Discriminating among Expectations Models Using Non-Nested Testing Procedures

by

Frances Antonovitz and Richard Green

DISCRIMINATING AMONG EXPECTATIONS MODELS USING NON-NESTED TESTING PROCEDURES

By

Frances Antonovitz and Richard Green*

Most agricultural production is characterized by a lag between the time input decisions are made and the time output actually reaches the market. Thus, producers are faced with the problem of determining optimal input choices before output price is known. This phenomena has typically been modeled by what has been called the supply response function. Quantity produced is hypothesized to depend on known input prices and producers' expectations of output price.

A problem arises, however, in the estimation of producers' price expectations since they are unobservable. Numerous theoretical and empirical models have been proposed in the literature. In particular, expectations have been frequently modeled based solely on past prices. Examples include naive expectations, adaptive expectations (extensively reviewed by Askari and Cummings (1977)), and ARIMA. More recently, others have suggested that producers may incorporate additional information available to market participants. Gardner (1976) posited that the price of a futures contract maturing in a later time period, say t, reflects the market's estimates of the cash price in t, and hence, can be interpreted as producers' expected price. Furthermore, Muth's (1961) concept of rational expectations has also been empirically tested for agricultural commodities by Goodwin and Sheffin (1982) and Shonkwiler and Emerson (1982). In these models, producers' expectations are estimated by simultaneously solving market supply and demand equations.

Most supply response models, however, have focused exclusively on the mean of producers' subjective distribution (or the price expectation) as it influences quantity produced, excluding the variance and higher moments from the model which may reflect risk-related behavior. However, a few authors have introduced risk into their supply response functions. Behrman (1968) quantifies yield and price risk for four major Thai crops by using the standard deviation of yields and prices over the three last preceding production periods. A supply response model incorporating the mean and variance of output price in an adaptive expectations framework was first developed by Just (1974, 1977) for determining production of various California field crops. Traill (1978) and Lin (1977) suggest polynomial lags to estimate supply response using simple moving average standard deviations of past prices and returns to represent risk. The supply of pinto beans is examined by Ryan (1977) in which an expectations model is posited with price risk variables constructed from variances and covariances of the price of pinto beans and the price of a major alternative crop. Antonovitz and Roe (1986) estimate producers' subjective means and variances of fed cattle price

---

*The authors are Assistant Professor and Professor, respectively, in the Department of Agricultural Economics at the University of California, Davis.

using an ARIMA model. All of these studies find the risk variables to be important to some extent.

The purpose of this paper is to develop, estimate, and compare a number of supply response models for fed beef incorporating the mean and the variance of the distribution of output price. First, a theoretical justification is provided for estimating supply response as a linear function of input prices and the mean and higher moments of output price. Then, six different estimates of the mean and variance are obtained from the following models: futures prices; ARIMA processes; and naive, adaptive, and rational expectations models. Empirical estimates of each are presented and compared using non-nested testing procedures.

THE THEORETICAL MODEL

The theoretical justification for estimating a linear supply response function can be derived by using the model of the competitive firm under price uncertainty. Consider a firm in a perfectly competitive market which must choose a vector of n inputs X_1, to produce q, using production function $F(X_1)$ while facing a stochastic output price P. It is assumed that output price is randomly distributed as $\bar{P} = \bar{P} + \varepsilon$ where $E(P) = P$ and $E(\varepsilon) = 0$ and that P comes from a family of distributions which can be expressed as a function of its central moments. Let θ represent the vector of moments of P. Output is produced at cost P_1X_1 where P_1 is a vector of input prices. The firm's utility function U is a strictly concave, continuous and differentiable function of profits π where $U'(\pi) > 0$ and $U''(\pi) < 0$. The objective of the firm is to maximize the expected utility of its profits, and the corresponding primal-dual Lagrangian function can be expressed as

$$L^* = EU(\pi^*(\theta, P_1)) - EU(PF(X_1) - P_1X_1) \tag{1}$$

where the first and second expressions are the indirect and direct expected utility functions, respectively. First order conditons are

$$\frac{\partial L^*}{\partial X_1} = -E[PF'(X_1)U'(\pi)] = 0 \tag{2}$$

$$\frac{\partial L^*}{\partial \delta} = \frac{\partial EU(\pi^*)}{\partial \delta} - \frac{\partial EU(\pi)}{\partial \delta} = 0 \tag{3}$$

where $\delta = (\theta, P_1)$. Using equation (3), the duality results can be more explicitly expressed as

$$\frac{\partial EU(\pi^*)}{\partial P_1} = - X_1^* \, EU'(\pi) \tag{4}$$

$$\frac{\partial EU(\pi^*)}{\partial EP} = F(X_1^*)\ EU'(\pi). \tag{5}$$

Because we are interested in estimating a supply response function rather than input demands, we focus on deriving an empirically useful expression from equation (5).

It should be noted that equation (5) does not yield output supplied as in the certainty case where the analogous counterpart is Hotelling's lemma. However, the certainty results will hold if the expected (direct) utility function is of the form suggested by Pope (1978),

$$EU(\pi) = \overline{\pi} + g(\sigma); \quad \sigma = (\sigma_2, \sigma_3, \ldots, \sigma_k) \tag{6}$$

where σ_k represents the k^{th} central moment of profit and $g(\sigma)$ is any function of the central moments of profit. From equation (6),

$$\frac{\partial EU(\pi)}{\partial EP} = q. \tag{7}$$

Denoting the indirect expected utility function by V, equations (3) and (7) imply

$$\frac{\partial V}{\partial EP} = q^*. \tag{8}$$

The class of expected utility functions given by equation (6) does not provide much insight into the functional form of the indirect utility function V because profit depends on, among other factors, the underlying production function. If V is approximated by a second order Taylor series expansion, say $\tilde{V}$, and the derivative is taken with respect to E(P),

$$\frac{\partial \tilde{V}}{\partial E(P)} \cong a_o + \sum_j a_j \delta_j. \tag{9}$$

For the restricted class of utility functions addressed here, $\partial \tilde{V}/\partial E(P) \cong q^*$. If equation (9) is aggregated over all market participants, the aggregate supply curve can be represented by

$$Q^s \cong b_o + \sum_j b_j \delta_j. \tag{10}$$

THE EMPIRICAL MODEL

Although the theoretical model just derived could be applied to many agricultural commodities, we examine the supply response for the United States fed cattle market. When feeder cattle are purchased by the feedlot operator, the price that will be received five to eight months later when the fed cattle are sold is not known. Most enterprise costs are comprised of direct costs which are primarily feeder cattle and feed. Hence, feeder cattle and corn prices, which are assumed to be known when the feeder cattle are purchased, are used as the relevant input prices in the supply equation. From equation (10), it is clear that any number of moments of producers' subjective distribution of fed cattle price could have been used in specifying supply response. In this study, however, only the mean and variance are considered. A bimonthly model is formulated because it lends itself to estimation of the price expectations models. The aggregate supply function for fed cattle can be specified as

$$QCAT_t = \beta_1 + \beta_2 PCN_{t-\ell} + \beta_3 PF_{t-\ell} + \beta_4 P_t^* + \beta_5 \sigma_t^* + \varepsilon_t \tag{11}$$

$QCAT_t$ = quantity of fed cattle marketed in bimonth t, total liveweight in mil. lb.

$PCN_{t-\ell}$ = average price of corn three to four bimonths prior to t, \$/bu.

$PF_{t-\ell}$ = average price of feeder cattle three to four bimonths prior to t, \$/cwt.

P_t^* = fed cattle price expected in bimonth t formulated three to four bimonths prior to t, \$/cwt.

σ_t^* = variance of fed cattle price expected in bimonth t formulated three to four bimonths prior to t, $\$^2/cwt.^2$

ε_t = error in bimonth t.

Eighty-six bimonthly observations from 1970 through the second bimonth of 1984 were used to estimate the functions. Data on commercial cattle slaughter were used to represent the quantity of fed cattle marketed. Corn price was expressed as the price received by farmers in Iowa averaged three to four bimonths prior to t. Feeder cattle price was determined by averaging 400-500 pound (four bimonths prior to t) and 600-700 pound (three bimonths prior to t) choice feeder steer prices in Kansas City. To discount for inflation, both input prices were specified in 1967 dollars by dividing by the index of prices by farmers for production items, interest, taxes, and wages. All data were obtained from USDA sources. In the next section, the six different models used to estimate P_t^* and σ_t^* will be discussed.

PRICE EXPECTATIONS MODELS

Naive Expectations

If the producer is assumed to simply use the output price at the time inputs are purchased as the expectation of what price will be when output is marketed, expectations are said to be naive. USDA data were used to estimate these expectations by deflating average monthly price received by U.S. farmers for beef cattle to 1967 dollars by the monthly consumer price index. (The bimonthly deflated fed cattle price calculated from this series is denoted by $PCAT_t$.) The mean and variance of the monthly prices three to four bimonths (or five to eight months) prior to bimonth t were used to estimate P_t^* and σ_t^*, and for this model are denoted by PNM_t^* and PNV_t^*, respectively.[1]

ARIMA Forecasts

Another method using only past prices to estimate price expectations is the ARIMA model. The bimonthly deflated fed beef price series, $PCAT_t$, between 1959 and 1984 was identified to most closely follow ARIMA(2,1,0) or ARIMA (1,1,1) processes. Different forecasts of the mean and variance were obtained for each model. A moving ARIMA model using 10 years of the $PCAT_t$ data series was used to find three- and four-bimonth ahead forecasts and their respective variances for each of the time periods between 1970 and 1984. Then the two forecasts for each time period were averaged, as were their variances, to approximate the first two moments of the distribution of fed beef price.[2]

Futures Prices

It has also been suggested that producers may use the price of the futures contract maturing when output will be marketed as their expectation of output price. The price expectations based on futures prices were estimated from data in the Chicago Merchantile Exchange Year Book. For the live cattle futures contract maturing in each bimonth from 1970 through 1984, 13 daily futures prices were selected from the three to four bimonths prior to contract maturity. From these observations, means and variances were calculated to approximate producers' price expectations for each bimonth. The price expectations computed from the futures data may not precisely correspond with the $PCAT_t$ data series because futures prices reflect a specific quality of cattle for particular delivery points while the $PCAT_t$ series is based on national average prices.

Adaptive Expectations

The adaptive expectations model (Nerlove (1958)) posits that producers revise their expectations in proportion to the error associated with the previous level of expectations:

$$P_t^* - P_{t-\ell}^* = \lambda(P_{t-\ell} - P_{t-\ell}^*) \qquad 0 < \lambda < 1 \qquad (12)$$

$$\sigma_t^* - \sigma_{t-\ell}^* = \gamma(\sigma_{t-\ell} - \sigma_{t-\ell}^*) \qquad 0 < \gamma < 1. \qquad (13)$$

Because producers purchase feeder cattle three to four bimonths prior to marketing, the naive expectations of mean and variance defined earlier, $PNM_{t-\ell}$ and $PNV_{t-\ell}$, are used to estimate the moments of fed cattle price in the previous periods, $P_{t-\ell}$, and $\sigma_{t-\ell}$. If these difference equations are solved for P_t^* and σ_t^*, infinite geometrically declining distributed lags result

$$P_t^* = \sum_{i=0}^{\infty} \lambda(1-\lambda)^i \, PNM_{t-\ell-i} \tag{14}$$

$$\sigma_t^* = \sum_{i=0}^{\infty} \gamma(1-\gamma)^i \, PNV_{t-\ell-i}. \tag{15}$$

Substituting equations (14) and (15) into (11), and performing Koyck transformations of the resulting expression, we obtain the supply response

$$AQCAT_t = \beta_1^a + \beta_2 APCN_{t-\ell} + \beta_3 APF_{t-\ell} + \beta_4 AP_t^* + \beta_5 A\sigma_t^* + V_t \tag{16}$$

where

$$\begin{aligned}
AQCAT_t &= QCAT_t - (2-\lambda-\gamma)QCAT_{t-\ell} + (1-\lambda)(1-\gamma)QCAT_{t-\ell-1} \\
APCN_{t-\ell} &= PCN_{t-\ell} - (2-\lambda-\gamma)PCN_{t-\ell-1} + (1-\lambda)(1-\gamma)PCN_{t-\ell-2} \\
APF_{t-\ell} &= F_{t-\ell} - (2-\lambda-\gamma)PF_{t-\ell-1} + (1-\lambda)(1-\gamma)PF_{t-\ell-2} \\
AP_t^* &= \lambda PNM_{t-\ell} - \lambda(1-\gamma)PNM_{t-\ell-1} \\
A\sigma_t^* &= \gamma PNV_{t-\ell} - \gamma(1-\lambda)PNV_{t-\ell-1} \\
V_t &= \varepsilon_t - (2-\lambda-\gamma)\varepsilon_{t-\ell} + (1-\lambda)(1-\gamma)\varepsilon_{t-\ell-1}.
\end{aligned}$$

The adaptive means and variances, AP_t^* and $A\sigma_t^*$, are estimated separately by using results from the naive expectations model. Just (1977), however, points out that more efficient estimates of the coefficients would be obtained by simultaneously estimating the means and variances within the supply response function.

Rational Expectations

The rational expectations hypothesis maintains that producers act as if they were solving the market supply and demand system when forming their expectations. The supply equation will be identical to the one defined earlier

$$QCAT_t = a + bP_t^* + c\sigma_t^* + dPCN_{t-\ell} + ePF_{t-\ell}. \tag{17}$$

A price dependent farm level demand equation is specified as

$$PCAT_t = f + gQCAT_t + hI_t + iY_t \tag{18}$$

where

Y_t = per capita disposable income in bimonth t
I_t = a farm level index of other meats in bimonth t
$(\sum_j P_t^j Q_t^j / (\sum_j P_t^j Q_t^j + PCAT_t \cdot QCAT_t)$ where P^j and Q^j are the farm level prices and quantities of chicken and pork).

Per capita disposable income was obtained from USDA sources and deflated to 1967 dollars by the consumer price index. The farm level index of other meats was calculated from the following USDA data: young chicken slaughter, commercial hog slaughter, and average prices received by farmers for broilers and hogs.

The rational expectation of the mean of fed cattle price was found by first substituting equation (17) into (18),

$$PCAT_t = f+g(a+bP_t^* + c\sigma_t^* + dPCN_{t-\ell} + ePF_{t-\ell}) + hI_t + iY_t. \quad (19)$$

Taking expectations of both sides of equation (19), assuming that expectations are rational (i.e., $E(PCAT_t) = P_t^*$), and solving for P_t^*, we obtain

$$P_t^* = \frac{f + ga + gc\sigma_t^* + gdPCN_{t-\ell} + gePF_{t-\ell} + hI_t^* + iY_t^*}{1-gb} \quad (20)$$

where I_t^* and Y_t^* are the expectations of the income and index variables formulated by producers when inputs are purchased. To find the rational expectation of the variance of fed cattle price, P_t^* was subtracted from both sides of equation (19), the resulting expression was squared, and the expected value was taken

$$E(PCAT_t - P_t^*)^2 = \sigma_t^* = h^2IV_t^* + i^2YV_t^* + 2hiCOV_t^* \quad (21)$$

where IV_t^* and YV_t^* are the expected variances of index and income for bimonth t and COV_t^* is the expected covariance between income and index for bimonth t, with all expectations formulated when inputs are purchased.

If the expressions for the rational expectations mean and variance, equations (20) and (21), are substituted back into supply equation (17), the demand and supply system can be written as

$$PCAT_t = f + gQCAT_t + hI_t + iY_t \quad (22)$$

$$QCAT_t = \frac{a+bf}{1-gb} + \frac{d}{1-gb} PCN_{t-\ell} + \frac{e}{1-gb} PF_{t-\ell} + \frac{ch^2}{1-gb} IV_t^* + \frac{ci^2}{1-gb} YV_t^* + \frac{bh}{1-gb} I_t^* + \frac{bi}{1-gb} Y_t^* + \frac{2hic}{1-gb} COV_t^* \quad . \tag{23}$$

Wallis (1980) suggests that the expected values of the exogenous variables, I_t^* and Y_t^*, can be estimated by ARIMA models. Hence, a procedure similar to that employed to obtain expectations of fed cattle price from ARIMA models was used. Using bimonthly data between 1959 and 1984, deflated per capita disposable income was identified to most closely follow an ARIMA(1,1,0) process; and the index variable followed an ARIMA(1,2,1) process. Moving ARIMA models, estimated with 10 years of data to find three and four bimonth ahead forecasts and variances of the forecasts, were again used to calculate I_t^*, Y_t^*, IV_t^*, and YV_t^*. The covariance variable was approximated by first determining a simple moving covariance between I_t and Y_t using the previous 10 years of data. The average of the covariances three and four bimonths prior to t formed the estimate of COV_t^*.

EMPIRICAL RESULTS

Naive, ARIMA, and Futures Models

Supply response functions as given by equation (11) were estimated for the naive expectations, ARIMA forecasts, and futures price models. Each of the four supply equations had significant first-order autocorrelation; and hence, modified Cochrane-Orcutt procedures were used to obtain maximum likelihood estimates of the autocorrelation coefficients which were used in transforming the data. Results are presented in Table 1.

The supply response function estimated with price expectations from the ARIMA(2,1,0) model gave coefficients most consistent with economic theory. Corn and feeder cattle prices were negative and significantly different from zero, indicating that higher input prices result in lower production. A positive significant coefficient on the expectation of fed cattle price suggests that production rises when producers expect higher fed cattle prices. Conversely, as producers expect greater variation in output price, production falls as indicated by the negative coefficient on fed cattle price variance. The ARIMA(1,1,1) model gives similar results; however, the corn price coefficient, although negative, is insignificant.

Results for the naive and futures prices were not as strong. Both gave significantly negative coefficients for feeder cattle price. The naive model also resulted in a positive and significant value for the expectation of fed cattle price. No other coefficients were found to be statistically significantly different from zero for either model.

Adaptive Expectations

To determine a supply response with adaptive expectations, it is necessary to estimate equation (16). However, if the ε_t's are independently and identically distributed as $N(0, \sigma_\varepsilon^2)$, then the V_t's follow a MA(2) process. Thus, the variance matrix for the V_t's can be written as

$$E(V'V) = \sigma_\varepsilon^2 \begin{bmatrix} \phi_0 & \phi_1 & \phi_2 & 0 & 0 & \cdots & 0 \\ \phi_1 & \phi_0 & \phi_1 & \phi_2 & 0 & \cdots & 0 \\ \phi_2 & \phi_1 & \phi_0 & \phi_1 & \phi_2 & \cdots & 0 \\ & \ddots & \ddots & \ddots & \ddots & \ddots & \\ 0 & 0 & 0 & 0 & 0 \cdots & \phi_2 \;\; \phi_1 & \phi_0 \end{bmatrix} \tag{24}$$

where

$$\phi_0 = 1 + (2-\lambda-\gamma)^2 + (1-\lambda)^2(1-\gamma)^2$$
$$\phi_1 = -(2-\lambda-\gamma)(1+(1-\lambda)(1-\gamma))$$
$$\phi_2 = (1-\lambda)(1-\gamma)$$

The estimation procedure used was a combination of generalized least squares and a two-dimensional grid search over λ and γ. The minimum weighted error sum of squares was obtained when $\lambda = .27$ and $\gamma = .09$. However, first order autocorrelation was detected. Hence, a correlation coefficient estimated from the Durbin-Watson statistic was used to transform the data.

Results are presented in Table 2. Because quantity of cattle, used as the dependent variable, is actually a weighted sum of current and lagged cattle quantities--and all independent variables are also weighted sums of past values--interpretation of coefficients is difficult. It is noted, however, that coefficients on both the adaptive mean and variance are significant. More importantly, however, is the ability of the model to predict actual supply, $QCAT_t$. This will be discussed in a later section.

Rational Expectations

The supply and demand system implied by rational expectations is given by equations (22) and (23). Because there are 12 variables in the equations but only nine underlying coefficients to be estimated (a through i), there are three restrictions. This system, with its restrictions, can be written succinctly as

$$PCAT_t = \alpha_1 + \alpha_2 QCAT_t + \alpha_3 I_t + \alpha_4 Y_t + \eta_t \tag{25}$$

$$QCAT_t = \beta_1^r + \beta_2^r PCN_{t-\ell} + \beta_3^r PF_{t-\ell} + \beta_4^r I_t^* + \beta_5^r Y_t^*$$

$$+ B_6^r IV_t^* + \beta_7^r YV_t^* + \beta_8^r COV_t^* + \varepsilon_t \tag{26}$$

where $\beta_4^r = \beta_5^r \alpha_3/\alpha_4; \quad \beta_6^r = \alpha_3^2 \beta_7^r/\alpha_4^2; \quad \beta_8^r = 2\beta_7^r \alpha_3/\alpha_4.$

Full information maximum likelihood estimates were obtained for equations (25) and (26) with and without the restrictions. Tests of the restrictions are often used to test the validity of the rational expectations hypothesis. The Wald test failed to reject the hypothesis that the three restrictions jointly held ($\chi^2 = 2.93$ with three degrees of freedom). Thus, the data does not reject the hypothesis that producers form expectations of the mean and variance of fed cattle price rationally.

The results for the restricted supply and demand system are presented in Table 3. The only statistically coefficient in the demand equation is for the quantity of fed cattle. It indicates that as quantity of fed beef placed on the market rises, price falls. In the supply equation, coefficients on feeder cattle price and the expected index of other meats are significantly negative. These results are intuitive. In particular, as proportionately more chicken and pork are marketed, beef price would be expected to fall and less cattle would be marketed. Only the significantly positive coefficient on corn price gives a counter intuitive result.

NON-NESTED HYPOTHESIS TESTS

Given the supply response functions estimated using each of the six models of price expectations, it would be useful to know which model gives the best specification and, hence, which price expectation model most precisely reflects actual expectations. Unfortunately, because the supply response functions are not nested (i.e., no one model is a more general specification of any other model), it is not possible to use common tests based on the F statistic. It is possible, however, to test among these non-nested models by using the J test suggested by Davidson and MacKinnon (1981).

Davidson and MacKinnon consider the case of the single equation, possibly nonlinear regression model, the truth of which we wish to test

$$H_o: \; y_i = f_i(X_i, \beta) + \varepsilon_{oi} \tag{27}$$

where y is the dependent variable, X is a matrix of independent variables, β is a vector of parameters to be estimated, and the error term ε_{0i} is assumed to be NID(0, σ_0^2). Suppose economic theory suggests an alternative hypothesis

$$H_1: \quad y_i = g_i(Z_i, \gamma) + \varepsilon_{1i} \tag{28}$$

where Z is a matrix of exogenous variables, γ is a vector of parameters to be estimated, and ε_{1i} is NID(0, σ_1^2) if H_1 is true. Consider the possibly nonlinear regression

$$y_i = (1-\psi)f_i(X_i, \beta) + \psi\hat{g}_i + \varepsilon_i \tag{29}$$

where $\hat{g}_i = g_i(Z_i, \hat{\gamma})$ and $\hat{\gamma}$ is the maximum likelihood estimate of γ. If H_0 is true, then the true value of ψ is zero. By using a conventional asymptotic t test, the validity of whether $\psi = 0$ can be tested; and this is called the J test.

In Table 4, the results of 20 different pairwise J-tests are presented. The null hypothesis for four different price expectations models were tested: ARIMA(2,1,0), ARIMA(1,1,1), naive, and futures prices. Each null hypothesis was tested against the remaining five models. When either the truth of the ARIMA(2,1,0) or the ARIMA(1,1,1) hypotheses of price expectations is tested against all other models, each is only rejected by both the adaptive and the rational expectations models. The naive expectations model is rejected by all models except the futures prices model. In turn, the futures prices model is rejected by all models except the naive expectations model. Testing the validity of the adaptive and rational expectations models against the others would also be useful but since they are nonlinear and multi-equation specifications, non-nested tests other than the J-test described here are appropriate and will be examined in further work by the authors. However, given the results obtained thus far, the data suggest that either the rational or adaptive expectations may be appropriate.

CONCLUSIONS

For the most part, the coefficient estimates of the supply response functions for all six models were consistent with economic theory. Furthermore, we have found evidence--particularly in the ARIMA(2,1,0), ARIMA(1,1,1), adaptive, and rational expectations models--that producers' expectation of variance is an important variable in determining supply response. It is also encouraging to note that the data do not reject the hypothesis of rational expectations. In addition, the non-nested hypothesis tests gave evidence to support the adaptive and rational expectation models of both the mean and variance as the most appropriate models.

The work presented here easily lends itself to further theoretical and empirical analysis. Other models of price expectations for fed beef could be tested such as vector autoregressions and composite forecasting. Higher moments could also be estimated and included in the supply response functions. Supply equations for other commodities could also be estimated.

Table 1

Estimates of the Supply Response for Naive, ARIMA, and Futures Models

Independent Variables	Price Expectations Models			
	Naive	ARIMA (2,1,0)	ARIMA (1,1,1)	Futures
Constant	7050.30**	8901.40**	8531.7**	7508.5**
Corn Price	-86.45	-579.79*	-292.23	42.88
Feeder Cattle Price	-97.58**	-149.73**	-127.10**	-55.89**
Expectation of Fed Cattle Price	87.74**	117.96**	90.87**	12.33
Variance of Fed Cattle Price	-4.13	-66.20**	-47.609**	13.98
R^2	.75	.76	.76	.74

*Indicates significance of a two-tailed test at the .1 level.
**Indicates significance of a two-tailed test at the .05 level.

Table 2

Estimate of Supply Response for Adaptive Expectations

Independent Variables	Coefficients
Constant	110.41**
Corn price+	129.90
Feeder cattle price+	-1.54
Adaptive Expectation of Fed Cattle Price+	-96.96**
Adaptive Variance of Fed Cattle Price+	247.67**

**Indicates significance of a two-tailed test at the .05 level.

+The dependent and all independent variables are weighted sums of lagged variables. (See equation (16) for specific expressions.)

Table 3

Estimates of the Restricted Supply Response and Demand Functions for Rational Expectations

SUPPLY: Independent Variables	Coefficients	DEMAND: Independent Variables	Coefficients
Constant	8155.04**	Constant	74.24**
Corn Price	408.08**	Quantity of Fed Cattle	$-.7287 \times 10^{-2}$**
Feeder Cattle Price	-60.42**	Index of Other Meats	-11.02
Mean of Index of Other Meats	-1421.58**	Per Capita Disposable Income	$.9339 \times 10^{-4}$
Mean of Per Capita Disposable Income	.01205		
Variance of Index	-20798.21		
Variance of Income	$-.1494 \times 10^{-5}$		
Covariance of Index and Income	.35250		

**Indicates significance of a two-tailed test at the 0.05 level.

Table 4

Pairwise Tests for Hypotheses+

Tested hypothesis \ Alternative hypothesis:	H_{A210}	H_{A111}	H_{NAIVE}	$H_{FUTURES}$	$H_{ADAPTIVE}$	H_{RE}
H_{A210}	--	.415	1.842	.418	4.756*	2.475*
H_{A111}	1.029	--	.814	.198	4.576*	2.395*
H_{NAIVE}	3.049*	2.955*	--	.533	5.353*	2.253*
$H_{FUTURES}$	3.202*	2.994*	.104	--	5.513*	2.398*

+Entries are ordinary t statistics for ψ in equation (29).

FOOTNOTES

[1]For example, to estimate the naive expectations variables for the first bimonth of 1970, the mean and variance of monthly prices from May through September of 1969 were calculated. For the second bimonth of 1970, monthly observations from July through November of 1969 were used, etc.

[2]More specifically, the mean and variance for the first bimonth of 1970 were estimated as follows. A three-step ahead forecast and variance of this forecast were obtained for the ARIMA model using data between the fifth bimonth of 1959 and the fourth bimonth of 1969. A four-step ahead forecast and its variance were also obtained using bimonthly price data between the fourth bimonth of 1959 and the third bimonth of 1969. The average of the three- and four-step ahead forecasts were used to approximate the mean, and the average of the variances of these forecasts formed the estimate of the variance. Estimates of the mean and variance for the second bimonth of 1970 were obtained from three bimonth ahead forecasts (using data from 1959-6 to 1969-5) and four bimonth ahead forecasts (using data from 1959-5 to 1969-4), and so forth.

REFERENCES

Antonovitz, Frances and Terry Roe. "A Theoretical and Empirical Approach to the Value of Information in Risky Markets." Review of Economics and Statistics 68 (1986):105-114.

Askari, Hossein and John Thomas Cummings. "Estimating Agricultural Supply Response with the Nerlove Model: A Survey." International Economic Review 18 (1977):257-292.

Behrman, Jere R. Supply Response in Underdeveloped Agriculture: A Case Study of Four Major Annual Crops in Thailand, 1937-1963. Amsterdam: North-Holland Publishing Co., 1968.

Davidson, Russell and James MacKinnon. "Several Tests for Model Specification in the Presence of Alternative Hypotheses." Econometrica 49 (1981): 781-793.

Gardner, Bruce L. "Futures Prices in Supply Analysis." American Journal of Agricultural Economics 58 (1976):81-84.

Goodwin, Thomas H. and Steven M. Sheffrin. "Testing the Rational Expectations Hypothesis in an Agricultural Market." Review of Economics and Statistics 64 (1982):658-657.

Just, Richard E. "Estimation of an Adaptive Expectations Model." International Economic Review 18 (1977):629-644.

______________. "An Investigation of the Importance of Risk in Farmers' Decisions." American Journal of Agricultural Economics 56 (1974):14-25.

Lin, William. "Measuring Aggregate Supply Response Under Instability." American Journal of Agricultural Economics 59 (1977):903-907.

Muth, John F. "Rational Expectations and the Theory of Price Movements." Econometrica 29 (1961):315-335.

Nerlove, Marc. "Adaptive Expectations and the Cobweb Phenomena." Quarterly Journal of Economics 72 (1958):227-40.

Pope, Rulon D. "The Expected Utility Hypothesis and Demand-Supply Restrictions." American Journal of Agricultural Economics 62 (1978):619-627.

Ryan, Timothy J. "Supply Response to Risk: The Case of U.S. Pinto Beans." Western Journal of Agricultural Economics 2 (1977):35-43.

Shonkwiler, J. Scott and Robert D. Emerson. "Imports and the Supply of Winter Tomatoes: An Application of Rational Expectations." American Journal of Agricultural Economics 64 (1982):634-641.

Traill, Bruce. "Risk Variables in Econometric Supply Response." Journal of Agricultural Economics 24 (1978):53-61.

Wallis, Kenneth F. "Econometric Implications of the Rational Expectations Hypothesis." Econometrica 48 (1980):49-71.