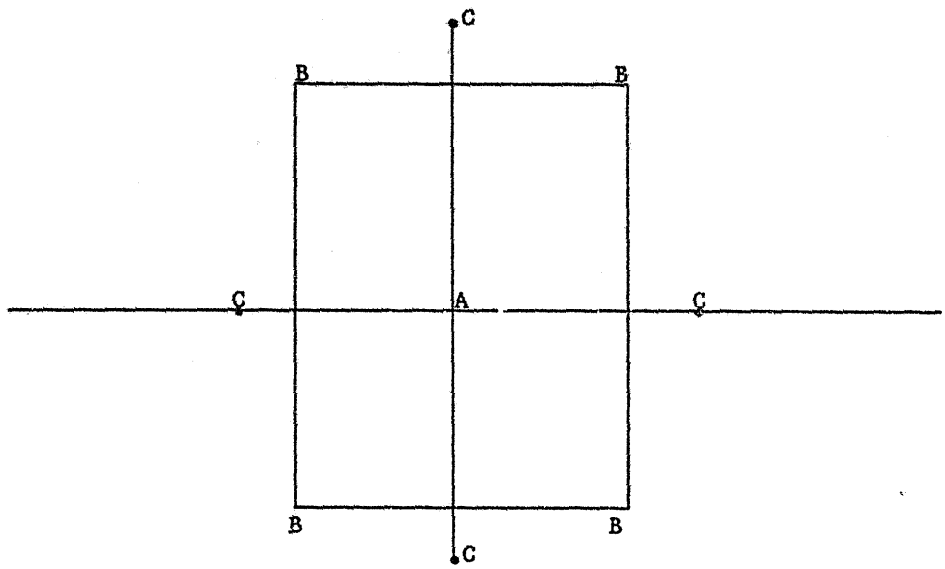

FIGURE A.1: Central Composite Design.

TABLE A.1

Data for Determination of Response Surfaces from the Regional Programming Model

Treatment	Prices				Production responses			
	Wool	Sheep meat	Crops	Beef	Wool	Sheep meat	Crops	Beef
	c/kg	c/kg	$/t	c/kg	t	t	kt	t
1	3.09	1.05	164	1.81	733 555	434 295	23 570	1 572 495
2	3 09	1.05	164	1.81	733 555	434 295	23 570	1 572 495
3	3.09	1.05	164	1.81	733 555	434 295	23 570	1 572 495
4	3 09	1.05	164	1.81	733 555	434 295	23 570	1 572 495
5	3 09	1.05	164	1.81	733 555	434 295	23 570	1 572 495
6	3.09	1.05	164	1.81	733 555	434 295	23 570	1 572 495
7	3 09	1.05	164	1.81	733 555	434 295	23 570	1 572 495
8	3.40	1.05	164	1.81	1 097 178	727 261	22 753	781 989
9	2.78	1.05	164	1.81	413 825	209 193	24 535	2 074 842
10	3.09	1.50	164	1.81	1 126 411	991 186	22 556	647 469
11	3.09	0.60	164	1.81	427 424	79 841	24 535	2 094 069
12	3.09	1.05	164	2.45	252 373	74 240	24 351	2 506 551
13	3.09	1.05	164	1.17	1 205 859	872 568	22 754	344 743
14	3.09	1.05	194	1.81	492 125	271 724	27 631	1 943 265
15	3.09	1.05	134	1.81	674 703	394 744	14 267	1 516 860
16	2.87	0.73	143	1.36	875 774	546 526	14 930	781 366
17	3.31	0.73	143	1.36	1 245 236	416 717	19 597	349 164
18	2.87	1.37	143	1.36	1 129 835	1 044 226	19 351	344 920
19	3.31	1.37	143	1.36	1 169 483	945 121	18 569	344 920
20	2.87	0.73	185	1.36	898 008	552 482	24 822	841 282
21	3.31	0.73	185	1.36	1 218 504	394 490	24 822	410 619
22	2.87	1.37	185	1.36	1 099 538	1 016 842	24 573	406 724
23	3.31	1.37	185	1.36	1 204 644	920 061	22 792	345 645
24	2.87	0.73	143	2.26	189 313	34 803	17 096	2 511 474
25	3.31	0.73	143	2.26	229 845	39 519	18 576	2 471 850
26	2.87	1.37	143	2.26	221 869	55 163	18 470	2 476 067
27	3.31	1.37	143	2.26	489 324	278 829	18 569	2 046 344
28	2.87	0.73	185	1.36	898 008	552 482	24 822	841 282
29	3.31	0.73	185	1.36	1 218 504	394 490	24 822	410 619
30	2.87	1.37	185	2.26	261 074	80 548	27 605	2 450 185
31	3.31	1.37	185	2.26	465 193	261 669	27 605	2 080 911

Point A where the axes intersect is the centre of the experiment - the base situation. It is replicated seven times. In the analysis presented here, this is the base price in Table 1. The four points labelled B are a 2 x 2 factorial - in this analysis, 16 (that is, 2 x 2 x 2 x 2) combinations of prices, at one standard deviation above and below the base price (that is, the high and low levels in Table 1). Finally, the factorial is supplemented by the four points labelled C which have one variable outside the range of the factorial and the rest at the base level. In this analysis, there are 8 (that is, 2 x 4) such observations, set 2 standard deviations either side of the base price (that is, highest and lowest levels in Table 1). Each of the 31 treatments provided one observation each of production of cereals, beef, sheep meat and wool at a given combination of prices (see Table A.1). The observations were summarised using quadratic functions to approximate a response surface for each product (see Table A.2).

TABLE A.2

Estimated Supply Functions: Australia

Variable	Wool	Sheep meat	Beef	Crops
Intercept	-1 665 844 971	865 752 421	-11 132 711 270	-143 059 876
PW	-7 334 299	-14 234 477	78 222 801	173 544
PS	3 150 103	-3 210 460	7 130 876	450 587
PB	-8 407 165	-21 650 259	40 574 828	-157 994
PC_2	48 122 946	49 157 640	-45 960 291	1 359 749
PW_2^2	18 344	-2 334	-120 577	112
PS_2^2	19 131	31 761	-85 148	5
PB_2^2	-2 132	721	-29 503	4
PC^2	-175 036	-155 662	209 773	-2 934
PW.PS	-39 949	32 658	55 561	-766
PW.PB	3 871	7 124	-38 578	4
PW.PC	33 611	6 900	-73 444	-978
PS.PB	27 157	-52 041	-33 061	-234
PS.PC	22 253	12 912	-43 807	-1 101
PB.PC	-24 988	-14 055	40 581	1 243
$\bar{R}^2$	0.93	0.93	0.94	0.97

Note: PW is the price of wool; PS is the price of sheep meat; PB is the price of beef; and PC is the price of cereals.

References

ABARE (Australian Bureau of Agricultural and Resource Economics) (1987), Quarterly Review of the Rural Economy 9(4), 376-83

Adams, P.D. (1985), Agricultural Supply Response in ORANI, Working Paper No. 0.44, University of Melbourne.

BAE (Bureau of Agricultural Economics) (1987), Farm Surveys Report: March 1987, AGPS, Canberra.

Bond, G. and Wonder, B. (1980), 'Risk attitudes amongst Autralian farmers', Australian Journal of Agricultural Economics 24(1), 16-34.

Candler, W. and Cartwright, W. (1969), 'Estimation of performance functions for budgeting and simulation studies', American Journal of Agricultural Economics 51(1), 159-69.

Cochran, W.G. and Cox, G.M. (1957), Experimental Designs, John Wiley & Sons, New York.

Colman, D. (1983), 'A review of the arts of supply response analysis', Review of Marketing and Agricultural Economics 51(3), 201-30.

Day, R.H. (1963), Recursive Programming and Production Response, North Holland Publishing Co., Amsterdam.

Dewbre, J., Shaw, I., Corra, G. and Harris, D. (1985), EMABA: Econometric Model of Australian Broadacre Agriculture, AGPS, Canberra.

Ezekiel, M. (1938), 'The Cobweb Theorem', Quarterly Journal of Economics 52, 255-80.

Hall, N.H. and Menz, K. (1985), 'Product supply elasticities for the Australian broadacre industries, estimated with a programming model', Review of Marketing and Agricultural Economics 53(1), 6-13.

Hall, N.H., Quiggin, J., Fraser, L. and Purtill, A. (1987), New wine in an old bottle. BAE paper presented at the 31st Annual Conference of the Australian Agricultural Economics Society, Adelaide, 10-12 February.

Lembit, M. and Hall, N.H. (1987), Supply response on Australian dairy farms. BAE paper presented at the 31st Annual Conference of the Australian Agricultural Economics Society, Adelaide, 10-12 February.

Lewis, P., Hall, N. and Kingston, A. (1986), Determinants of investment in the Australian sheep industry. BAE paper presented at the 15th Conference of Economists (convened by the Economic Society of Australia), Monash University, Melbourne, 25-29 August.

Longmire, J.L., Brideoake, B.R., Blanks, R.H. and Hall, N.H. (1979), A Regional Programming Model of the Grazing Industry, BAE Occasional Paper No. 48, AGPS, Canberra.

Miller, T.A. (1972), 'Evaluation of alternative flexibility restraint procedures for recursive programming models used for prediction', American Journal of Agricultural Economics 54(1), 68-76.

Powell, A.A. and Gruen, F.H. (1968), 'The constant elasticity of transformation production frontier and linear supply system', International Economic Review 9(3), 315-28.

Vincent, D.P., Dixon, P.D. and Powell, A. (1980), 'The estimation of supply response in Australian agriculture: the CRESH/CRETH production system', International Economic Review 21(1), 221-41.