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

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Risky output prices and production characterise Australian agriculture. Exports are vitally important, sometimes relying heavily on a particular market. In this study a model is developed to include explicitly both output price and technological risks as well as multiple output relationships. It is used to show that changes in US beef import policy generating a 10 per cent beef price fall could reduce Australian beef supply by 3.5 per cent and grazing industry net revenue by 8.4 per cent, despite some switching from beef production to other enterprises.

Introduction

Production and price risks affect the economic welfare of Australian farmers. There is high variability in precipitation over time and many regions are subject to harsh climatic conditions. Widely fluctuating yields are a frequent result. Furthermore, many rural commodities are exported and prices received by producers are subject to the volatility inherent in international agricultural product markets.

Over 60 per cent of agricultural exports from Australia are represented by beef (including veal), wheat and wool. In 1981, less than 4 per cent of the world's beef was produced on Australian farms but almost half of this production was exported, representing about 20 per cent of the world total beef exports. In the same year, the volume of beef exported from Australia was equivalent to some 43 per cent of total beef imports to the U.S.A., although it constituted only 3 per cent of US beef consumption. Therefore, whilst changes in US beef import policies might have only marginal effects 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 1978-79 through 1982-83, Australia exported between 38 per cent and 100 per cent of its total wheat production. Presently, Australia contributes almost 25 per cent of total wool production in the world. Virtually all Australian wool production is exported, accounting for around half 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 64.7c/kg, their lowest level since the mid-1940s.

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 mm. Some extensive beef cattle and sheep operations encroach on the 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 linearised estimate¹ of the price and yield risks determining the variability of export revenues during the period 1949-50 through 1972-73 was used to ascertain that, for beef and veal, 37.7 per cent is attributable to price changes and 62.3 per cent to yield changes. For wool, the respective proportions are 94.1 per cent and 5.9 per cent; for sheep meat, 64.7 per cent and 35.3 per cent; and for wheat, 3.1 per cent and 96.9 per cent.

Having established the importance of output price risk, production uncertainty and exports, the objective in this paper is to examine the potential effect on Australian broadacre-industry producers if US beef import policy became restrictive and limited Australian access to this important market. In the near term, such an event would be likely to be associated with a production upswing in the beef cycle and a reduction in domestic beef prices. In order to evaluate the effects of a beef price fall, a supply model is developed which explicitly and separately includes risk in output prices and risk in input-output coefficients. Because of enterprise diversification opportunities among the principal broadacre-industry export commodities, multiple output relationships are also modelled explicitly.

The Australian grazing industry

In order to focus on the problem of price and yield risks and to facilitate its analysis, the area of study is limited to the Australian grazing industry (AGI) for which comprehensive data are available. Information on the physical and financial characteristics of AGI farms has been collected annually by officers of the Bureau of Agricultural Economics since 1975, in the Australian Grazing Industry Survey (AGIS). The survey sample is drawn from all farms which carry at least 200 sheep and/or 50 beef cattle.² Thus, the industry encompasses virtually all commercial production of wool, sheep meat, beef and veal. Production systems are relatively extensive and are typical of dryland (non-irrigated) 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, specialised 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. Taken together, beef, wheat and wool exports represent almost 90 per cent of the value of AGI exports.

¹ Variances and covariances were calculated using deviations of prices and quantities from a trend as explained by Burt and Finley (1968).

² But it excludes, as atypical, those for which stud activities represent the principal source of revenue. Subsequently, from 1976-77, the sample was extended to include farms with over 40 ha of crops. The survey is now known as the Australian Agricultural and Grazing Industries Survey, but data may still be extracted for the original AGI. Survey results are reported in BAE (1983).

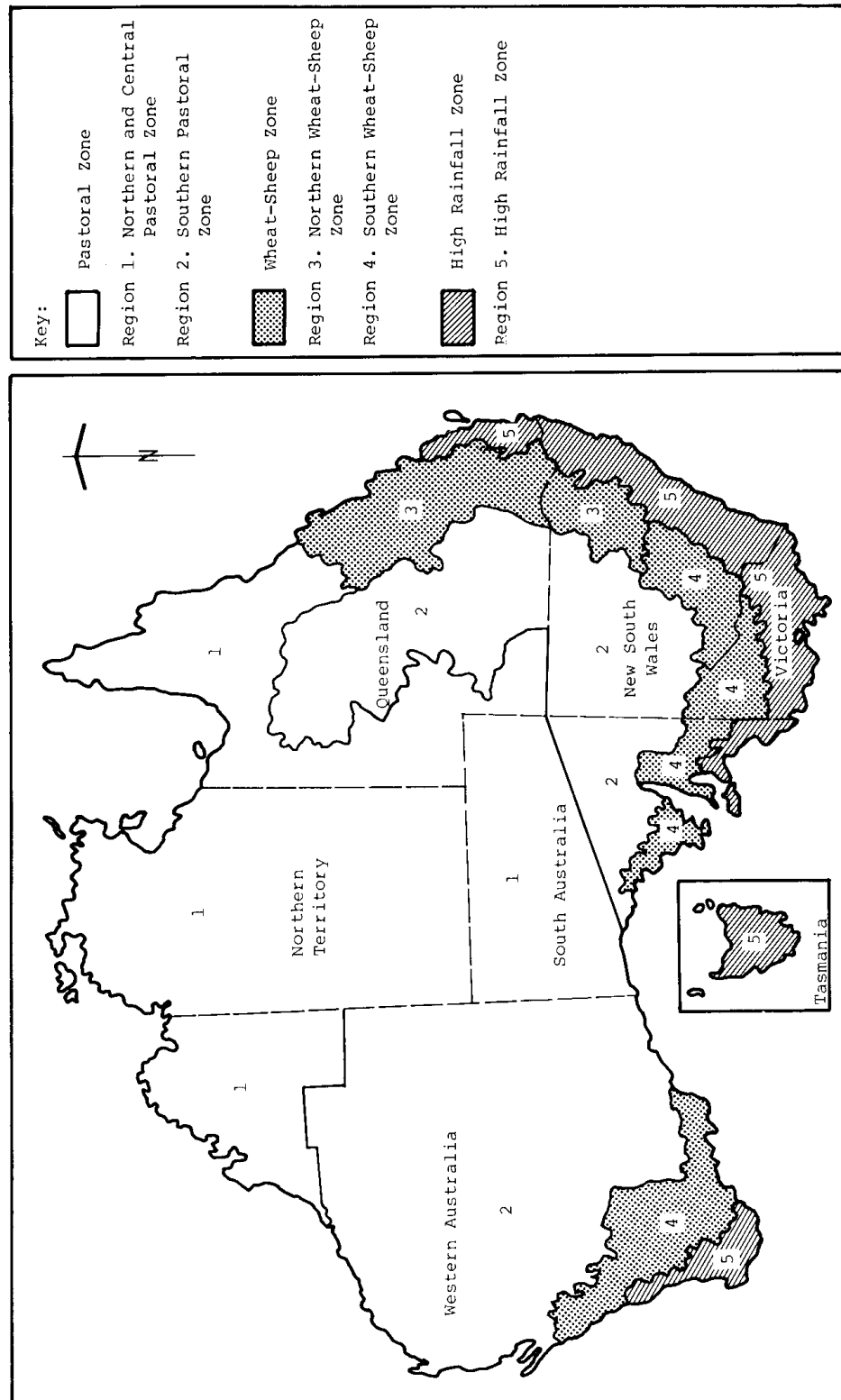


FIGURE 1—Australia: Zones and Regional Boundaries for the Mathematical Programming Model.

TABLE 1

Production (P), Exports (E) and Percentages Exported (%) for Principal Australian Grazing Industry Commodities

Commodity		Unit	1978-79	1979-80	1980-81	1981-82	1982-83 ^a
Wheat	P	kt	18 090	16 188	10 856	16 330	9 000
	E	kt	6 931	14 953	10 674	10 996	9 000
	%		38.3	92.4	98.3	67.3	100.0
Barley	P	kt	4 006	3 703	2 682	3 511	1 740
	E	kt	2 028	3 406	2 076	2 038	1 277
	%		50.6	92.0	77.4	58.0	73.4
Oats	P	kt	1 763	1 411	1 128	1 619	800
	E	kt	290	472	196	153	60
	%		16.4	33.4	17.4	9.5	7.5
Sorghum	P	kt	1 125	922	1 204	1 311	1 450
	E	kt	516	580	463	1 271	760
	%		45.9	62.9	38.5	96.9	52.4
Wool	P	kt	706	713	700	716	694
	E	kt	713	663	694	648	609
	%		101.0	93.0	99.1	90.5	87.8
Beef & Veal	P	kt	2 018	1 564	1 467	1 573	1 555
	E	kt	814	581	498	545	585
	%		40.3	37.1	33.9	34.6	37.6
Mutton	P	kt	239	275	299	234	261
	E	kt	110	143	187	129	146
	%		46.0	52.0	62.5	55.1	55.9
Lamb	P	kt	253	273	280	276	277
	E	kt	41	48	42	33	32
	%		16.2	17.6	15.0	12.0	11.6
Live sheep	E	'000	5 034	5 660	5 771	6 051	6 200

^a Estimated by BAE.

Source: BAE (1983).

Risk, Supply Response, and Policy

Production risks arise from the variability of yields and technology or, as Magnusson (1969 p. 17) states, from the uncertain performance of production factors. 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, Dillon and Hardaker 1977). Shortage risk, reflecting the uncertain availability of factors of production, has limited relevance for Australian farmers.

Except in the case of wool, for which Australia is a major supplier in the world market, price risk in the AGI reflects the industry's role as a price-taker in international agricultural commodity markets. As such, price risk influences agricultural decisions rather uniformly 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.

From the results of researchers such as Francisco and Anderson (1972) who found that Australian farmers had a non-neutral attitude to risk, the impact of risk is of evident importance in the determination of AGI output levels and the industry responsiveness to changes in economic stimuli. In addition to producers' attitudes toward risk, expectations of commodity prices are theoretically fundamental determinants of supply. Furthermore, *ex ante* 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 is the industry's ability to generate export income and the establishment of permanent trade arrangements via the stabilisation 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 1974 through 1976, retail beef prices were at record low levels and domestic per person beef consumption rose from 40 to 65 kg. Thus, whilst short-run benefits were received by domestic consumers, the variability of market conditions created problems for beef producers that could lead to deleterious problems for consumers in the longer term.

The Framework for Analysis

To accommodate the different aspects of multiple output response of the AGI outlined above, a suitable analytical framework is in the form of response surfaces associated with 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; and, finally, it 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 variables: total expected net revenue less the risk premium (*TNR*); table beef production (*TB*); manufacturing beef production (*MB*); total beef production (*BEEF*); wool production (*WOOL*); total sheep meat production (*SHMEAT*); and wheat production (*WHEAT*).

The response of these variables is related in a systematic way to 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:

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

where X = the quantities supplied; and
 $i = 1, \dots, 7$ is the response variable index.

It is also assumed that the collective goal of agricultural entrepreneurs in the AGI can be represented by the maximisation of an expected utility of money with constant risk aversion, ϕ . Justification for this assumption is discussed at length by Easter (1980). Briefly, the assumption is consistent both with the findings of Dillon and Anderson (1971), who concluded that farmers in traditional agriculture (and elsewhere) attempt to maximise expected utility, and with the implications from the Francisco and Anderson (1972) results. Further, a duality relation between expected utility maximisation with constant risk aversion and the safety-first principle has been established by Paris and Pope (1978). The safety first principle was proposed by Roy (1952) and many others, later, to be closer to real world behaviour than some alternative decision criteria. 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:

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

subject to:

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

where $i = 1, \dots, m$;

Prob = the probability of (*);

b_i = the i th resource level;

α_i = the probability of fulfilling the i th constraint;

ϕ = a risk aversion coefficient;

$E(p)$ and Σ_p = the mean vector and covariance matrix of prices, respectively; and

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

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 0.5. The value $(1 - \alpha)$ is referred to as the risk level.

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

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

subject to:

$$(5) \quad E(A_i')x + \Theta^{-1}(\alpha_i)(x' \Sigma_{A_i} x)^{1/2} \leq b_i, x \geq 0,$$

where $i = 1, \dots, m$; and

B

$\Theta^{-1}(\alpha_i)$ denotes the point on the standard normal distribution where the i th constraint will be satisfied with a probability of at least α_i .³

Constraints of the type (5) are nonlinear in the quantity levels, x . The solution of the nonlinear problem, equations (4) and (5), was achieved in an iterative way. The nonlinear portion of the constraint was shifted to 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, Plan 8A.5, p. 373) was used to select and support the parametric variations of four output prices (P_{tb} , P_{mb} , P_{wl} and P_{wh}), and the coefficient of risk aversion (block effects). The information so generated was utilised in the estimation of the response surfaces for the six commodities and total expected net revenue. In Table 2 the price levels used in the experimental design are illustrated.⁴

Empirical Implementation of the Model

A five-region classification of the production environment was chosen as a basis for characterising technological opportunities in the AGI. This choice was founded on a previous programming study by Easter and Kingma (1976).

The principal territorial division was according to the broad climatic zonal classification of the AGI into Pastoral, Wheat-Sheep and High Rainfall Zones. The final demarcation among these three zones was by

TABLE 2
Output Prices Used in the Estimation of Response Date

Price ^a	Experimental design code				
	+ 2	+ 1	0	- 1	- 2
$P_{wh} = x_3$	114.0375	100.3530	91.2300	82.1070	68.4225
$P_{wl} = x_2$	2.2875	2.0130	1.8300	1.6470	1.3725
$P_{tb} = x_3$	1.1715	1.0309	0.9372	0.8435	0.7029
$P_{mb} = x_4$	0.7859	0.6916	0.6287	0.5659	0.4715

^a Price codes are: P_{wh} , wheat; P_{wl} , wool; P_{tb} , table beef; and P_{mb} , manufacturing beef. All values are rounded to four decimal places.

³ While the required joint probability with which all stochastic constraints should be satisfied simultaneously is potentially low (the product of individual α_i values), this is not considered to be a serious limitation of the model. The risky input-output coefficients are either contained within output reconciliations of the A matrix or directly determine output levels. Given the structure of the objective function, such constraint inequalities will normally be binding. Thus, to obtain a feasible optimum solution to the programming model, each stochastic constraint will be satisfied with a required prespecified probability. Hence, the requirement that the totality of risky constraints be met with a lower probability seems largely a matter of statistical interest.

⁴ MINOS, developed by Murtagh and Saunders (1977) was used as the solution procedure. In total, the execution of the experimental design required 30 solutions of the nonlinear program of equations (4) and (5). For all of them convergence was achieved with less than five cycles.

Local Government Area. A subsequent subdivision of the Wheat-Sheep Zone into Northern (NWSZ) and Southern (SWSZ) areas was similar to that used in previous studies by Easter and Kingma (1976) and Easter, Spillman and Scougall (1977). For the Pastoral Zone, the boundary between the Northern and Central cattle area (NCPZ) and the Southern cattle and sheep area (SPZ) was more accurately defined. The five regions and their boundaries are shown in Figure 1.

Region 1, NCPZ, is generally semi-arid and mainly supports extensive beef cattle production. Crop enterprises were limited to native pasture and a single category of moderately improved pasture. Livestock activities were selected as cattle, including steer, store, and bullock production. Heifer transfers were allowed among this zone and the SPZ and NWSZ zones. Store cattle transfers were only allowed outward to the fattening areas of the NWSZ.

Region 2, SPZ, is typified by extensive grazing sheep and beef cattle production. The sheep are grown predominantly for wool. Relatively favorable wheat prices of recent experience have led to an increase in 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 the NWSZ and SWSZ. Store transfers were allowed to represent store cattle movements to fattening areas in the NWSZ and the SWSZ.

Region 3, NWSZ, has a similar annual average rainfall as for all the WSZ but the seasonality results in different patterns of pasture production. In the NWSZ, rainfall occurs predominantly during summer months, influencing significantly seasonal pasture production and livestock fattening enterprises. The NWSZ is a mixed (livestock and cereal) cropping area. It represents the most comprehensive region in terms of the number of enterprise possibilities.

Region 4, SWSZ, is subject to a winter rainfall pattern. All general WSZ activities, with the exception of a wheat-sorghum rotation, are represented in the SWSZ.

Region 5, the High Rainfall Zone (HRZ), extends to all States except the Northern Territory. Owing to topographical and climatic features, cropping enterprises are limited. Activities in this region are centred on intensive livestock grazing, producing sheep meat and beef.

Schematically, the model tableau is a block diagonal structure in which submatrices on the main diagonal represent regions. They are connected by an inter-regional transfer matrix which allows 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:

- (a) regional resource constraints relating to land availability, feed supply and demand, livestock numbers, labour use and investment;
- (b) regional behavioural and managerial constraints limiting expansion or contraction of land types and enterprises;
- (c) regional institutional constraints on credit availability and investment; and
- (d) national output and reconciliation constraints.

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

The risk components in the model

Risks in output prices and input-output coefficients were incorporated separately in the model. First, 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 sheep meat, table beef and manufacturing beef. In the objective function, equation (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 through 1979, deflated by the Consumer Price Index. The coefficient of risk aversion, ϕ , was determined according to a procedure suggested by Paris (1979) who shows that, under a reasonable specification, ϕ can be estimated by the relation:

$$(6) \quad \phi = -\tau(x_a' \Sigma_p x_a)^{-1/2},$$

where τ = a standardised normal random variable chosen to represent a risk level $(1 - \beta)$ of a monetary loss to the producer;

x_a = the vector of actual realised levels of production; and

Σ_p = the variance-covariance matrix of stochastic prices.

Using the available information on x_a and Σ_p , and assuming $\beta = 0.95$, the implied value of ϕ is 0.369. Similarly, for $\beta = 0.90$, $\phi = 0.287$ and for $\beta = 0.995$, $\phi = 0.577$. These three values of ϕ correspond to the three block effects in the experimental design discussed above.

The second element of risk, that associated with input-output coefficients, was restricted to livestock fecundity and production and to crop yields. Not all coefficients in the system of constraints are, or need to be considered, stochastic but pasture production might be expected to involve technological risk. However, a lack of information prevented feed pool input-output coefficients from being included among the stochastic elements. Given the nature of pasture production as an intermediate output endogenised in the model, its omission as a technological risk may, in fact, avoid possible double counting of risk effects. In total, 95 coefficients involving 33 constraints were considered stochastic. The probability with which each of the chance constraints had to be satisfied, α , was set at 0.95 for calving rates which corresponds to $\Theta^{-1}(\alpha_i) = 1.645$. Since the beef cattle enterprise has a long production cycle, it was hypothesised 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, $\Theta^{-1}(\alpha_i)$ was set at 1.282 for all zonal constraints. Similarly, for wool cut per head, α was set at 0.90. For cross-bred lamb and lamb (meat), where production indicates a specialisation away from wool and lean sheep meat, α was set at 0.95.

Cereal crops are usually high-value but relatively high-risk enterprises. Yields vary according to Australia's fluctuating climatic influences while prices move according to world cereal production and the forces of international markets. However, cereal areas within the AGI continue to expand to increasingly marginal regions. This tends to indicate that the relative profitability of cereal-growing is still favourable and that it is reasonable to assume that farmers accept greater risks from grain production. Thus, while having expectations of crop yields, producers may accept a wider margin of yield variance. Therefore, α was set at 0.80, corresponding to $\Theta^{-1}(\alpha_i) = 0.842$.

Although all of the above probabilities were assumed, it would seem feasible to elicit the required information from AGI farmers using the sample survey structure already set up. Perhaps α could be included as a variable in the experimental design in order to evaluate the sensitivity of the model results to changes in the assumed probabilities. However, given the objectives of the present analysis and the fact that the required number of model runs increases sharply as variables are added to the experimental design, this extension of the study was unable to be explored.

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 3. A second degree polynomial seemed to fit the data satisfactorily. The 't-ratios' reported in Table 3 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 sheep meat and wheat, the estimated functions formed good approximations to the actual responses. They all show R^2 values in excess of 0.95. Therefore, the estimated functions form a useful basis from which supply response information can be generated and analysed. Own-price and cross-price elasticities derived from the polynomial supply function are presented in Table 4.⁵ Except for wheat, output supplies are inelastic with respect to own-price and 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 the AGI, estimates of the 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 5, various estimates of Australian elasticities are drawn together from the literature. Some long-run, medium-run and short-run estimates are presented where the specific medium-run elasticities were not available. These estimates are used to illustrate a range of results

⁵ The relative sizes of the estimated constant terms and coefficients on the dummy variables suggested that changes in the coefficient of risk aversion in the range 0.287 to 0.577 had a limited effect on supply response. Therefore, elasticities were calculated only for the central ϕ value of 0.369. Further analysis, using a wider range of ϕ , to show the impact of different risk attitudes on supply responsiveness could prove interesting.

Coefficient ^c	Variable ^b						
	TNR	TB	MB	BEEF	WOOL	SHMEAT	WHEAT
Constant	-2 965.48 (-1.34)	-302.01 (-0.32)	411.87 (0.70)	109.85 (0.13)	299.76 (1.13)	1 810.42 (2.13)	-160.40 (-1.73)
P_t	1 191.62 (0.71)	1 688.30 (2.37)	-688.59 (-1.49)	1 019.79 (1.65)	21.13 (0.10)	35.84 (0.05)	49.27 (0.70)
P_{mb}	1 639.40 (0.65)	699.68 (0.65)	195.51 (0.29)	504.11 (0.55)	225.36 (0.75)	81.58 (0.08)	69.75 (0.66)
P_w	733.56 (0.85)	-129.46 (0.35)	-307.05 (-1.33)	177.59 (0.56)	30.00 (0.29)	-740.60 (-2.22)	40.08 (1.11)
P_{wn}	15.93 (0.92)	0.67 (0.09)	-1.45 (-0.31)	-0.78 (-0.12)	1.23 (0.60)	-14.80 (-2.22)	1.77 (2.44)
$(P_t)^2$	-375.56 (-0.79)	-979.32 (-4.86)	-31.45 (-0.25)	-1 010.77 (5.78)	23.57 (0.41)	48.11 (0.26)	-23.09 (-1.16)
$(P_{mb})^2$	-916.44 (-0.60)	257.39 (0.57)	-80.93 (-0.29)	176.46 (0.45)	-264.41 (-2.09)	-115.32 (-0.28)	-51.01 (-1.15)
$(P_w)^2$	-75.14 (-0.60)	-38.59 (-0.73)	55.46 (1.66)	16.87 (0.37)	-12.85 (-0.86)	123.54 (2.56)	-8.20 (-1.57)
$(P_{wn})^2$	-0.03 (-0.65)	-0.07 (-3.46)	-0.01 (-0.83)	-0.06 (-3.39)	-0.002 (-0.33)	0.04 (1.91)	-0.01 (-3.47)

TABLE 3 (continued)

Coefficient ^c	Variable ^b					
	TNR	TB	MB	BEEF	WOOL	SHMEAT
$P_{tb} * P_{mb}$	-200.95 (-0.15)	-1 217.49 (-2.20)	1 417.06 (4.05)	199.57 (0.42)	56.10 (0.36)	86.29 (0.17)
$P_{tb} * P_{wl}$	3.98 (0.01)	152.72 (0.80)	-118.42 (-0.99)	34.30 (0.20)	-80.80 (-1.50)	-137.83 (-0.79)
$P_{tb} * P_{wh}$	3.99 (0.44)	11.13 (2.91)	-0.73 (-0.30)	10.40 (3.14)	0.39 (0.36)	0.59 (0.17)
$P_{mb} * P_{wt}$	-21.25 (-0.01)	29.00 (0.10)	-558.23 (-3.12)	-529.23 (-2.15)	198.00 (2.47)	129.35 (0.49)
$P_{mb} * P_{wh}$	0.39 (0.08)	1.02 (0.52)	-0.82 (-0.67)	-0.20 (-0.12)	0.26 (0.47)	4.68 (2.62)
$P_{wt} * P_{wh}$	-0.15 (-0.01)	-0.58 (-0.10)	2.62 (0.73)	2.04 (0.41)	-3.92 (-2.44)	-3.22 (-0.62)
$D1^d$	-34.07 (-2.48)	-0.53 (-0.09)	-2.50 (-0.68)	-3.04 (-0.60)	-2.67 (-1.62)	-9.78 (-1.83)
$D2^d$	-87.79 (-5.97)	-0.81 (-0.13)	-7.62 (-1.93)	-8.43 (-1.56)	-9.21 (-5.23)	-31.71 (-5.57)
R^2	0.987	0.957	0.939	0.950	0.958	0.901
						0.868

^a Figures in parentheses are *t* values.^b Variable codes refer to total expected net revenue (TNR) and production of table beef (TB), manufacturing beef (MB), total beef (BEEF), greasy wool (WOOL), sheep meat (SHMEAT) and wheat (WHEAT).^c Coefficient codes refer to own-price and cross-price effects for table beef (P_{tb}), manufacturing beef (P_{mb}), wool (P_{wl}) and wheat (P_{wh}).^d $D1$ and $D2$ are dummy variables used to represent block effects (coefficient of risk aversion) in the experimental design.

TABLE 4
Price Elasticities of Supply^a

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

^a Calculated for $\phi = 0.369$.

^b For variable and price codes, see footnotes b and c, respectively, on Table 3.

from studies using different estimation methods and, therefore, place the results from this analysis in context.

The price elasticities for beef supply estimated in this study were lower than those from the Longmire et al. (1979) 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 Longmire et al. 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 lower than that estimated in the Longmire et al. model. It is close, however, to the medium-run elasticity estimated by Gruen et al. (1967) and falls within the range of elasticities econometrically derived by Malecky (1971) for a ten-year 'medium-run'.

Sheep meat elasticities may not be strictly comparable because of the different definitions used in the two models. However, the estimates of the wool price elasticity of sheep meat supply from this analysis is the same as that in the Longmire et al. model. In addition, 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 than 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 the Gruen et al. (1967) estimate of medium-run own-price elasticity of wheat supply, the Longmire et al. estimate is lower, while that derived in this study is higher.

An Alternative Estimate of Supply Response

The researcher can only postulate that a particular functional form will represent adequately the response surfaces analysed, since the nature of the true response function is unknown. In the case of the experiment described above, either linear or quadratic response functions may be

TABLE 5
Alternative Estimates of Supply Response Elasticities^a

Commodity and source of estimate	Price				
	Term ^b	Beef ^c	Wool	Wheat	Cereal ^d
<i>Beef^e</i>					
Gruen et al. (1967)	SR	0.16	0	0	—
Longmire et al. (1979)	MR	0.69	-0.18	—	-0.12
<i>Wool</i>					
Dahlberg (1964)	SR	—	0.08	—	—
Dalton & Lee (1975)	SR	—	0.08-0.09	—	—
Gruen et al. (1967)	SR	0	0.05	-0.04	—
Malecky (1971)	SR	—	0.05-0.17	—	—
Longmire et al. (1979)	MR	-0.24	0.32	—	-0.13
Gruen et al. (1967)	MR	—	0.25	—	—
Malecky (1971)	MR	—	0.35	—	—
Malecky (1975)	MR ^f	—	0.16-0.71	—	—
Gruen et al. (1967)	LR	—	3.59	—	—
Malecky (1975)	LR	—	3.94-4.70	—	—
<i>Sheepmeat^g</i>					
Longmire et al. (1979)	MR	-0.23	0.18	—	-0.01
<i>Lamb</i>					
Gruen et al. (1967)	SR	0	-0.05	0	—
<i>Wheat</i>					
Gruen et al. (1967)	SR	0	-0.11	0.18	—
Gruen et al. (1967)	MR	—	—	0.82	—
Gruen et al. (1967)	LR	—	—	3.82	—
<i>Cereals^h</i>					
Longmire et al. (1979)	MR	-0.10	-0.06	—	0.35

^a A dash indicates that the particular elasticity was not estimated.

^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 these sheep meat results included the lean shipment component specified in the IAQP model. It is possible that this latter commodity may have been termed live sheep exports, in which case sheep meat would refer to mutton and lamb only.

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

assumed. However, this does not restrict the use of other functional forms which better summarise the response data. The application of alternative forms simply means that the response data may have been generated more efficiently using a different experimental design.

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 realised through the estimation of a translog response function for total net revenue in the form of output share equations such as:

$$(7) \quad p_i x_i / TNR = \alpha_i + \sum_{j=1}^4 \beta_{ij} \ln p_j + D1 + D2,$$

where $j = \text{TB, MB, WOOL and WHEAT}$.

The corresponding translog estimates presented in Table 6 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 TB, MB 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 US Beef Imports

General opinion in Australia seems to be that the new US policy will engender beef price destabilisation. Subjective evaluations conclude that the forecast upswing in the US beef cycle in the mid-1980s would result in beef price reductions and would have a direct bearing on Australian producers' 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 in beef prices. A 10 per cent 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

For the AGI, the medium-term impacts of a sustained (five-year) 10 per cent fall in beef prices are shown in Table 7. Following the inception of countercyclical beef import measures in the U.S.A., Australian producer expectations with respect to beef prices would be affected. Because the US market is largely one for manufacturing beef, whereas most table beef is sold domestically and in other markets, it is useful to consider the influence on price expectations extending to table beef (P_{tb}) and manufacturing beef (P_{mb}) separately, as well as 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 and because it is possible that price expectations for the two types of beef may be influenced separately due to separation of both the markets for the products and the areas of production.

In Table 7 it is shown that, for the AGI, 84 per cent of the assumed change in total beef price would be transmitted to total net revenue less the risk premium (TNR). In other words, TNR would fall by 8.4 per cent for a 10 per cent reduction in beef prices. The underlying cause of this revenue loss was a 3.5 per cent cut-back in total beef output. Offsetting the revenue effect of the negative beef supply response were positive

TABLE 6
Translog Estimates of Supply Response Functions^a

Commodity ^b	Regressor ^b							
	Constant	P_{t_b}	P_{m_b}	P_{w_t}	P_{w_h}	$D1$	$D2$	R^2
<i>TB</i>	5.68 (22.66)	0.53 (9.56)	-0.19 (-3.53)	-0.70 (-12.82)	-1.03 (-18.83)	0.02 (1.72)	0.06 (4.54)	0.966
<i>MB</i>	1.44 (15.95)	-0.19 (-9.86)	0.24 (12.05)	-0.20 (-10.06)	-0.24 (-11.92)	ns	0.01 (2.72)	0.956
<i>BEEF</i>	7.12 (24.48)	0.33 (5.25)	0.04 (0.69)	-0.90 (-14.17)	-1.27 (-19.93)	0.03 (1.70)	0.07 (4.76)	0.966
<i>WOOL</i>	6.63 (25.74)	-0.72 (-12.78)	-0.21 (-3.73)	0.24 (4.28)	-1.33 (-23.71)	0.03 (2.02)	0.07 (5.16)	0.972
<i>SHMEAT</i>	7.86 (19.20)	-0.77 (-8.64)	-0.21 (-2.31)	0.35 (3.88)	-1.60 (-17.92)	0.02 (0.81)	0.04 (1.87)	0.948
<i>WHEAT</i>	-5.48 (-6.00)	-0.83 (-4.18)	-0.16 (-0.81)	-0.97 (-4.85)	1.54 (7.72)	0.03 (0.57)	0.23 (4.82)	0.849

^a ns indicates that the estimated coefficient is less than 0.005. Figures in parentheses are *t*-values.

^b Dummy variables *D1* and *D2* are used to represent block effects (coefficient of risk aversion) in the experimental design. For other commodity and price codes, see footnotes b and c, respectively, on Table 3.

TABLE 7

Medium-Term Impacts on Revenue and Production Levels of a 10 per cent Reduction in Beef Prices

Revenue/ commodity supplied ^a	Estimated percentage impact of ^a :		
	P_{tb} – 10 per cent	P_{mb} – 10 per cent	P_{tb} and P_{mb} – 10 per cent
<i>TNR</i>	– 6.9	– 1.5	– 8.4
<i>BEEF</i>	– 2.6	– 0.9	– 3.5
<i>WOOL</i>	+ 0.2	+ 0.6	+ 0.8
<i>SHMEAT</i>	+ 0.3	+ 0.5	+ 0.8
<i>WHEAT</i>	+ 0.1	+ 0.1	+ 0.2

^a For commodity and price codes, see footnotes b and c, respectively, on Table 3.

(albeit small) impacts on the production of wool (0.8 per cent), total sheepmeats (0.8 per cent) and wheat (0.2 per cent).

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 per cent reduction in beef prices would reduce beef supply of the aggregate grazing industry by 3.5 per cent. 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 to be 8.4 per cent.

If the less likely assumption is adopted, that the 10 per cent reduction in beef price resulting from a change in US beef import policy affects 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 per cent.

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 importance of the accuracy of information disseminated to producers is also highlighted. A prevailing opinion in Australia is that the countercyclical US beef import policy will cause price reductions during the rising phase of the beef cycle. It seems likely

that producers' expectations of price could be affected by the occurrence 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 US 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 mix it would be unrealistic to surmise possible revenue effects.

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