SUPPLY RESPONSE OF AUSTRALIAN WHEAT GROWERS

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Alternative specifications of models of the supply response of Australian wheat growers and their economic implications are considered in terms of the existence and nature of production lags, and the choice between expected prices and expected gross returns as the preferred explanator of producers' response to changing economic conditions. The analysis indicates that there are lags which are due primarily to the difficulties and costs of rapid adjustment rather than to the time required to revise expectations. The statistical results were similar for the alternative specifications of gross margins and prices as the economic decision variables. However, the price elasticities derived using the gross margins specification were about a third of those using the prices specification. The gross margins specification yielded additional information in the form of yield and input cost elasticities.

Introduction

Econometric studies of agricultural supply response are based on a number of somewhat arbitrary assumptions about the appropriate set of causal variables and relationships. Included in these assumptions are the choice of prices, costs and technology as determining variables, the way in which expectations of these variables are formed and revised, and the extent of and form of the adjustment process. In general, published papers have made little comment about the choice of the particular specification reported. Of course, the choice among alternative specifications is important only if alternative models have different structural, forecast or policy implications.

The aim in this paper is to investigate the implications of some alternative ways of specifying the area response function for established wheat-growing areas in N.S.W. The emphasis is on three aspects of the model specification, namely: whether expected prices or a measure of expected gross returns which include price, yield and cost factors are better explanators; the way in which past prices are combined to form expected prices; and whether there are adjustment lags. Consideration is given to *a priori* reasoning, to the comparative statistical properties of the differently specified models and to economic implications of the estimated models in terms of price, yield and cost elasticities of supply.

Issues in Specification of Supply Models

In this section previous studies of the Australian wheat area response function are reviewed and consideration is given to economic theory and other *a priori* information as they relate to the specification of the principal economic determining variables, the adjustment process, and the formation of price expectations.

Price or gross returns

The majority of Australian econometric models have used price per unit of output as the principal economic determinant of wheat area, e.g., Duloy and Watson (1964), Gruen et al. (1967), Fisher (1975) and Smith and Smith (1976). Griffiths and Anderson (1978) compared model specifications using price and gross returns (yield times price) and reluctantly concluded that the price specification was preferred on the sole ground that it resulted in a slightly superior explanatory model, although they provided no evidence of whether the gain was significant. Vincent, Dixon and Powell (1977) specified a gross margin variable in terms of activity-specific input costs. Builders of programming models, e.g. Kingma and Kerridge (1977) and Walker et al. (1977), have used gross margins as the explanatory variables.

Economic theory and observation favour the use of a gross margin rather than a price variable. The classical producer decision model expresses desired area as a function of product price, product yield and input costs.[1] In a world of stationary yield and of constant costs it may be reasonable to ignore the yield and cost terms. That is, price would be a good proxy for gross return. For a situation with changing technology, of changes in input combinations, and of different growth rates of input costs, it is desirable to include explicitly yield and cost variables in the model specification. Of course, it would be preferable to include all these factors as separate variables. However, this is seldom feasible because of the limited availability of data for empirical work.

The gross margin variable is readily interpreted from the programming literature. It specifies the return per unit activity accruing to the bundle of fixed factors—usually land and the farmer's own capital and labour.

Adjustment lag

Previous studies have made different specifications regarding the possibility of adjustment lags and the lags estimated have varied considerably. Duloy and Watson (1964), Fisher (1975) and Griffiths and Anderson (1978) assumed that producers can and do fully adjust to their desired long-run or comparative static equilibrium area each year. Others, including Gruen et al. (1967) and Smith and Smith (1976), allowed for partial adjustment, although the latter did not find a significant lag. The programming models of Kingma and Kerridge (1977) and Walker et al. (1977) included adjustment lags.

Several reasons can be advanced for the hypothesis that there will be partial adjustment to the desired area within a year. Wheat production requires a substantial investment in specialised equipment which provides a flow of services over several years. In general, the salvage value of specialised equipment to the wheat industry will be substantially less than its purchase price. To some extent, this argument is of less importance where the enterprise switch is between different grain crops. However, in the established wheat areas of N.S.W., the focus of this study, much of the movement into and out of wheat is as a substitute for grazing activities, particularly wool. A rising supply price of investment funds due to internal and external capital rationing will operate to force partial adjustment. Time is required for producers to adapt to and to learn to

[1] Similar results would be obtained from models which are extended to allow for risk aversion, decision making under uncertainty and other objectives such as satisficing behaviour.

operate their farms with a different enterprise mix. No information could be found on the general form of and the extent of the adjustment cost function.

Expected prices

Generally the theoretical model expresses the area response function in terms of prices expected to be received by producers. Unfortunately, there are no available measures of producers' expected prices. A number of proposals have been adopted for specifying a proxy variable for expected prices in terms of observed variables.

A common procedure has been to specify expected price as some function of observed current and past prices. Some have used the current observed price as a proxy for expected prices, e.g. Smith and Smith (1976). The efficient markets theory (Fama 1970) provides support for this hypothesis; there will be abitrage by speculators between current and future prices so that the former is the best estimate of the latter. Perhaps more common is the adaptive expectations model where expected price is specified as a declining geometric lag distribution of current and past prices. This specification was used by Watson and Duloy (1968), Gruen et al. (1967) and others. The intuitive basis of this specification is that producers revise their previous estimate of future prices by a fraction of the difference of that estimate and the current actual price. Fisher (1975) specified a more general second-order polynomial distribution function of prices over the past four years. Other possibilities include the arithmetic lag structure model and the extrapolative expectations model.

Smith and Smith (1976) used a 'partially' rational expectations model. They included wheat and flour stocks as an indicator of optimistic (small stocks) and pessimistic (large stocks) anticipations. On reflection, this explanation is subject to doubt. If producers are rational then so too will be the market traders. If stocks are high, indicating low future prices, then available stocks will continue to be sold until current prices fall. That is, as in the perfect markets theory (Fama 1970) and the storage decision model (Working 1949), current prices will reflect anticipated future prices and the stocks data will provide no additional information. The results of Smith and Smith might be explained as follows. Generally large stocks indicate a longer period before full payment is received than is the case with small stocks. Here the stock variable might be considered an indicator of the present or discounted value of current production at current and expected prices.[2]

Little is known either *a priori* or from direct interviews with producers as to how price expectations are formed.[3] Until such information is collected and analysed, most of the evaluation of which is the more suitable price expectation proxy measure will have to rely on the relative performance of estimated models using the alternative measures.

[2] A preferable procedure would be to use a properly discounted price.

[3] Published work seems to have to go back to the early 1950s by Heady and Kaldor (1954) and Williams (1953). They found that different farmers had a diversity of price expectation models and expected prices. A common procedure was to extrapolate past prices and adjust for anticipated shifts in product supply and demand.

An Empirical Evaluation

To assess the quantitative implications of the alternative model specifications, this section reports the results of estimates of alternative specifications of wheat area response functions for four regions in the wheat-sheep zone of N.S.W. While the estimates are directly relevant to the particular problem, they also illustrate and perhaps provide some guidance for the choice of model specification of supply response models for other situations.

Model specification

The general model takes the form

$$(1) \qquad A_t^* = a + bX_t^* + e_t$$

where A_t^* is desired wheat area, X_t^* is expected value of the economic decision variable discussed in detail below and e_t is a random error term with classical properties.

To allow for the possibility of adjustment lags, a Nerlovian partial adjustment model is specified,

$$(2) \qquad A_t - A_{t-1} = \gamma(A_t^* - A_{t-1}), \ 0 \leq \gamma \leq 1,$$

where γ is the coefficient of adjustment.[4] Substituting (1) into (2) and readjusting gives the estimable model

$$(3) \qquad \begin{aligned} A_t &= a\gamma + b\gamma X_t^* + (1-\gamma)A_{t-1} + \gamma e_t, \\ &= \pi_0 + \pi_1 X_t^* + \pi_2 A_{t-1} + u_t. \end{aligned}$$

Then, in (3), testing the null hypothesis that $\pi_2 = 0$, which means $\gamma = 1.0$, can be used to assess a significant adjustment lag.

The economic decision variable X_t in (1) is specified as expected relative returns from wheat and wool production. Such a parsimonious specification simplifies reality. Omitted from the explanatory variables are returns from cattle and other activities, wheat quotas, and seasonal conditions. Such a simplification is chosen on the basis of previous studies, particularly that of Watson and Duloy (1968), and on the assumption that the excluded variables either are not highly correlated with the included variables or have a very small effect.[5] The relative return variable imposes the assumption of a constant production possibility curve for wheat and wool production. This may represent a reasonable approximation for the extablished areas under study. It has the advantage of saving degrees of freedom and reducing multicollinearity among the explanatory variables.

The expected economic decision variable is defined in two ways to reflect the use of either relative prices or relative gross returns. The relative price specification is

[4] This, of course, is not the only adjustment model but it is one commonly used as a first approximation.

[5] For the purposes of this study it is important only that the excluded variables be uncorrelated with the included variables. Then the OLS parameter estimates will remain unbiased.

(4) $$X_t^* = Pwh_t^* / Pwo_t^*$$

where Pwh_t^* is expected price of wheat and Pwo_t^* is expected price of wool. The relative gross margin specification is

(5) $$X_t^* = (Pwh_t^* Ywh_t^* - \Sigma_i awh_{it} C_{it}) / (Pwo_t^* Ywo_t^* - \Sigma_i awo_{it} C_{it})$$

where Ywh_t^* and Ywo_t^* are, respectively, expected yield for wheat and wool, C_{it} is cost of input i in period t, and the awh_{it} and awo_{it} coefficients denote use of input i in period t in production of wheat and wool, respectively. The alternative specifications (4) and (5) are subsitituted into (3) to evaluate whether relative prices or relative gross margins are used to make decisions about the wheat area. In each case, values for expected prices and yields are prespecified (discussed below).

Choice between the price and gross return specifications on a statistical basis involves the testing of non-nested hypotheses since one model is not a special case of the other. The theory of non-nested hypothesis testing is only in its infancy. A good review is given by Gaver and Geisel (1974). A common procedure involving the comparison of R^2 (or $\bar{R}^2$), which in turn is a monotonic function of the estimated error term variance, is decribed as an informal procedure only. Further, these statistics are specific to the sample observations and, hence, one needs to be able to say whether R^2 for one model is significantly different from the R^2 for another model. Such a test is not available, except for the special case of models with a single explanatory variable. Since we have diffuse priors on the models and the parameters of each model, Bayesian procedures are not applicable; in fact, Geisel's (1975) procedures then becomes a comparison of R^2. Pesaran (1974) discusses two statistical tests. One procedure involves embedding the two alternative models into a larger joint model in which the two alternatives are special cases. One then uses the F test for significance of the variables of the different models. This test often does not give unambiguous results, particularly in the case of small samples and when the sets of variables of the alternative models are highly correlated. Pesaran's second procedure is based on a comparison of likelihood functions in which each model in turn is assumed to be the correct model. The actual procedure used to compute Pesaran's d statistics for this paper is that reported by Quandt (1974). Again, this procedure may give inconclusive results. On the basis of Monte Carlo experiments, Pesaran found this second test to have greater discriminatory power than the first test when the sample size is small (≤ 40 observations) and the correlation between the competing sets of explanatory variables is large.

In addition to the statistical tests, the implications of the relative price and relative gross return variable specifications on estimates of the elasticity of area with respect to price, yield and cost variables are discussed.

The yield expectation variables in (5) are assumed to be given by the mean sample value in the case of wheat and a three-year moving average of annual wool yields in the case of wool. In both cases, changes in yield refer primarily to genetic improvements. The wheat assumption follows from the work of Ryan (1974) and others who have found that regional wheat yields have had no trend or cyclical pattern over time. On the other hand, fleece weight increases indicate that there has been significant technological advance in wool production (Donald 1965; Powell and Gruen 1966).

Four variants of the way in which producers extract information from observed prices in forming price expectations were considered. These were the naive model, $P_t^* = P_{t-1}$, the extrapolative expectations model, $P_t^* = P_{t-1} + \varrho(P_{t-1} - P_{t-2})$ with $-1 < \varrho < 1$, the arithmetic lag model $P_t^* = \Sigma n_i(2(n(n-1)/(n+1)))P_{t-1}$, and the truncated adaptive expectations model, $P_t^* = \phi\Sigma_r\, \beta(1-\beta)^r$ with $\phi = 1.0/(\Sigma_r\, \beta(1-\beta)^r)$ and $r = 0, 1, \ldots, 4$.

With the extrapolative and adaptive expectations models, the parameters ϱ and β were varied in units of 0.1 over the feasible range. In the arithmetic lag model, values of n of 2, 3 and 4 were tried. For these experiments, the choice of ϱ, β and n was based on comparison of the R^2 value which is a monotonic function of the value of the concentrated likelihood function. Comparison of estimated models with the different price expectation specification were based on statistical properties of the estimated models.

Data

The sample period extends from 1945/6 to 1974/5. Four Statistical Divisions of New South Wales—Central Tablelands, Central Western Slopes, South Western Slopes and Riverina—were studied.

The dependent variable was given by the intentions to sow wheat area collected by ABS. Wheat price was measured by total realisation of the crop. This was the variable used by Watson and Duloy (1964) and Smith and Smith (1976). The average annual greasy wool price data were obtained from the National Council of Wool Selling Brokers. For the yield variables, the average yield per hectare for N.S.W. and the average weight of fleece per sheep shorn in N.S.W. were used (ABS). The state averages were assumed to be good proxies for averages for the Statistical Divisions. For the gross margins, costs were separated into labour costs and machinery costs.[6] The input coefficients were obtained from BAE farm surveys (e.g. BAE 1971, 1975). The BAE index of wages paid by farmers was used for labour cost, the index of land preparation and crop growing machinery prices was used for wheat machinery and the index of prices paid for livestock machinery was used in the case of wool. All data are available in Sanderson (1978).

All models were estimated by ordinary least squares.

Results

Price expectations. Table 1 summarises some of the results obtained in terms of the $\bar{R}^2$ values for each of the four Statistical Divisions and for the different specifications of expected price. In general, the results are more satisfactory with the naive or simple price expectations model in which expected price is given by current price. With the extrapolative and adaptive expectations models, the likelihood surfaces were very flat as is indicated by the narrow ranges in the $\bar{R}^2$ values. To illustrate, a likelihood surface for the Central Tablelands Statistical Division is shown in Figure 1. For the extrapolative expectations model, the value of

[6] Over the sample period, machinery and labour costs accounted for between 20 and 25 per cent of the total cash costs incurred by wheat farmers in N.S.W.

TABLE 1

Ranges of the $\bar{R}^2$ Values Obtained from the Four Variants of the Statistical Models

Gross margin ratio as explanatory variable

Region	Expectations model			
	Simple	Extrapolative	Fisher's	Adaptive
1	0.590	0.536-0.592	0.562-0.590	0.573-0.590
2	0.699	0.629-0.699	0.666-0.699	0.661-0.699
3	0.738	0.672-0.744	0.700-0.738	0.707-0.738
4	0.737	0.649-0.739	0.699-0.737	0.686-0.737

Price ratio as explanatory variable

Region	Expectations model			
	Simple	Extrapolative	Fisher's	Adaptive
1	0.613	0.536-0.629	0.548-0.613	0.565-0.613
2	0.701	0.629-0.710	0.639-0.701	0.651-0.701
3	0.740	0.672-0.754	0.685-0.740	0.697-0.740
4	0.746	0.648-0.757	0.680-0.746	0.677-0.746

$\bar{R}^2$ was greatest for ϱ in the range 0.0 to 0.2. Slightly higher values for $\bar{R}^2$ were obtained using the adaptive expectations model as β approached unity. Best results were obtained from the Fisher model with $n = 1$.

The finding that expected price is as satisfactorily represented by current price as by a weighted average of current and previous prices is at variance with the findings of Watson and Duloy (1968) and Fisher (1975). However, these studies assumed instantaneous adjustment.

Adjustment lag. In most model specifications there is considerable evidence of significant area adjustment lags. For the preferred models, estimates of the coefficient of adjustment, γ, fall in the range 0.25 to 0.35 (see Table 2). This implies that about a quarter to a third of the desired area adjustment occurs in the current year and 95 per cent of the adjustment occurs by the end of eight years.

Price versus gross margin. The statistical tests do not enable us to choose between the model with prices as the explanatory variable and the model with gross margins as the explanatory variable. From Tables 1 and 2 it can be seen that generally the $\bar{R}^2$ statistic is greater for the price variable, but the difference is no more than a few percentage points. Estimates of the joint model which includes the price and gross margin models as special cases are shown in Table 3. For each region, both the estimated coefficients on the price variable and the gross return variable are not statistically different from zero at conventional levels of significance. This means that it is not possible to choose between the two models using the augmented model procedure.

Results of the second test proposed by Pesaran are reported in Table 4. The d_i statistics are asymptotically distributed as standard normal variates on the assumption that model i ($i = 1$ for the gross margin model

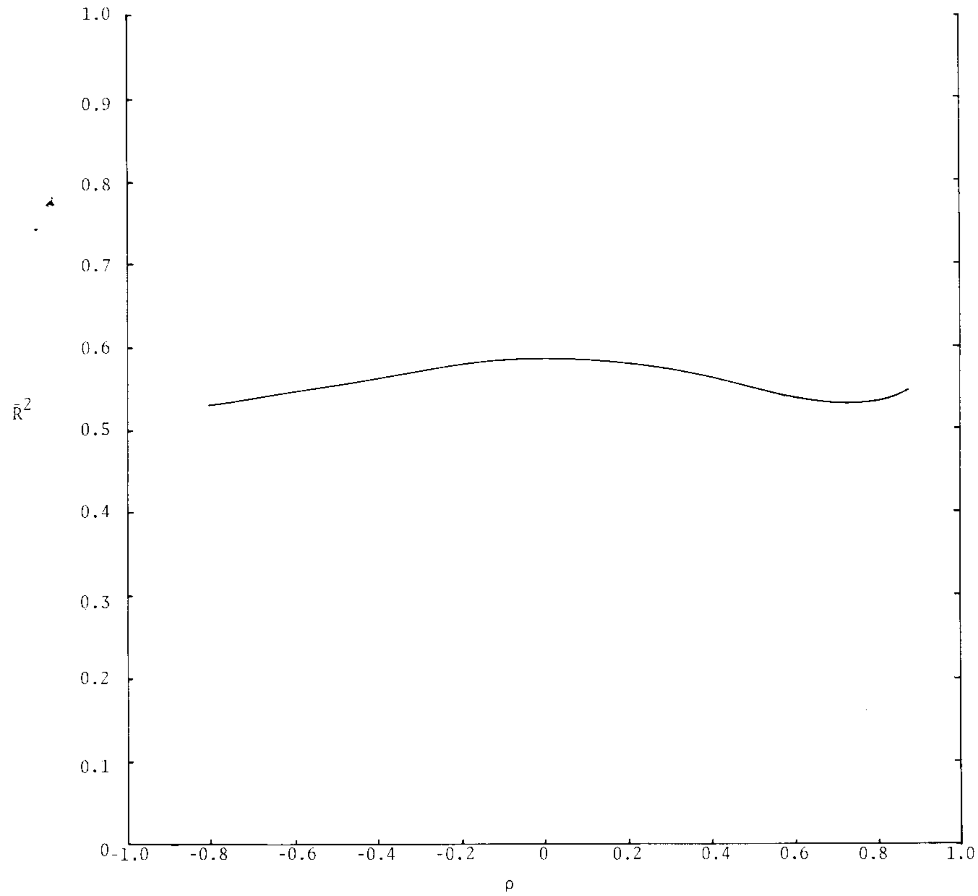

FIGURE 1—Maximum likelihood surface for Region 1: extrapolative price expectations.

and $i=2$ for the price model) is true. The results in Table 4 indicate that both models can be accepted.

Thus, on the basis of statistical criteria, there is no basis for preferring the prices model or the gross margins model. Such a result is not very surprising when account is taken of the high level of correlation between the two variables—a partial correlation coefficient of 0.87—and the small sample of 29 observations (see Pesaran's Monte Carlo results).

There are, however, markedly different economic implications for the alternative specifications in terms of the implied area response elasticities with respect to the output prices of wheat and wool, the input prices of labour and machinery, and the average yields per production unit. Estimates of these elasticities are shown in Tables 5 and 6 for the short run (one year) and the long run, respectively. The elasticities have been calculated at the average sample values of the variables.

In the case of the output price elasticity estimates, the ones obtained with the relative price specification are at least three times as large (in absolute terms) as those obtained from the relative gross margin specification. Even allowing for sampling errors, the elasticity estimates of the two models are significantly different. This holds for both the short-run and the long-run estimates.

TABLE 2

Preferred Estimates of Wheat Area Response Functions[a] by Regions

Region	Explanatory variables[b]				Durbin *h*	$\bar{R}^2$
	Constant	Gross margin	Price	Lagged area		
C. Tablelands	0.189	0.096 (0.055)[c]		0.666 (0.136)	1.98[d]	0.59
C. Tablelands	0.033		0.658 (0.308)	0.624 (0.137)	1.96	0.61
C. W. Slopes	0.717	0.506 (0.217)		0.685 (0.123)	1.24	0.70
C. W. Slopes	0.001		2.875 (1.215)	0.676 (0.124)	1.22	0.70
S. W. Slopes	0.541	0.490 (0.203)		0.698 (0.120)	0.61	0.74
S. W. Slopes	−0.159		2.784 (1.134)	0.690 (0.121)	0.32	0.74
Riverina	0.526	0.737 (0.263)		0.683 (0.155)	0.25	0.74
Riverina	−0.590		4.267 (1.427)	0.679 (0.113)	0.06	0.75

[a] Simple price expectation model.

[b] Dependent variable is intended area of sown wheat (in 100 000 ha). Explanatory variables are relative gross margin for wheat ($/ha) and wool ($/ha) or relative price of wheat ($/t) and wool (c/kg) and area in previous year.

[c] Standard errors in parentheses here and in Table 3.

[d] With the exception of the C. Tablelands region, Durbin's *h* statistic indicates the absence of first-order autocorrelation at the 95 per cent confidence level.

For the yield and input costs elasticities, the relative price specification presumes these to be zero whereas they are estimated to be important in the case of the relative gross margin specification.

While the statistical tests do not permit a distinction between the alternative model specifications, the models have markedly different implications as regards the effects of output price changes, of technological change in the sense of yield increases, and of input cost changes on the desired area of wheat.

Conclusions and Implications

The results raise two issues of model specification which have particular interest. These are the source of lags in supply response and the appropriate economic decision variable. While the numerical results obtained here are specific to the problem studied and are conditional on a number of contentious assumptions, they do have general implications for a wider set of examples.

There has been considerable debate as to whether there are lags in the

TABLE 3

Estimates of the Joint Model[a] in which the Price and Gross Margin Models are Embedded as Special Cases

Region	Explanatory variables[b]				$\bar{R}^2$
	Constant	Gross margin	Price	Lagged area	
C. Tablelands	0.028	−0.004 (0.104)	0.677 (0.595)	0.624 (0.140)	0.60
C. W. Slopes	0.298	0.257 (0.361)	1.665 (2.252)	0.669 (0.126)	0.69
S. W. Slopes	0.130	0.251 (0.361)	1.625 (2.024)	0.679 (0.123)	0.73
Riverina	−0.244	0.300 (0.482)	2.875 (2.664)	0.669 (0.115)	0.74

[a] Simple price expectation model.
[b] Variables as defined for Table 2.

response of farmers to changes in economic conditions and as to the primary source of the lags. For the wheat regions considered here, the findings indicate that there are lags and that these lags are due primarily to difficulties and costs of rapid adjustment rather than to time required to revise expectations.

Results of the study highlight the potentially important effect of alternative model specifications on the implied economic properties of estimated functions. This is particularly evident in the choice of gross margin or price as the economic decision variable. Both specifications give similar statistical results but markedly different elasticity estimates.

We would argue for the gross margin specification. It follows from economic theory and observation that productivity and production costs

TABLE 4

Estimates of the d_i Statistics of Pesaran's Test for Model Discrimination

Region	Test statistics[a]	
	d_1	d_2
C. Tablelands	0.1286	−1.5220
C. W. Slopes	−0.7200	−0.8618
S. W. Slopes	−0.7874	−0.9478
Riverina	−0.6550	−1.3245

[a] See text for discussion of calculation of statistics and their interpretation.

TABLE 5
Estimated Short-run Elasticities

Region	Gross margin ratio as explanatory variable					
	Wheat price	Wool price	Wheat yield	Wool yield	Wheat cost	Wool cost
1	0.10	−0.14	0.10	−0.14	−0.24	0.05
2	0.11	−0.17	0.11	−0.17	−0.28	0.06
3	0.12	−0.18	0.12	−0.18	−0.30	0.06
4	0.16	−0.24	0.16	−0.24	−0.39	0.08

Region	Price ratio as explanatory variable					
	Wheat price	Wool price	Wheat yield	Wool yield	Wheat cost	Wool cost
1	0.31	−0.31	0	0	0	0
2	0.31	−0.31	0	0	0	0
3	0.34	−0.34	0	0	0	0
4	0.44	−0.44	0	0	0	0

as well as output prices influence returns from production and in turn choices of what to produce. The gross margin specification does force a specific relationship between the different variables but it is one which has intuitive appeal and is readily accepted by builders and users of programming models. In the particular application considered, there was nothing to choose between the gross margin and price specification in terms of statistical properties of the model. In terms of economic proper-

TABLE 6
Estimated Long-run Elasticities

Region	Gross margin ratio as explanatory variable					
	Wheat price	Wool price	Wheat yield	Wool yield	Wheat cost	Wool cost
1	0.29	−0.43	0.29	−0.43	−0.71	0.15
2	0.36	−0.53	0.36	−0.53	−0.88	0.18
3	0.41	−0.61	0.41	−0.61	−1.00	0.21
4	0.50	−0.74	0.50	−0.74	−1.23	0.26

Region	Price ratio as explanatory variable					
	Wheat price	Wool price	Wheat yield	Wool yield	Wheat cost	Wool cost
1	0.84	−0.84	0	0	0	0
2	0.94	−0.94	0	0	0	0
3	1.08	−1.08	0	0	0	0
4	1.37	−1.37	0	0	0	0

ties, the gross margin specification gave much lower output price elasticities—about a third of the estimates from the price specification—and important yield and input cost elasticities. The model can be used to evaluate the effect of changes in yield and production costs as well as changes in output prices on output decisions.

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