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SPECIFICATION OF AGRICULTURAL SUPPLY FUNCTIONS — EMPIRICAL EVIDENCE ON WHEAT IN SOUTHERN N.S.W.

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The implications of alternative disturbance specifications in supply functions have been considered in recent theoretical work but little, if any, empirical evidence has been provided on such specifications. Any empirical investigation of the nature of a supply function disturbance is hampered by considerable uncertainty about the deterministic part of the function. Nevertheless, some progress might be made by considering alternative disturbance specifications in conjunction with a variety of deterministic specifications. Applying this approach to the supply of wheat in southern N.S.W., we find some empirical support for an additive disturbance and, surprisingly, for the use of price, rather than revenue, as an argument in supply functions.

Recent theoretical work has thrown into prominence the issue of the nature of the 'stochastic' part(s) of supply functions. Specifically, Hazell and Scandizzo (1975), Newberry (1976) and Turnovsky (1976, 1977) have demonstrated that important differences arise in the distribution of welfare associated with price and stabilization policies if the stochastic disturbances enter multiplicatively rather than additively.

One general formulation of a supply function is

$$Q_t = Q(S(X^*_t, Z_t, T(t)), U(u_t)), \tag{1}$$

where S denotes the deterministic part[1] of the supply function with arguments consisting of the expectational variables, X^*, technology or time related effects, T, and other conditioning variables, Z, and U denotes the stochastic part of the function. An analytical device commonly used has been to disaggregate Q_t into an area harvested, A_t, and a yield, Y_t, component in the identity

$$Q_t = A_t Y_t \tag{2}$$

and to model area and yield effects separately. Alternatively, for livestock, Q_t is sometimes disaggregated into numbers of animals and yield per animal. Many analysts have concentrated on estimating an area response function (similar to (1) but in which A_t replaces Q_t), regarding A_t as the primary decision variable and implying that yields are unresponsive to price, although perhaps recognizing that yields may change systematically with time. Others, such as Guise (1969) and Houck and Gallagher (1976), have explicitly modelled the price responsiveness of yields in yield response functions (similar to (1) but in which Y_t replaces Q_t).

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[1] This formulation is restrictive in that we are not considering stochastic specification of S as a random coefficient model (Griffiths 1972).

A feature of the disaggregation in (2) is that, if Y_t is a random variable (a seemingly inevitable result, given the vagaries of climate and pestilence), as Hazell and Scandizzo (1975) have argued, Q_t necessarily features 'multiplicative risk' in the sense that, for a given harvested area, A_t,

$$V(Q_t|A_t) = A_t^2 V(Y_t|A_t), \tag{3}$$

where V denotes the variance operator. Viewed in this way, no matter what may be the stochastic structure of the area response function, risk is *a fortiori* multiplicative.

Given the sensitivity of policy implications to the stochastic specification of the quantity supplied function, (1), it is pertinent to consider whether the question of the nature of the stochastic part can be resolved empirically. Unless a crucial theoretical assumption can be supported by 'observations', it can hardly lead to convincing policy prescriptions. One difficulty is that the stochastic part can be 'observed' only as residuals estimated from empirical supply functions. Some of the difficulties and uncertainties inherent in estimating the deterministic part, S, are discussed below. For the moment, attention is directed to the stochastic part, U.

Representing Stochastic Disturbances in Supply Functions

Many plausible stochastic specifications of (1) are possible, although two particular forms have been most popular, namely

$$Q_t = S_t + u_t \tag{4}$$

and

$$Q_t = S_t e^{u_t}, \tag{5}$$

where the arguments of S are suppressed for brevity. The specification in (4) of 'additive risk' has usually been adopted when S is estimated as a linear function of its arguments. The 'multiplicative risk' variant in (5) has usually been employed when S is estimated as a power (e.g. constant elasticity) function.[2] Analysts have seemingly been influenced in their choice between (4) or (5) by considerations relating primarily to S rather than to u.

A method for choosing between (4) and (5) has been suggested by Leech (1975) and illustrated by Leech and by Mizon (1977). Leech uses the Box and Cox (1964) power transformation of both Q_t and a given S_t which has (4) and (5), but not a mixture of these, as special cases. Specifically, he recommends estimating

$$Q_t^{(\lambda)} = S_t^{(\lambda)} + \delta_t, \tag{6}$$

where $Q_t^{(\lambda)} = (Q_t^{\lambda} - 1)/\lambda$ if $\lambda \neq 0$ and $Q_t^{(\lambda)} = \log Q_t$ if $\lambda = 0$, and where the deterministic part of the right-hand side, S_t, is transformed in a similar manner. Using E to denote the expectation operator it is assumed

[2] A disturbance such as e^{u_t} in (5) can be rewritten as $\phi + \epsilon_t$, where ϵ_t has zero mean. Hence (5) can be re-expressed in terms of an additive disturbance, say $Q_t = S_t' + v_t$, where $S_t' = \phi S_t$ and $v_t = S_t \epsilon_t$. The essential distinction between (4) and (5) (in terms of the welfare implications for, say, price stabilization policies) is not whether the disturbance is additive or multiplicative, but rather whether Q_t is homoscedastic or heteroscedastic, where, in the heteroscedastic case, $V(Q_t)$ depends on S_t. These alternative properties of Q_t are usually guaranteed, as indeed they are in this paper, by assuming that the disturbances in both (4) and (5) have constant variances.

in (6) that $E\delta_t = 0$, $E\delta_t^2 = \sigma^2$ and $E\delta_t\delta_s = 0$ $(t \neq s)$. Maximum likelihood estimation under the assumption of normality enables the construction of a confidence interval for λ. This interval may include unity (which would support (4) as the correct hypothesis) or zero (which would support (5) as the correct hypothesis). Alternatively, it could include both of these polar specifications or neither. Unfortunately, the evaluation is conditional on the somewhat arbitrary specification of the form of S.

Some Uncertainties about the Systematic Part of Supply Functions

Uncertainty seemingly prevails about several aspects of the systematic or 'deterministic' part of supply functions. Some of these aspects are discussed briefly. The purpose here is not to exhaust the topic but rather to identify several uncertainties which make resolution of the stochastic specification difficult, both in general and in our empirical work that follows.

The price units

Product price is usually expressed in money per unit of Q, namely a unit price, P. When Q_t is the dependent variable, the usual practice thus accords with the Powell and Gruen (1966, p. 113) proclamation that units should be consistent (i.e. if Q_t was replaced by A_t, then price should be in money per unit of A, namely a unit revenue, R).

Beyond this intuitive consideration of consistency, Hazell and Scandizzo (1977) have raised a new uncertainty about the type of price variable by showing that conflicting policy results are found, depending on whether price or revenue anticipations are assumed for X^*. This conflict has nothing to do with consistency but relates rather to assumptions about behaviour based on possible correlations between observed prices and yields.

Expectation structures

Most analysts of agricultural supply have recognized that, typically, farmers must commit resources to production (i.e. make decisions about planned A_t and anticipated Y_t) before product prices are known with certainty. In modelling the price that farmers are presumed to plan on, it has invariably been assumed that past observed prices are projected forward. The most naive expectation is that the planning or anticipated price is simply the previous price, i.e. $P^*_t = P_{t-1}$. Alternatively, a slightly richer form of simple expectations is a linear combination of prices in two or a few previous periods.

More complex forms of expectations involve various distributed lags. The most widely used model through the 1950s and 1960s (see, e.g. Askari and Cummings 1976, 1977; Heady *et al.* 1961; Tomek and Robinson 1977) was the Nerlove (1958) adaptive expectations model postulated to involve updating by a constant fraction of expectational deviation as in

$$(7) \qquad P^*_t = P^*_{t-1} + \theta(P_{t-1} - P^*_{t-1})$$

Such an expectations assumption has often performed well (see, e.g. Anderson 1974; Watson and Duloy 1968), but some analysts have found the monotonically diminishing weights to be unacceptably restrictive. They have opted instead for a more flexible means of imposing a pattern of weights that is potentially more varied, such as the Almon-type polynomial distributed lag (Chen *et al.* 1972; Fisher 1975; Lin 1977).

Risk responsiveness

Analysts of risky decision making by individual firms have argued that price uncertainty will modify producers' production plans, generally in a manner reducing average output relative to that produced in the absence of price risk (e.g. Sandmo 1971). Such modifications tend to be reinforced by the added assumption that producers are averse to risk (e.g. Blandford and Currie 1975), and by recognition of the prevalence of production uncertainty (e.g. Anderson, Dillon and Hardaker 1977, Ch. 6; Hildreth 1977; Turnovsky 1973). Supply analyses in which some allowance for this effect has been made include those of Behrman (1968), Freebairn and Rausser (1975), Just (1974a, b, 1976), Ryan (1977) and Traill (1978).

Other conditioning factors

Clearly, many factors unrelated to prices exert significant influences on the supply of agricultural products. Government interventions through restrictions on input use, voluntary land retirement policies, production quotas, etc. have sometimes had important consequences for supply (see the work of Fisher 1975; Houck and Ryan 1972; Houck *et al.* 1976; Just 1974b; Smith and Brennan 1978). Technological changes can be important in shifting supplies of specific crops such as of Asian wheat in the mid-1960s. Uncontrolled environmental factors, such as drought, flood, fire, tempest and diseases, clearly influence yields of many activities and, in some cases, their areas. Just as clearly, there are distinct limits to the accuracy with which all such conditioning factors, and especially the geographically dispersed environmental factors, can be captured in empirical supply functions.

Functional form

The problem of specifying functional forms of S and T is, of course, not unique to supply analysis. Empiricists, presumably in the interests of simplicity, have invariably chosen (a) a linear or (b) a power (constant elasticity) function for S and, respectively, (a) a linear or (b) an exponential (constant growth rate) function for T. Often, these two particular specifications are compared and the 'best' selected according to several statistical-cum-economic criteria.

What has implicitly confused such comparisons is that they have involved simultaneously contrasting a linear function with additive error against a power function with multiplicative error. That is, the hypothesis usually tested has not been decomposed to the separable hypotheses that are of separate and distinctive importance.

A Case Study: Wheat in Southern New South Wales

Several uncertainties that pervade the art of agricultural supply analysis have been noted above. One implication is that, in the absence of the (unlikely imminent) resolution of some of these uncertainties, it will be difficult to arrive at definitive results about the others. In particular, there seems to be such significant uncertainty about the systematic part of supply functions that it is perhaps unreasonable to hope for any very firm conclusions to emerge about the nature of the stochastic part. However, a comparison of results from (4) and (5), for a number of 'reasonable' specifications of S, may provide some evidence. This is the approach taken in the following empirical work.

Wheat production in southern N.S.W. (i.e. the Statistical Divisions of Southern Slopes and Riverina) is the subject of attention. Dealing with the 1969-1972 quota arrangements (see Fisher 1975; Smith and Brennan 1978) was shirked by confining attention to the 1948/49 to 1968/69 seasons.

The data used are as described by Fisher (1975)—indeed he generously gave them to us—with the exception that we have deflated his index of total pool payments by the BAE index of prices paid by Australian farmers. As Powell and Gruen (1966), Watson and Duloy (1968) and Fisher (1975) have emphasized, the stabilization operations of the Australian Wheat Board have added to the ambiguity of price expectation models that might underlie wheat supply response. This difficulty is also shirked in this case study.

Empirical evidence was sought on two main questions:

(a) Are supply decisions based on price or revenue expectations?

(b) Is the stochastic specification better represented by an additive or a multiplicative disturbance?

To consider the price-revenue question, yield uncertainty was bypassed by using the disaggregation in (2) and the alternative functional forms $A_t = \alpha + \beta\ X^*_t + \gamma t + u_t$ and $A_t = \alpha X^{*\,\beta}_t e^{\gamma t} e^{u_t}$ where $X^*_t = P^*_t$ (price expectations) or $X^*_t = R^*_t$ (revenue expectations). In each of these cases two alternative expectations models, namely simple and adaptive, were employed. To simplify the analysis, and in line with previous tradition, simple expectations were assumed to be 'multiplicative' in conjunction with the multiplicative model ($P^*_t = P_{t-1}w_1 P_{t-2}w_2$), and 'additive' in conjunction with the additive model ($P^*_t = w_1 P_{t-1} + w_2 P_{t-2}$). Adaptive expectations were assumed to be additive ($P^*_t = (1-\theta)P^*_{t-1} + \theta P_{t-1}$) with both functional forms. This seems more realistic to us than a multiplicative form of adaptive expectations and, since correct handling of adaptive expectations requires non-linear estimation, it does not present much of an additional complication.

Thus eight different models were estimated. The aim was not to choose the best of these models (although we would hope that some light would be shed on this question) but rather to answer conditional questions of the type: given a specific functional form and a specific method of expectations formation, which is the appropriate variable, price or revenue?

The limiting of simple expectations to two previous prices, the inclusion of a time trend and the exclusion of other conditioning factors are in line with Fisher's (1975) work. The method of expectations formation differs somewhat. He used simple expectations but, after some preliminary testing, restricted the coefficients of past prices to lie on a declining straight line.

Equations (4), (5) and (6) were estimated to facilitate the investigation of the question of stochastic specification. By varying the functional form ($S_t = \alpha + \beta P^*_t + \gamma t$ vs. $S_t = \alpha P^{*\,\beta}_t e^{\gamma t}$) and the method of expectations formation (simple vs. adaptive), four cases were considered for each stochastic specification, making a total of 12 alternative models. Again, our main objective was not to choose the best of these models but rather to identify the most appropriate stochastic specification for a given S_t and a given $X^*_t(P^*_t)$. The dependent variable in this case is Q_t (not A_t) because the policy implications of multiplicative vs. additive disturbances relate to the function for quantity supplied. Strictly speaking, we should not be investigating the stochastic specification independently from the price vs. revenue question. However, the results obtained using A_t as the dependent variable overwhelmingly supported the use of price, and so the marginal information from estimating an additional 12 models (with P^*_t replaced by R^*_t) was likely to be small. In terms of other possible models, we were discouraged by the escalating size of the study from adding further interesting factors such as risk responsiveness[3], other functional forms, additional conditioning variables and alternative expectation structures. We were similarly discouraged from grappling with the potentially complex structure of the 'quantity' equations implied by (2) when both A and Y are stochastic. There is thus an inconsistency in contrasts between the 'area' and 'quantity' equations.

The alternative specifications studied are summarized in Table 1. For each model it is assumed that the u_t are normally and independently distributed with zero mean and constant variance. Ordinary least squares (OLS) regression is then appropriate (in some cases after logarithms have been taken) for all simple expectations models with 'conventional' disturbances, for example, $Q_t = \alpha P_{t-1}{}^{\beta_1} e^{\gamma t} e^{u_t}$. However, in adaptive expectations models, OLS estimates will be biased and inconsistent because of the presence of a lagged dependent variable and a moving average disturbance (Johnston 1972, p.307). Accordingly, maximum likelihood (ML) methods were used for models with adaptive expectations and models with 'unconventional' disturbances[4], for example, $Q_t = \alpha P^*_t{}^{\beta} e^{\gamma t} + u_t$. In the adaptive expectations models, assuming we have T observations indexed by $t = 0,1, \ldots, T-1$, use was made of the decomposition suggested by Klein (1958) and subsequently used by Dhrymes (1971), $X^*_t = X^*_0$, $t = 0$, and

$$(9) \qquad X^*_t = \theta \sum_{i=0}^{t-1} (1-\theta)^i X_{t-i-1} + X^*_0(1-\theta)^t, \; t = 1, 2, \ldots, T-1.$$

Price (or revenue) expectation in the initial period, X^*_0, was estimated as an additional parameter. With the exception of models derived from (6), in all cases where ML methods were used, maximizing the likelihood function is equivalent to minimizing the relevant residual sum of squares and so ML estimates were obtained using a non-linear least squares program. For models derived from (6), ML estimates were obtained from the same program by minimizing the residual sum of squares multiplied by $(\prod_{t=1}^{T} Q_t)^{2(1-\lambda)/T}$. This equivalence can be demonstrated readily, using the likelihood function (Leech 1975).

[3] In pilot investigation it was found that, in this particular region, risk responsiveness was statistically insignificant in models of the type discussed by Just (1976).

[4] See Malinvaud (1970, p. 546) for conditions sufficient for maximum likelihood estimates to be consistent.

TABLE 1

Summary of the Alternative Specifications Examined

Reference code[a]	Model
ALa	$A_t = \alpha+\beta X^*_t+\gamma t+u_t$ $\quad \Big\} X^*_t = P^*_t$ or R^*_t
ACm	$A_t = \alpha X^{*}{}_t{}^{\beta}\, e^{\gamma t}\, e^{u_t}$
QLa	$Q_t = \alpha+\beta P^*_t+\gamma t+u_t$
QLm	$Q_t = (\alpha+\beta P^*_t+\gamma t)e^{u_t}$
QCm	$Q_t = \alpha P^{*}{}_t{}^{\beta} e^{\gamma t} e^{u_t}$
QCa	$Q_t = \alpha P^{*}{}_t{}^{\beta} e^{\gamma t}+u_t$
QLbc	$\dfrac{Q_t{}^{\lambda}-1}{\lambda} = \dfrac{(\alpha+\beta P^*_t+\gamma t)^{\lambda}-1}{\lambda}+\delta_t$
QCbc	$\dfrac{Q_t{}^{\lambda}-1}{\lambda} = \dfrac{(\alpha P^{*}{}_t{}^{\beta} e^{\gamma t})^{\lambda}-1}{\lambda}+\delta_t$
Expecations	
Simple[b] (L)	$\beta X^*_t = \beta_1 X_{t-1}+\beta_2 X_{t-2}$
(C)	$X^{*}{}_t{}^{\beta} = X_{t-1}{}^{\beta_1}\, X_{t-2}{}^{\beta_2}$
Adaptive	$X^*_t = \theta \sum_{i=0}^{t-1}(1-\theta)^i X_{t-i-1}+X^*_0(1-\theta)^t$
Argument	
Price	$X^*_t = P^*_t$
Revenue	$X^*_t = R^*_t$

[a] In this code: the first symbol (A or Q) denotes the dependent variable (area sown or quantity supplied, respectively); the second symbol (L or C) denotes the form of the systematic part of the supply function (linear with linear time trend or constant elasticity with constant growth rate, respectively); the final symbol(s) (a, m, bc) denotes the structure of the disturbance term (additive, 'multiplicative' or with Box-Cox transformation, respectively).

[b] In simple expectations when $X^*_t = P^*_t$, β_2 was found to be close to zero and was constrained to zero in the results reported.

To compare the 'goodness of fit' of alternative models, two descriptive criteria were used:

(a) the value of the logarithm of the likelihood function, in terms of units of the original variable (A_t or Q_t) and evaluated at the ML estimates; and

(b) R^2(corr.), calculated as the square of the correlation coefficient between Q_t (or A_t) and $\hat{Q}_t$ (or $\hat{A}_t$) where, for example, $\hat{Q}_t$ is S_t evaluated at the ML estimates.

Any choice between price and revenue and between alternative stochastic specifications will depend on both economic and statistical considerations. For a choice between (4) and (5), a particularly relevant statistical criterion is the forementioned confidence interval for λ suggested by Leech (1975).

Results

Estimates and summary statistics for models using adaptive and simple expectations are presented in Tables 2 and 3, respectively. With the exception of estimates for X^*_0 and for λ of the Box-Cox models, asymptotic standard errors are given in parentheses below the coefficients.[5] The estimates for X^*_0 are not consistent (Dhrymes 1971, p. 101) and hence the relevance of their standard errors for hypothesis testing is questionable. For the Box-Cox models, the asymptotic covariance matrix calculated by the computer program may not be a good approximation because of the fact that $E(\partial^2 L/\partial\lambda\partial\sigma^2) \neq 0$ is ignored, where L is the logarithm of the likelihood function (Goldfeld and Quandt 1972, p. 71). Twenty-one observations were used to estimate the adaptive expectations models whilst, for the simple expectations models, the lagging of price and revenue reduced the number to twenty and nineteen, respectively.

Two R^2 measures are presented. The conventional one (unity less the ratio of residual to total sum of squares) is a measure of goodness of fit for a given equation but, because the dependent variables are often measured in different units, it cannot be used to compare equations. On the other hand, R^2 (corr.), calculated as a squared correlation coefficient (of observations with predictions transformed into original units), can be used to compare the explanatory performance (over the sample period) of different models. Alternatively, where the number of observations is the same, goodness of fit can be compared using the logarithm of the likelihood function. As indicated by the Durbin-Watson (DW) statistics, there are no cases of very serious autocorrelation.

Price vs. Revenue

Turning to the question of price or revenue, our interpretation of the results with area as the dependent variable is that these provide some support for the hypothesis that price is the more appropriate argument. When using adaptive expectations and revenue, contrary to our expectation, both $\hat{\beta}$ and X^*_0 were negative for model ALa whilst for model ACm, $\hat{X}^*_0$ was extremely large.[6] Price was favoured over revenue, according to both the R^2 criteria and the logarithm of the likelihood function, although the differences were not very large.

With simple expectations, we are led to similar (counterintuitive) conclusions. Although the use of revenue yielded feasible results, it is somewhat difficult to explain why revenue lagged two years is indicated as having a slightly greater influence than revenue in the immediate past year. The goodness-of-fit statistics are not directly comparable because of the different numbers of observations used. However, the residual sums of squares for the revenue equations were greater than those for the respective price equations which used one more observation.

[5] The computer program used calculates the asymptotic covariance matrix numerically as $\hat{\sigma}^2[(\partial u/\partial\zeta)'(\partial u/\partial\zeta)]^{-1}$, where u is the residual vector and ζ is the vector of all parameters other than σ^2.

[6] The positive elasticity of model ALa was a result of *both* $\hat{\beta}$ and $\hat{X}^*_0$ being negative.

TABLE 2
Results Obtained for Models with Adaptive Expectations

Parameters	Model									
	ALa (revenue)	ALa (price)	ACm (revenue)	ACm (price)	QLa (price)	QLm (price)	QCm (price)	QCa (price)	QLbc (price)	QCbc (price)
α or log α	−170·6	144·4	1·47	−8·42	205·3	−308·3	−11·99	−10·52	234·2	−10·34
	(220·6)	(32·1)	(0·41)	(2·18)	(83·0)	(150·3)	(4·33)	(3·38)	(97·2)	(3·53)
γ	13·39	8·77	0·113	0·131	11·71	14·9	0·155	0·146	12·63	0·144
	(9·27)	(1·20)	(0·023)	(0·017)	(2·64)	(6·23)	(0·033)	(0·024)	(3·72)	(0·025)
β	−0·075	0·895	0·218	2·34	1·406	1·820	3·098	2·823	1·492	2·789
	(0·563)	(0·212)	(0·088)	(0·44)	(0·503)	(0·678)	(0·853)	(0·656)	(0·536)	(0·686)
θ	0·106	0·361	0·278	0·640	0·732	0·367	1·131	1·752	0·495	1·743
	(0·094)	(0·141)	(0·192)	(0·228)	(0·566)	(0·265)	(0·412)	(0·164)	(0·375)	(0·193)
X^*_0	−3223	239·3	$3·7\times10^6$	223·2	195·7	204·5	184·5	161·9	203·4	161·9
λ	[a]	[a]	[a]	[a]	1·0	0·0	0·0	1·0	0·450	0·885
σ	9·949	9·042	0·204	0·196	34·53	0·4582	0·4644	27·72	3·02	17·40
DW	1·53	1·72	1·36	1·55	3·04	2·17	1·93	2·49	2·57	2·45
R^2(corr.)	0·900	0·917	0·867	0·920	0·647	0·626	0·678	0·774	0·642	0·773
R^2(1-RSS/TSS)	0·900	0·917	0·790	0·847	0·647	0·625	0·615	0·773	0·714	0·774
log likelihood	−75·19	−73·18	−83·35	−79·58	−101·32	−100·82	−101·10	−96·71	−99·12	−96·64
LR elasticity[b]	1·0	1·7	0·2	2·3	1·9	2·3	3·1	2·8	2·1	2·8

[a] Lambda values are irrelevant in the first four models.
[b] For linear models the long-run elasticities were calculated at the means of Q_t and P^*_t or A_t and X^*_t.

TABLE 3
Results Obtained for Models with Simple Expectations

Parameters	Model									
	ALa (revenue)	ALa (price)	ACm (revenue)	ACm (price)	QLa (price)	QLm (price)	QCm (price)	QCa (price)	QLbc (price)	QCbc (price)
α or log α	−41·8	−122	0·098	−8·34	−198	−178	−12·2	−9·49	−191	−10·50
	(17·7)	(22)	(1·23)	(1·88)	(70)	(59)	(4·2)	(4·57)	(60)	(4·29)
γ	4·98	7·21	0·070	0·122	11·26	9·50	0·158	0·142	10·63	0·148
	(0·60)	(0·67)	(0·012)	(0·014)	(2·11)	(2·22)	(0·031)	(0·032)	(2·04)	(0·030)
β_1	0·147	0·965	0·310	2·36	1·412	1·351	3·13	2·61	1·39	2·80
	(0·079)	(0·139)	(0·177)	(0·37)	(0·440)	(0·406)	(0·83)	(0·89)	(0·39)	(0·84
β_2	0·221	[a]	0·346	[a]	[a]	[a]	[a]	[a]	[a]	[a]
	(0·081)		(0·188)							
λ	[b]	[b]	[b]	[b]	1·0	0·0	0·0	1·0	0·530	0·504)
σ	13·5	10·6	0·282	0·201	33·5	0·478	0·4508	32·2	4·21	3·62
DW	1·32	1·33	1·36	1·45	2·98	1·84	1·96	2·89	2·48	2·44
R^2(corr.)	0·825	0·880	0·789	0·915	0·646	0·636	0·667	0·673	0·645	0·672
R^2(1-*RSS*/*TSS*)	0·825	0·880	0·697	0·826	0·646	0·566	0·614	0·673	0·702	0·725
log likelihood	−74·19	−73·90	−78·88	−77·27	−97·00	−97·90	−96·73	−96·22	−95·28	−94·48
Elasticity[c]	0·7	1·6	0·7	2·4	1·8	1·7	3·1	2·6	1·7	2·8

[a] Estimates of β_2 were found to be not significantly different from zero (at the 5 per cent level) for equations with price expectations and were set to zero for the regressions reported.
[b] Lambda values are irrelevant in the first four models.
[c] For price, short-run and long-run elasticities are equivalent because only one lagged price is considered. For revenue, a 'long-run' elasticity is obtained by summing the two coefficients. Elasticities are evaluated at the means in the linear models.

Initially, revenue was included in several of the equations where Q was specified as the dependent variable. The findings were consistent with those just reported and so, to ease the problem of reporting an additional set of results, they were omitted. Stochastic specification comparisons were based only on price.

Stochastic specification

Depending upon the type of expectations (simple or adaptive) and the functional form (linear or constant elasticity), four pairwise comparisons of the stochastic specification can be made. Using the likelihood ratio test to compare each of these four with the relevant Box-Cox specification yielded the χ^2 values given in Table 4. Under the appropriate null hypothesis, the test statistic, calculated as twice the difference of the logarithms of the likelihood functions, has an asymptotic χ^2 distribution with one degree of freedom. For any given model, two rejections imply an asymptotic confidence interval that does not contain either value of λ; two acceptances imply a confidence interval containing both values; and one acceptance and one rejection imply a confidence interval containing one λ value but not the other.

TABLE 4

χ^2 Values for the Likelihood Ratio Test[a]

Null Hypothesis	Adaptive expectations		Simple expectations	
	Linear	Const. elast.	Linear	Const. elast.
Additive disturbance ($\lambda = 1$)	$\chi^2 = 4 \cdot 40$ reject	$\chi^2 = 0 \cdot 14$ accept	$\chi^2 = 3 \cdot 44$ accept	$\chi^2 = 3 \cdot 48$ accept
Multiplicative disturbance ($\lambda = 0$)	$\chi^2 = 3 \cdot 40$ accept	$\chi^2 = 8 \cdot 92$ reject	$\chi^2 = 5 \cdot 24$ reject	$\chi^2 = 4 \cdot 50$ reject

[a] At a 5% significance level, with 1 degree of freedom, the critical χ^2 value is $3 \cdot 84$.

The results are not consistent for all models. A multiplicative disturbance appears appropriate for an adaptive expectations model with linear functional form; but an additive disturbance is accepted, and the multiplicative one rejected, for all other models. If one chose models based on R^2 (corr.) then, in all four cases, the additive disturbance model would be chosen. From an economic standpoint, estimates from all models are equally plausible and so this does not provide a basis for choice.

Special mention should be made of the adaptive expectations models with a constant elasticity function. In these cases the estimate of θ was infeasible ($\theta > 1$). Restricted maximum likelihood estimation over the region $0 \leqq \theta \leqq 1$ yielded $\theta = 1$, which implies that these models reduce to the corresponding simple expectations ones.

Other comparisons

Other points worthy of mention are as follows.

(a) Based on R^2 (corr.), constant elasticity models performed somewhat better than the linear models.

(b) Elasticity estimates were higher when constant elasticity models were used.

(c) Based on 'goodness of fit', there is no clear choice between adaptive and simple expectations. However, simple expectations may be preferable because of the cases where adaptive expectations have $\hat{\theta} > 1$.

Conclusions

It is clearly dangerous to make generalizations about the nature of agricultural supply functions on the basis of one small case study. Nevertheless, some empirical support for an additive disturbance has been found, and this is surprising. If the disaggregation of supply into area and yield per unit area (as in (2)) is valid for decision-making purposes, as is suggested by the results with area as the dependent variable, then we would expect the disturbance to contain a multiplicative component. One possibility is that both an additive and a multiplicative component are relevant and a mixed model, such as that suggested by Goldfeld and Quandt (1970, 1972), or that obtained after the Box-Cox transformation, would be more appropriate. Indeed, with a model of the form $A_t = f(P^*_t, t) + u_t$, $Y_t = g(t) + v_t$, and $Q_t = A_t Y_t$, the resulting equation for Q_t will contain both types of disturbance components. Unfortunately, as noted earlier, this equation is not easily estimated and, because of the increased number of variables, including interaction terms, it is unlikely that acceptable estimation of the coefficients will be possible with the data used here.

The results were more conclusive, although more surprising (unbelievable?), in that price was chosen over revenue as the argument in the systematic part.[7] If, in addition to the price specification, one is prepared to accept an additive disturbance, one could conclude (at least for wheat in southern N.S.W.) that a competitive market is efficient. Thence the concern of Hazell and Scandizzo (1975), which in part motivated this study, would be unfounded.

In the more likely event that our analysis has been too restrictive and that the disturbance has both multiplicative and additive components, producers' use of price expectations would (following Hazell and Scandizzo (1975)) presumably still lead to an inefficient market. When revenue is the appropriate variable (Hazell and Scandizzo 1977), the effect of a combined disturbance on efficiency has not been established. If the possibility of having a disturbance with two components is supported by further empirical evidence, it may be profitable in future theoretical research to extend the results of Hazell and Scandizzo (1975, 1977), Newberry (1976) and Turnovsky (1976, 1977) to account for more complex disturbances.

[7] One of our reviewers suggested that this surprising result may have arisen from either trends in prices over the sample period or the restrictiveness of imposing identical expectational structures on both the price and yield components of revenue. However, real prices were remarkably trendless and, in some limited investigation of 'extended revenue' models in which prices and yield were permitted different expectations, the relative performance of revenue models was not improved.

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