

Rational Expectations and Agricultural Policy:
An Econometric Application to the U.S. Dairy Economy

by

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ABSTRACT

The conceptual and econometric implications of the rational expectations paradigm for modelling producers' expectations are derived for a simple macro-economic model of the dairy producing sector. It is demonstrated that the parameters of the estimated reduced-form equations are functions of the specific dairy price-support rule in effect.

RATIONAL EXPECTATIONS AND AGRICULTURAL POLICY:
AN ECONOMETRIC APPLICATION TO THE U.S. DAIRY ECONOMY

Agricultural policy in the United States has had a long history of promoting the production of specific commodities while simultaneously protecting agricultural producers from low prices by means of price-support programs. The federal dairy price-support program has provided producers with a minimum annual price for over three decades.

A question of central importance with regard to the dairy support program concerns the evaluation and assessment, on a historical basis, of the economic behavior of the dairy economy under alternative hypothetical price support policies.

Previous economic models and analyses of the dairy price-support program have been based on the conceptual paradigm of static profit maximization, which excludes any account of risk preference, and have relied either implicitly or explicitly on the ad hoc notion of adaptive expectations or partial adjustment models to impart dynamic elements to their econometric models (Chou, Dahlgren, Heien).

The fact that producers' expectations play a central role in determining optimal production and input use, and that price supports modify these expectations, necessitates that we specify how this interaction occurs (Nerlove). The rational expectations hypothesis (REH) has been put forth as an expectations model which can fulfill this need in a consistent and logically appealing manner. REH postulates that producers learn to expect prices as given by the conditional expectations of the economic system within which they must make their input and output decisions (Muth). Correctly modeling changes in exogenous policy variables

which may modify these conditional expectations, such as the price-support level, requires that the equations describing how producers formulate their expectation of endogenous variables and the linkage with exogenous policy variables become central elements in the complete economic model (Sargent, 1980). The purpose of this paper is to briefly review and illustrate the econometric implications of REH and to demonstrate how REH may be incorporated into an econometric model of the aggregate dairy economy for policy evaluation. The original work by the author incorporates a more detailed and comprehensive analysis of the price-support policy (Thraen, 1981).^{1/}

Rational Producer Expectations and Policy Evaluation: General Concepts

From the foregoing arguments, it should be apparent that price-supports and producer expectations of price supports are instrumental in determining dairy producer decisions. In this section, we will examine the relationship between the REH formulation of producers' price expectations and changes in the government's rules for establishing price supports.

Consider the following structural simultaneous equation model, in which anticipated or expected values of certain endogenous variables are included (Wallis, 1980; Fisher, 1982).

$$(1.1) \quad B(L)y_t + Ay_t^* + T_1x_{1t} + T_2x_{2t} = U_t$$

where y_t is a vector of g endogenous variables, y_t^* is a vector h of expected endogenous variables, ($h \leq g$), x_{1t} is a k_1 element vector of exogenous variables and x_{2t} is a $(k-k_1)$ vector of "known" exogenous variables.

$B(L) = B_0 + B_1L + \dots + B_rL^r$ is the matrix polynomial lag function

($L^r y_t = y_{t-r}$) which allows for lagged endogenous variables. The matrix dimensions are $B \sim (gxg)$, $A \sim (gxh)$, $T_1 \sim (gxk_1)$ and $T_2 \sim (gx(k-k_1))$.

The producer, under the REH, formulates his anticipations of the h variables y_t^* as conditional expectations, conditioned on the structure of the relevant economic system describing the economy, i.e., the model in (1.1). Thus y_t^* is defined as $y_t^* = E(y_t | \Omega_{t-1})$ where Ω_{t-1} is the producers information set based on (1.1).

From (1.1) we can rearrange terms

$$(1.2) \quad B_0 y_t + A y_t^* = -\{B_1 y_{t-1} + \dots + B_r y_{t-r}\} - T_1 x_{1t} - T_2 x_{2t} + U_t$$

and applying the conditional expectations operator E

$$(1.3) \quad E(B_0 y_t + A y_t^*) = E\{-B_1 y_{t-1} + \dots + B_r y_{t-r} - T_1 x_{1t} - T_2 x_{2t} + U_t\}$$

and given that $E(y_t | \Omega_{t-1}) = y_t^*$

$$(1.4) \quad y_t^* = -(B_0 + A)^{-1} \{T_1 E\{x_{1t} | \Omega_{t-1}\} + T_2 x_{2t} + B_1 y_{t-1} + \dots + B_r y_{t-r}\}$$

where $E\{x_{1t} | \Omega_{t-1}\} = \hat{x}_{1t}$ is the expectation of the exogenous variables x_{1t} and all other variables are either known or predetermined. Note at this point the substantive difference between the REH formulation of y_t^* as expressed in (1.4) and equivalent formulations of expectations models widely used in econometric modeling, i.e., naive and adaptive respectively,

$$(1.5) \text{ naive} \quad y_t^* = y_{t-1}$$

$$(1.6) \text{ adaptive} \quad y_t^* = (1-\lambda) \sum_{i=0}^{\infty} \lambda^i y_{t-i} .$$

It is apparent that these models are consistent with the REH model only if we are willing to impose substantial zero-order restrictions on the elements of the matrices $B(L)$, A , T_1 , T_2 . ^{2/}

Substituting (1.4) into (1.1) yields a simultaneous structural equation system in forecast and observable variables

$$(1.7) \quad B(L)y_t - A(B_0 + A)^{-1} \{T_1 \hat{x}_{1t} + T_2 x_{2t} + B_1 y_{t-1} + \dots + B_r y_{t-r}\} + T_1 x_{1t} + T_2 x_{2t} = U_t .$$

The reduced form of the structural system becomes

$$(1.8) \quad y_t = \Pi_1 \hat{x}_{1t} + \Pi_2 x_{2t} + \sum_{i=1}^r \Pi_{2+i} y_{t-i} \\ + \Pi_{r+3} x_{1t} + \Pi_{r+4} x_{2t} + V_t$$

where $\Pi_1 = B_0^{-1}A(B_0 + A)^{-1}T_1$, $\Pi_2 = B_0^{-1}A(B_0 + A)^{-1}T_2$, $\Pi_3 = B_0^{-1}A(B_0 + A)^{-1}B_1$
 $\Pi_{2+i} = B_0^{-1}A(B_0 + A)^{-1}B_i$, $\Pi_{r+3} = -B_0^{-1}T_1$, $\Pi_{r+4} = -B_0^{-1}T_2$ and $V_t = B_0^{-1}U_t$.

Note that in (1.8), the exogenous variables x_{1t} appear as both forecast or expected values \hat{x}_{1t} and as non-forecast values x_{1t} . This suggests that by imposing the REH, the endogenous variables y_t are determined by both the producers expectations of the exogenous variables and their actual realized values. An alternative argument would suggest that if x_{1t} needs to be forecast at all, then $x_{1t} \equiv \hat{x}_{1t}$ and the endogenous variables depend upon only the forecast values of these x_{1t} exogenous variables. If we accept the first argument, then the endogenous variables will be determined by current and lagged values of the exogenous variables, whereas with the second argument, only lagged values of the x_{1t} variables will appear in the reduced form equations.

A third alternative is to recognize that the reduced form equations are simply algebraic constructs which do not have a behavioral economic interpretation. In this case, if producers expectations of an endogenous variable depend upon expectations of more fundamental exogenous variables, then when the rational expectation is substituted into the original structural equation, all of these expected exogenous variables are entered as expectations and not as known values. Again, the final form of the structural equation will contain only lagged values of the expected variables.

To complete the specification of the reduced form model (1.8), we need to postulate a model for x_{1t} . Note that the imposition of the REH onto the structural model has nothing to do with how we formulate the forecasting model for x_{1t} . The implications of REH are focused exclusively on the endogenous variables in the economic system.

To proceed with the modeling of x_{1t} we can move along two lines of reasoning. If a particular variable of the vector x_{1t} is itself an endogenous variable in another economic system, and assuming that the producer has full information on that system also, we can impose the REH onto that system and repeat the same steps as detailed above. Following this line of reasoning, the particular economic model we are studying would include determining variables from many other economic systems in addition to those bearing directly on our own system.

A second line of reasoning, and one which is most often used in the REH literature, is to assume that the producers in our model do not have full information of the structure of all of the other systems and, therefore, use much more simplistic forecasting rules for these exogenous variables. Such a model or forecasting rule is usually given as a vector autoregressive moving average (ARMA) model of varying degrees of complexity (Wallis, 1980; Fisher, 1982).

A simple form of this model is the first-order autoregressive model,

$$(1.9) \quad x_{1t} = \phi x_{1t-1} + \varepsilon_t$$

where ε_t is a white noise process, assumed to be independent of V_t . The optimal one-step-ahead forecast for this model is $E(x_{1t} | \Omega_{t-1}) = \hat{x}_{1t} = \phi x_{t-1}$.

On substituting (1.9) into (1.8) we have the final form equations

$$(1.10) \quad y_t = (\Pi_1 + \Pi_{r+3}) \phi \hat{x}_{1t} + (\Pi_2 + \Pi_{r+4}) x_{2t} + \sum_{i=1}^r \Pi_{2+i} y_{t-i} + V_t$$

Equations (1.9) and (1.10) represent the system of equations to be

estimated. From this development of the final form equations and the specification that producers' expectations are formed rationally, it is apparent that changes in the "structure," i.e., Φ , which generates the forecast values of x_{1t} , as well as the "structure," i.e., the fundamental parameters comprising the Π_i matrices, determine the values of the endogenous variables.

A Digression on Expected Price, Price Supports and Producers Output Decisions

Dairy producers operate in an economic environment which can be characterized by its asset owning nature. Dairy cows represent unique capital assets which generate a stream of revenues from joint outputs of livestock (new capital) and milk. Because a dairy farmer must make substantial capital investments today, in order to capture net revenues tomorrow and on into the future, his expectations of market prices, for both inputs and outputs play a central role in deciding on the desirability of owning the dairying assets. Specifically, the value of an asset (V_t) can be expressed as

$$(2.1) \quad V_t = \frac{E(R_t)}{k_t}$$

where $E(R_t)$ is the expected return to the asset and k is the capitalization factor. $E(R_t)$ includes all net revenues while k_t includes both market factors as well as individual risk discount factors.

The value of $E(R_t)$ for a specific period depends upon the dairy farms expectations of market price, production level and variable input costs. Assuming that production and input costs can be taken as known, the only non-deterministic variable is market price.

Within the current U.S. policy structure for dairy, producers are paid a weighted average or blend price for milk. This price reflects the distribution of milk sold, at two different prices in two separate markets.

Specifically, the blend price can be expressed as

$$(2.2) \quad P_t^B = \frac{P_t^f F_t + P_t^m M_t}{TMS_t}$$

where $P_t^f \equiv$ fluid milk price, F_t is fluid use, $P_t^m \equiv$ manufacturing milk price, $M_t \equiv$ manufacturing use and $TMS \equiv$ total milk sold. In addition, the two prices are linked by the relationship

$$(2.3) \quad P_t^f = P_t^m + \Theta_t$$

where Θ_t is a specified differential between P_t^m and P_t^f , established under the Federal Milk Marketing Order program.

By using (2.3) and substituting into (2.2), the blend price can be expressed as

$$(2.4) \quad P_t^B = P_t^m + \gamma_t \Theta_t$$

where
$$\gamma_t = \frac{F_t}{TMS_t}.$$

From this derivation it is apparent that a dairy producer's expectations of the blend price are fundamentally expectations of the manufacturing price, fluid utilization and the price differential Θ , i.e.,

$${}_{t-i}E_t(P_t^B) = {}_{t-i}E_t\{P_t^m + \gamma_t \Theta_t\} = {}_{t-i}E_t\{P_t^m\} + {}_{t-i}E_t\{\gamma_t \Theta_t\}$$

where ${}_{t-i}E_t$ is the expectations operator at a prior time $t-i$.

First, consider the term ${}_{t-i}E_t\{\gamma_t \Theta_t\}$. If γ_t is taken as a known variable, then the expectation of this term is

$$\gamma_t {}_{t-i}E_t\{\Theta_t\}.$$

Therefore, the producers expected market blend price is

$$(2.5) \quad {}_{t-i}E_t\{P_t^B\} = {}_{t-i}E_t\{P_t^m\} + \gamma_t {}_{t-i}E_t\{\Theta_t\}.$$

From this, it is apparent that expected revenues from milk production depend on the producer's expected manufacturing price ${}_{t-i}E_t\{P_t^m\}$ and the utilization weighted expectation of the pricing differential $\gamma_t {}_{t-i}E_t\{\Theta_t\}$.

Because P_t^m is not a freely varying market price, but instead a price which is limited from below by the price support program, the dairy producer must also formulate his expectation of the government set price support level P_t^S . If P_t^m , unaffected by a guaranteed minimum price, is assumed to be normally distributed, then the linkage between $E_{t-1}\{P_t^m\}$ and P_t^S can be shown. The producers price expectation is transferred from P_t^m to a weighted average price P_t . This price is a combination of the expected minimum price P_t^S and the expected price which the producer would realize if the actual market price is higher than the support price P_t^S .

Formally,

$$(2.6) \quad E(P_t) = \int_0^{P_t^S} N(p; \bar{P}^m, \frac{\sigma_p^2}{p}) dp P_t^S + \int_{P_t^S}^{\infty} N(p; \bar{P}^m, \frac{\sigma_p^2}{p}) p dp$$

where \bar{P}^m and σ_p^2 are the first and second moments of the price distribution. The first-term on the right-hand side of (2.6) gives the probability weighted value of the support price P_t^S , while the second term is the expected value of the addition to P_t^S , given some positive probability that the market price will be above the support price. If this latter probability is zero, then the expected market price is the support or expected support price $E\{P_t^S\}$ and the expected blend price is

$$E\{P_t^B\} = E\{P_t^S\} + \gamma_t E\{O_t\}$$

With these price relationships, we can see that the dairy producer's expected market blend price is more fundamentally determined by his expectations of the level of price-support $E\{P_t^S\}$, the expected level of price differential $E\{O_t\}$ and the assessed probability that market prices will exceed the prevailing support price P_t^S .

The Dairy Production Sub-Model

From (2.1) the explicit objective of the dairy firm can be characterized as attempting to choose the time path of capital stock K_t so as to ensure a maximum value of expected net returns to the dairy enterprise:

$$(3.1) \quad \text{Maximize} \quad V_t = E_t \sum_{i=0}^{\infty} b^i \{ P_{t+j}^m m_{t+j} K_{t+j} - C_{t+j}^F \\ K_{t+j}, K_{t+j+1}, \dots \quad K_{t+j} - W_{t+j} L_{t+j} - q_{t+j} (K_{t+j} - K_{t+j-1}) - \frac{d}{2} (K_{t+j} - K_{t+j-1})^2 \}$$

where the gross income from milk output of the dairy herd stock, which is equal to the price of milk times the number of milking animals, multiplied by average yield:

$$(i) \quad GI_{t+j}^m = P_{t+j}^m \cdot K_{t+j} \cdot m_{t+j};$$

and the total feed cost of the dairy herd (K_{t+j}):

$$(ii) \quad TC_{t+j}^F = C_{t+j}^F K_{t+j};$$

and the cost of animals added to the dairy herd in ($t+j$):

$$(iii) \quad CA_{t+j} = q_{t+j} (K_{t+j} - K_{t+j-1});$$

and the labor cost defined at wage rate W_{t+j} :

$$(iv) \quad LC_{t+j} = W_{t+j} \cdot L_{t+j};$$

the capital stock adjustment cost:

$$(v) \quad CAC_{t+j} = \frac{d}{2} (K_{t+j} - K_{t+j-1})^2. \quad \text{The solution to this}$$

problem which satisfies the boundary (transversality) condition is:

$$(vi) \quad K_{t+j} = \beta K_{t+j-1} - \frac{1}{d} \sum_{i=0}^{\infty} b^i E_{t+j} \{ q_{t+j+1} - b q_{t+j+1+i} \\ + C_{t+j+1}^F - P_{t+j+1}^m m_{t+j+1} \}$$

where the expectations operator E_{t+j} is reintroduced and b is the

discount factor. Given specific stochastic processes for

$\{ q_{t+j+1} \}$, $\{ C_{t+j+1}^F \}$, $\{ P_{t+j+1}^m \}$, and

$\{ m_{t+j+1} \}$; expressions for $E_{t+j} q_{t+j+1}$, $E_{t+j} C_{t+j+1}^F$, $E_{t+j} P_{t+j+1}^m$, and $E_{t+j} m_{t+j+1}$ can be calculated and substituted into (vi) to yield an expression for optimal capital stock K_{t+j} in terms of observable variables.

The conceptual equations from the production sub-model are:

Capital Stock Equation:

$$(3.2) \dots K_t = g_1(K_{t-1}, E_{t-1}(P_t^m | \Omega_{t-1}), E_{t-1}(q_t | \Omega_{t-1}), \sigma_{dt}^2, \sigma_{at}^2, U_{1t}),$$

Domestic Production Equation:

$$(3.3) \dots Q_t^{dp} = g_2(K_t, Z_t, U_{2t}),$$

Rational Expectations formulation:

$$(3.4) \dots E_{t-1}(P_t^m | \Omega_{t-1}) = g_3(E_{t-1}(P_{gt}^S | \Omega_{t-1}), E_{t-1}(X_t | \Omega_{t-1}), U_{3t}),$$

Price Support Rule:

$$(3.5) \dots P_{gt}^S = g_4(P_{gt-1}^S, U_{4t}),$$

where:

K_t = A measure of dairy capital stock in period t,

$E_{t-1}(P_t^m | \Omega_{t-1})$ = the rational expectation of market price in period t, conditioned on the information set Ω_{t-1} ,

$E_{t-1}(q_t | \Omega_{t-1})$ = the rational expectation of the market price of capital in period t, conditional on the information Ω_{t-1} ,

$E_{t-1}(P_{gt}^S | \Omega_{t-1})$ = the rational expectation of the level of dairy price support in period t, conditional on the information set Ω_{t-1} ,

σ_d^2 = A measure of the "riskiness" of dairying as an economic activity,

σ_a^2 = A measure of the "riskiness" of an alternative economic activity, other than dairy,

Q_t^{dp} = total annual domestic production of milk in period t,

Z_t = A vector of exogenous variables which helps explain short-run fluctuations in domestic production in period t,

P_{gt}^S = the U.S. Federal dairy price support level in period t,

X_t = relevant economic variables contained in the producers information set Ω_{t-1} , which helps form the expectation on market price,

The following four equation model is postulated as characterizing the dairy production sub-model of a more complete model of the dairy economy. The first equation is the price identity, the second is the capital stock equation, the third is the production relationship and the fourth is an aggregate demand specification.

$$(3.6) \quad P_t - P_t^m - \lambda\theta = 0$$

$$(3.7) \quad \beta_{11}K_t + \alpha_{13}P_t^{m*} + \gamma_{11}PC_t + \gamma_{14}P_{gt}^S + \gamma_{15}k_{t-1} + \gamma_{16}\sigma_D^2 + \gamma_{17}(\bar{\lambda}\bar{\theta})_t + I = U_{1t}$$

$$(3.8) \quad \beta_{11}K_t + \beta_{22}Q_t + I = U_{2t}$$

$$(3.9) \quad \beta_{32}Q_t + \beta_{33}P_t^m + \gamma_{32}Y_t + \gamma_{33}P_t^S + I = U_{3t}$$

where the parameter matrices are

$$B = \begin{bmatrix} 1 & 0 & 0 \\ \beta_{21} & 1 & 0 \\ 0 & \beta_{32} & 1 \end{bmatrix}, \quad A = \begin{bmatrix} 0 & 0 & \alpha_{13} \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \quad T_1 = \begin{bmatrix} \gamma_{11} & 0 & 0 & \gamma_{14} \\ 0 & 0 & 0 & 0 \\ 0 & \gamma_{32} & \gamma_{33} & 0 \end{bmatrix}$$

$$T_2 = \begin{bmatrix} \gamma_{15} & \gamma_{16} & \gamma_{17} & \gamma_{18} \\ 0 & 0 & 0 & \gamma_{28} \\ 0 & 0 & 0 & \gamma_{38} \end{bmatrix}.$$

The variable vectors are

$$y = \{K_t, Q_t, P_t^m\}$$

$$y^* = \{K_t^*, Q_t^*, P_t^{m*}\}$$

$$x_{1t} = \{PC_t, Y_t, P_t^S, P_{gt}^S\}$$

$$x_{2t} = \{K_{t-1}, \sigma_D^2, \bar{\lambda}\bar{\theta}_t, 1\}$$

where $K_t \equiv$ index of productive capital (i.e., herd stock), $Q_t \equiv$ domestic milk production, $P_t^m \equiv$ market price of milk, K_t^* , Q_t^* and P_t^{m*} are expectations on these variables respectively. The anticipated exogenous variables are $PC_t \equiv$ feed price concentrate, $Y_t \equiv$ real consumer disposable income, $P_t^s \equiv$ index of substitute prices, $P_{gt}^s \equiv$ government price support level. The exogenous variables taken as known are $K_{t-1} \equiv$ last periods capital capacity, $\sigma_D^2 \equiv$ a measure of economic risk in dairying, $\bar{\lambda}\bar{\theta} \equiv$ the utilization weighted class I differential.

With this model specification, we have the special relationship that capital capacity K_t is in part influenced by producers' expectations of the federal dairy price-support level and domestic milk production is then determined by the chosen level of capital capacity.

By carrying out the matrix multiplications and inversions indicated by the general matrix equation

$$(3.10) \quad y_t = B^{-1}A(B+A)^{-1}T_1\hat{X}_{1t} - B^{-1}T_1X_{1t} + B^{-1}A(B+A)^{-1}T_2X_{2t} - B^{-1}T_2X_{2t} + B^{-1}U_t,$$

the dairy producers' aggregate capital stock equation can be expressed as

$$(3.11) \quad K_t = \{\alpha_{13} - \beta_{21}\alpha_{13} + \beta_{21}\beta_{32}\alpha_{13}/\omega - \gamma_{18}\} + (\beta_{21}\beta_{32}\alpha_{13}\gamma_{15}\omega - \gamma_{15})K_{t-1} + (\beta_{21}\beta_{32}\alpha_{13}\gamma_{11}\omega) \hat{PC}_t - \gamma_{11}PC_t + (\alpha_{13}\gamma_{32}\omega)\hat{Y}_t + (\alpha_{13}\gamma_{33})\hat{P}_t^s + (\beta_{21}\beta_{32}\alpha_{13}\gamma_{14}\omega) \hat{P}_{gt}^s - \gamma_{14}P_{gt}^s + (\beta_{21}\beta_{32}\alpha_{13}\gamma_{16}\omega - \gamma_{16})\bar{\sigma}_D^2 + (\beta_{21}\beta_{32}\alpha_{13}\gamma_{17}\omega - \gamma_{17}) \bar{\lambda}\bar{\theta}_t + v_t .$$

As stated earlier, an important problem at this point, and one which has received little attention in the applied REH literature, is how to deal with the repetition of some of the exogenous variables. More specifically, any exogenous variable which appears in the structural form of the capital stock equation, along with the expected price variable, will show up in the estimable equation as both the expectation of that variable and the current value itself. Thus, we can see that in equation (3.11) we have both \hat{PC}_t and PC and \hat{P}_{gt}^S and P_{gt}^S .

The usual practice has been to ignore this question and to estimate the equation with both the expectation and the current value. This does not seem to be reasonable. If the value of the exogenous variable needs to be forecast to derive the expected market price, then it is only reasonable to assert that it does not belong on the structural equation as a known variable and that in this form the equation is misspecified. More appropriately, these variables, and in particular, PC_t and P_{gt}^S should originally appear as anticipated exogenous variables PC_t^* and P_{gt}^{S*} . In this way, we can reasonably combine terms in equation (3.11) to get

$$(3.12) \quad K_t = \lambda_0 + \lambda_1 K_{t-1} + \lambda_2 \hat{P}_{gt}^S + \lambda_3 \hat{PC}_t + \lambda_4 \hat{Y}_t + \lambda_5 \hat{P}_t^S + \lambda_6 \bar{\sigma}_D^2 + \lambda_7 (\bar{\lambda} \theta_t) + v_t$$

where the λ_i 's represent the parameters in equation (3.11) with respect to each exogenous variable.

The only remaining question concerns the particular form which the forecasting equations for P_{gt}^S , PC_t , Y_t , P_t^S should take. Following the simplest form, we propose univariate autoregressive models ARIMA(1,0,0) such that

$$\begin{aligned}
 P_{gt}^S &= \phi_1 P_{gt-1}^S + \xi_{1t} \quad \text{and} \quad \hat{P}_{gt}^S = \hat{\phi}_1 P_{gt-1}^S \\
 PC_t &= \phi_2 PC_{t-1} + \xi_{2t} \quad \text{and} \quad \hat{PC}_t = \hat{\phi}_2 PC_{t-1} \\
 Y_t &= \phi_3 Y_{t-1} + \xi_{3t} \quad \text{and} \quad \hat{Y}_t = \hat{\phi}_3 Y_{t-1} \\
 P_t^S &= \phi_4 P_t^S + \xi_{4t} \quad \text{and} \quad \hat{P}_t^S = \hat{\phi}_4 P_{t-1}^S
 \end{aligned}
 \tag{3.13}$$

where ξ_{it} is a stochastic variable with $E(\xi_{it}) = 0$, $E(\xi_{it} \xi_{it-1}) = 0$.

Substituting (3.13) into (3.12) we arrive at the REH form of the capital stock equation

$$\begin{aligned}
 K_t &= \lambda_0 + \lambda_1 K_{t-1} + \lambda_2 \phi_1 P_{gt-1}^S + \lambda_3 \phi_2 PC_{t-1} + \lambda_4 \phi_3 Y_{t-1} \\
 &+ \lambda_5 \phi_4 P_{t-1}^S + \lambda_6 \bar{\sigma}_D^2 + \lambda_7 (\bar{\lambda} \bar{O})_t + V_t
 \end{aligned}
 \tag{3.14}$$

The exogenous policy variable in this equation is P_g^S , therefore, this equation, along with the forecast rule for P_{gt}^S yields the basis for linking K_t to the policy parameter ϕ_1 .

The rational expectation implications of a change in price support can be seen by examining the partial derivative of K_t with respect to \hat{P}_{gt}^S .

This derivative is given by

$$\delta K_t = \lambda_2 \delta \hat{P}_{gt}^S
 \tag{3.15}$$

$$\text{and} \quad \delta E(P_{gt}^S | \Omega_{t-1}) = \delta \hat{P}_{gt}^S = \phi_1 \delta P_{gt-1}^S$$

so we have

$$\begin{aligned}
 \delta K_t &= \lambda_2 \{ \phi_1 \delta P_{gt-1}^S + P_{gt-1}^S \delta \phi_1 \} \\
 &= \lambda_2 \phi_1 \delta P_{gt-1}^S + \lambda_2 P_{gt-1}^S \delta \phi_1
 \end{aligned}
 \tag{3.16}$$

The interpretation of this last equation is that the change in K_t with respect to $\delta E(P_{gt}^S | \Omega_{t-1})$ is given by $\lambda_2 \phi_1$ only as long as the $\delta \phi_1 = 0$.

Therefore, any change in the expected level of price-supports which

implies a different ϕ_1 , i.e., $\hat{P}_{gt}^S = \phi_1 \hat{P}_{gt-1}^S$, is accounted for in the

capital stock equation by both terms and not just the $\lambda_2\phi_1$ term. This would manifest itself in the capital stock equation (3.14) by a change in the parameter $\lambda_2\phi_1$. Suppose that the federal authority in charge of establishing the price support rule shifts from a policy of continually increasing price-supports, represented by:

$$(3.17) \quad P_{gt}^S = \phi_1 P_{gt-1}^S + \xi_t \quad \text{with } \phi_1 > 1$$

to a policy designed to gradually phase out price-supports, represented by

$$(3.18) \quad P_{gt}^S = \phi_1 P_{gt-1}^S + \xi_t \quad \text{with } \phi_1 < 1$$

New levels of capital stock K_t would be determined by changes in both the level of price-supports over time and the value of the parameter $\lambda_2\phi_1$. This would become $\lambda_2\phi_1 \neq \lambda_2\phi_1$ to reflect producer anticipation of the new "structure" of the support policy.

In contrast to the more traditional models of policy impacts, not only does the exogenous variable P_g^S change but also the parameter of the producers capital stock equation changes to reflect the shift in government policy. Also notice that the kinds of policy evaluations which can be undertaken are severely constrained by the adoption of the rational expectations viewpoint. Having chosen a new value for the policy parameter ϕ , we are constrained to specify each new level of price-support P_{gt+1}^S such that it is consistent with the policy equation (3.18).

In addition to altering the interpretation of policy evaluation, the rational expectations hypothesis also has another economic and econometric implication. Recalling equation (3.14), we can see that market price does not appear as an explanatory variable in determining capital stock. Rational expectations does not imply that K_t is independent of market prices. K_t is determined by expected market prices, which are determined by more fundamental economic variables (Wallis, 1981).

The Econometric Model and Policy Evaluation

The evaluation of the impact of price-supports on prices, production and consumption under the REH requires that we specify more than alternative levels of the support price from one period to the next. What is required is that we specify a policy rule, i.e., an explicit form for equation (3.17). In this way, the level of price support in period t is linked in a logical way to the level in period t-1.

Recalling the discussion on producer expectations and their relationship to the reduced-form parameters, the estimate of ϕ from the data on price supports 1949-1978, along with the estimate of the parameter on lagged price-support in the capital capacity equation allows us to estimate the policy invariant component of the reduced form coefficient. The estimated equations for (3.14) and (3.17) are presented in equations (3.19) and (3.20).^{3/}

Dairy Capital Stock:

$$(3.19) \dots K(t) = 18255.57 + 0.56K(t-1) + 2.99 P_g^S(t-1)$$

$$(4.46) \quad (5.61) \quad (3.15)$$

$$- 1.58 ACP(t-1) + 26.68 \left(\frac{\sigma_d^2}{\sigma_a^2} \right)$$

$$(-4.33) \quad (2.13)$$

$$\bar{R}^2 = 0.84 \quad F = 36.56 \quad \text{Durbin } "h" = +0.68$$

where ACP is the average annual cull cow price and the other variables have already been defined.

Price-Support Policy Rule:

$$(3.20) \dots P_g^S(t) = 1.067611 P_g^S(t-1)$$

$$(38.93)$$

$$\bar{R}^2 = .98 \quad F = 1516.1 \quad D/W "d" = 1.23$$

As an example of the implications of the REH and the AR(1,0,0) forecasting rule for the period 1949-1978, consider the estimated parameters on ϕ from (3.20) and $P_g^S(t-1)$ from (3.19). With this estimated AR(1) forecasting "rule" the implied structurally invariant parameter is:

$$\begin{aligned} B &= 2.99 / 1.067611 \\ &= 2.80 \end{aligned}$$

Any other historical time path of price-supports implies a different rule, i.e., AR (ϕ) parameter and hence a different value of B. In order to be consistent with the view that expectations are formed rationally, it is not possible to evaluate dairy price-support policy by simply specifying hypothetical levels of price-support from one year to another and calculating a level for the endogenous capital stock K. By adopting the REH perspective we are constrained, when making hypothetical policy evaluation, to alter, in a logical fashion, both the support rule parameter, i.e., the value of ϕ , and those of the reduced form to generate hypothetical behavior for the endogenous variables. The traditional method of policy analysis, that of setting the policy variable to alternative, arbitrary levels from period to period is inconsistent with this reasoning. Such a policy would imply an autoregressive parameter close to zero with a very large error-term variance. Under such an implied structure, producers would be unable to form any reasonable forecasts of the policy variables, and such a variable would logically not be a determinant in optimal economic decisions.

What this discussion suggests for actual policy evaluation is that we must carefully consider the usefulness and validity of econometric policy evaluations such as "what happens if we set the level of price support to zero in 1949 and maintain it there through 1978?" Clearly,

the implied behavior of endogenous variables resulting from such a policy evaluation would have to be viewed with substantial skepticism. Instead, we must pose the question in a more reasonable manner, "What are the economic implications of a price-support rule which, historically, would have maintained a constant or possibly a more rapidly declining level of support from 1949 through 1978?" To answer this question, we would select a value of ϕ such that the price-support declined rapidly, for example, from 1949 onward. We would then use the invariant estimate of B to calculate a new parameter for $P_g^s(t-1)$. Using this in equation (3.19), we would estimate capital stock in each year consistent with the new price-support rule.^{4/}

Conclusions:

The concept of REH constitutes a phenomenon which is both logically simple and empirically complex. Its simplicity lies in the fact that applied econometricians have been for a long time constructing equilibrium models within which the REH has been implicitly embedded. Once recognized, however, the REH is not as easily incorporated explicitly into these models. The intent of this paper was to develop and explore the conceptual and econometric implications of REH in an aggregate econometric model of the U.S. Dairy economy. This development illustrates the nature of the constraints which must be placed on future policy models in dairy and elsewhere, if the econometricians view of the world is to be consistent with the concept of rational economic agents. The view of the world developed here is clearly not the most complex one which could conceivably be taken. If the endogenous variables are anticipated in a rational manner, then what constitutes a rational model for exogenous variables? Clearly the more complex the

model posited for a variable such as P_g^s , the more intricate and complex the econometric model becomes. Notice also that I have said nothing about testing the econometric model in a manner which would allow the rejection of the REH (Hoffman and Schmidt). This constitutes yet another area of research which the applied econometrician must undertake if he/she is to develop maximum confidence in the descriptive and prescriptive performance of his/her models.

Notes

1. Thraen, Cameron S., (1981), An Econometric Assessment of the U.S. Dairy Price Support Policy With Special Emphasis on Risk, Uncertainty and Rational Producer Behavior., unpublished Ph.D. Dissertation, Agricultural and Applied Economics, University of Minnesota.
2. Wallis (1981) in an unpublished paper points out that these models can in fact be considered "rational" expectations if in fact the implied restrictions on the parameter space are valid.
3. Coefficients in parentheses are "t" values based on 28df.
4. Note that there is nothing in the rational expectations hypothesis which rules out the case in which the authorities decide to set $\phi = 0$, which would occur when a program was simply cancelled. However, in a situation such as this, $\phi = 0$ is econometrically equivalent to setting $P^S_{gt-1} = 0$ for all t. Note that the question of policy evaluation with this type of policy change is difficult to address because the implications of the REH become indistinguishable from that of the naive models.

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