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EXPECTATIONS, THE LUCAS CRITIQUE AND AGRICULTURAL POLICY: AN ECONOMETRIC APPLICATION TO THE U.S. DAIRY ECONOMY

by

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ABSTRACT

The Lucas critique is developed in a conceptual and econometric application of a rational or 'model consistent' expectations paradigm for modeling producers' economic behavior in a simple macro-economic model of the United States dairy economy. It is demonstrated that the parameters of the estimated behavioral equations are functions of the specific dairy price-support rule in effect.

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 U.S. federal dairy price-support program have been based on the conceptual paradigm of risk neutral 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).

In a more recent paper, Lafrance and de Gorter attempt to estimate the social welfare costs of the price-support program over the period 1965 to 1980. They do this by constructing and estimating an equilibrium econometric model of the U.S. dairy sector. This model is estimated using data from a period when the price-support policy was in effect. Welfare measures are arrived at by the usual method of arbitrarily setting the support price to zero and simulating the econometric model over time at the implicit equilibrium levels of prices and quantities.

The difficulty with the Lafrance and de Gorter approach is that there is no recognition made of the fact that the existence and operation of the price-support program would have had direct influence on producers behavior and the implied equilibrium state of the sector. This would be captured directly in an econometric model estimated with data generated during this period. Simply setting the level of the support price to equal zero and to simulate a new "competitive" equilibrium from which to measure consumer and producer surplus is suspect. This fails to recognize that producers economic behavior would most likely be altered in such an event and that this should be captured to the extent possible in the econometric model.

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) is an expectations model which can fulfill this need in a consistent and logically appealing manner.[1] 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 (Lucas, 1976). Lucas argued that traditional econometric policy models did not capture the changing structure of policy rules with their assumption of a fixed parameter vector and could therefore not usefully serve to indicate how economic agents would respond to new policy regimes.

The purpose of this paper is to illustrate the econometric implications of REH and the Lucas critique (LC/REH) and to demonstrate how this may be incorporated into an econometric model of the aggregate dairy economy for policy evaluation. The paper takes the following form. The concept of rationally formed expectations is reviewed in the next section. A model of the U.S. dairy sector, taking into account the LC/REH is presented in section three. In the fourth section an estimated econometric model of the dairy economy and U.S. price support policy is presented. Summary and conclusions are developed in the final section.

Rational Producer Expectations and Policy Evaluation

Price-supports and producer expectations of price supports are instrumental in determining dairy producer decisions. In this section, I will examine the relationship between the formulation of producers' price expectations and changes in the government's rules for establishing price supports in a general economic model.

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

$$(1.1) \qquad B(L)y_t + Ay_t^* + \Gamma_1 x_{1t} + \Gamma_2 x_{2t} = U_t$$

where y_t is a vector of g endogenous variables, y_t^* is a vector of h anticipated 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. $B(L) = B_o + B_1 L + \ldots + B_r L^r$ is the matrix polynomial lag function $(L^r y_t = y_{t-r})$ which allows for lagged endogenous variables. The matrix dimensions are $B\sim(gxg)$, $A\sim(gxg)$, $\Gamma_1\sim(gxk_1)$ and $\Gamma_2\sim(gx(k-k_1))$.

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 $y_t^* = \mathcal{E}(y_t|\Omega_{t-1})$ where Ω_{t-1} is the producer's information set based on (1.1).

From (1.1) we can rearrange terms

$$(1.2) \quad B_o y_t + A y_t^* = -\{B_1 y_{t-1} + \ldots + B_r y_{t-r}\} - \Gamma_1 x_{1t} - \Gamma_2 x_{2t} + U_t$$

and applying the conditional expectations operator $\mathcal{E}$

$$(1.3) \quad \mathcal{E}(B_o y_t + A y_t^*) = \mathcal{E}\{-B_1 y_{t-1} + \ldots + B_r y_{t-r} - \Gamma_1 x_{1t} - \Gamma_2 x_{2t} + U_t\}.$$

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

$$(1.4) \quad y_t^* = -(B_o + A)^{-1}\{\Gamma_1 \mathcal{E}\{x_{1t}|\Omega_{t-1}\} + \Gamma_2 x_{2t} + B_1 y_{t-1} + \ldots B_r y_{t-r}\}$$

where $\mathcal{E}\{x_{1t}|\Omega_{t-1}\} = \hat{x}_{1t}$ 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 used in econometric modeling, i.e., naive and adaptive respectively,

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

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

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, Γ_1, Γ_2.[2]

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

$$(1.7) \quad B(L)y_t - A(B_o + A)^{-1}\{\Gamma_{1t}\hat{x}_{1t} + \Gamma_2 x_{2t} + B_1 y_{t-1} + \dots + B_r y_{t-r}\} + \Gamma_1 x_{1t} + \Gamma_2 x_{2t} = U_t.$$

The reduced form of the structural system can be expressed as,

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

where $\Pi_1 = B_o^{-1}A(B_o + A)^{-1}\Gamma_1$; $\Pi_2 = B_o^{-1}A(B_o + A)^{-1}\Gamma_2$; $\Pi_3 = B_o^{-1}A(B_o + A)^{-1}B_1$

$\Pi_{2+i} = B_o^{-1}A(B_o + A)^{-1}B_i$; $\Pi_{r+3} = -B_o^{-1}\Gamma_1$; $\Pi_{r+4} = -B_o^{-1}\Gamma_2$ and $V_t = B_o^{-1}U_t$.

To complete the specification of the reduced form model (1.8), we need to postulate a model for $\hat{x}_{1t}$. Note that the imposition of the REH onto the structural model has nothing to do with how we formulate the forecasting model for $\hat{x}_{1t}$. 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 economic agents do not have full information of the structure of all of the other systems, and therefore, use 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 is a white noise process, assumed to be independent of V_t. The optimal one-step-ahead forecast for this model is $\mathcal{E}(x_{1t}|\Omega_{t-1}) = \hat{x}_{1t} = \phi x_{t-1}$. 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 Conceptual Model of the U.S. Dairy Economy

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 values of an asset (V_t) can be expressed as

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

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

The value of $\mathcal{E}(R_t)$ 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.

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

$$\underset{Cs_{t+j},\, Cs_{t+j+i},\, \ldots}{\text{Maximize}} \quad V_t = \mathcal{E}_t \sum_{j=0}^{n} b^j \{((P^m_{t+j}\, Y_{t+j}\, Cs_{t+j} - (C^f_{t+j}\, Cs_{t+j} - W_{t+j}\, L_{t+j}) - q_{t+j}(Cs_{t+j} - Cs_{t+j-1}) - \frac{d}{2}(Cs_{t+j} - Cs_{t+j-1})^2 \} \tag{2.2}$$

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:

$$\text{(i)}\quad GI^{m}_{t+j} = P^{m}_{t+j} \quad Cs_{t+j} \quad Y_{t+j};$$

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

$$\text{(ii)}\quad TC^{F}_{t+j} = C^{f}_{t+j}\; Cs_{t+j};$$

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

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

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

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

the capital stock adjustment cost:

$$\text{(v)}\quad CAC_{t+j} = \frac{d}{2}\,(Cs_{t+j} - Cs_{t+j-1})^{2}.$$

The solution to this problem which satisfies the boundary (transverality) condition (Sargent, p. 191):

$$\text{(2.3)}\quad \begin{aligned} Cs_{t+j} = \lambda\, Cs_{t+j-1} - \frac{1}{d} \sum_{i=0}^{n} b^{i}_{t+j}\{q_{t+j+i} - b q_{t+j+1+i} \\ + C^{f}_{t+j+1} - P^{m}_{t+j+1}\; Y_{t+j+1}\} \end{aligned}$$

where the expectations operator $\mathcal{E}_{t+j}$ is reintroduced and b is the discount factor. Given specific stochastic processes for

$\{q_{t+j+1}\}$, $\{C^{f}_{t+j+1}\}$, $\{P^{m}_{t+j+1}\}$ and $\{Y_{t+j+1}\}$; expressions for $\mathcal{E}_{t+j} q_{t+j+1}$, $\mathcal{E}_{t+j}$ C^{F}_{t+j+1}, $\mathcal{E}_{t+j}\; P^{m}_{t+j+1}$, and $\mathcal{E}_{t+j} Y_{t+j+1}$ can be calculated and substituted into (2.3) to yield an expression for optimal capital stock Cs_{t+j} in terms of observable variables.

Expected Market Price, Price Supports and Producers Output Decisions

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

$$(2.4) \quad P^B_t = \frac{P^f_t F_t + P^m_t M_t}{TMS_t}$$

where P^f_t ≡ fluid milk price, F_t ≡ fluid use, P^m_t ≡ manufacturing milk price, M_t ≡ manufacturing use, and TMS_t ≡ total milk sold. In addition, the two prices are linked by the relationship,

$$(2.5) \quad P^f_t = P^m_t + \Theta_t$$

where Θ_t is a specified differential between P^m_t and P^f_t, established under the U. S. Federal Milk Marketing Order program.[3]

By using (2.5) and substituting into (2.4), the blend price can be expressed as

$$(2.6) \qquad P^B_t = P^m_t + \gamma_t\Theta_t$$

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

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_t, i.e.,

$$_{t-i}\mathcal{E}_i(P^B_t) = {}_{t-i}\mathcal{E}_i\{P^m_t + \gamma_t\Theta_t\} = {}_{t-i}\mathcal{E}_i\{P^m_t\} + {}_{t-i}\mathcal{E}_i\{\gamma_t\Theta_t\}$$

where $_{t-i}\mathcal{E}_i$ is the expectations operator at a prior time t-i.

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

$$\gamma_t \; {}_{t-i}\mathcal{E}_i\{\Theta_t\}.$$

Therefore, the producers expected market blend price is

$$(2.7)\quad {}_{t-i}\mathcal{E}\{P^B_t\} = {}_{t-i}\mathcal{E}\{P^m_t\} + \gamma_{t}\,{}_{t-i}\mathcal{E}\{\Theta_t\}.$$

Expected revenues from milk production depend upon the producer's anticipated or expected value of manufacturing price ${}_{t-i}\mathcal{E}\{P^m_t\}$ and the utilization weighted expectation of the pricing differential $\gamma_{t}\,{}_{t-i}\mathcal{E}\{\Theta_t\}$.

Because P^m_t is not a freely varying market price, but instead a price which is limited from below by the price support program, the producer must also formulate his expectation of the government set price support level P^s_t . If P^m_t, unaffected by a guaranteed minimum price, is assumed to be normally distributed, then the linkage between ${}_{t-i}\mathcal{E}\{P^m_t\}$ and P^s_t can be shown (Boehlji and Griffin, 1979). The producer's price expectation is transferred from P^m_t to a weighted average price $\mathcal{E}(P_t)$.

This price is a combination of the expected value of the federal minimum price P^s_t and the expected price which the producer would realize <u>if</u> the actual market price is higher than the support price P^s_t. Formally,

$$\begin{aligned}\mathcal{E}(P_t) &= \int_0^{P^s} N(p;\ \bar{P}^m,\ \bar{\sigma}^2_p m)\ dp\ P^s_t \\ (2.8)\qquad & \\ &+ \int_{P^s}^{\infty} N(p;\ \bar{P}^m,\ \bar{\sigma}^2_p m))\ P\ dp\end{aligned}$$

where $\bar{P}^m$ and $\bar{\sigma}^2_p m$ 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^s_t, while the second term is the expected value of the addition to P^s_t , 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 expected support price $\mathcal{E}\{P^s_t\}$ and the expected blend price is

$$(2.9) \qquad \mathcal{E}\{P^B_t\} = \mathcal{E}\{P^s_t\} + \gamma_t\mathcal{E}\{\Theta_t\}$$

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

A remaining question concerns the particular form which the forecasting equation for P^s_t should take. The usual approach is to use a univariate autoregressive models ARIMA (1,0,0) representation such that

$$(2.11) \qquad P^s_t = \phi P^s_t + \varepsilon_t \text{ , and the one-step ahead forecast is given as}$$

$$(2.12) \qquad \hat{P}^s_t = \phi P^s_{t-1}$$

where ε_t is a stochastic variable with $\mathcal{E}(\varepsilon_t) = 0$, $\mathcal{E}(\varepsilon_t \varepsilon_{t-1}) = 0$. Substituting (2.12) into an empirical representation of the capital stock equation (2.2) we arrive at the LC/REH form of the capital stock equation

$$(2.13) \quad K_t = \lambda_0 + \lambda_1 K_{t-1} + \lambda_2\phi P^s_{t-1} + \lambda_3\Phi_t(\gamma\Theta) + \sum_{i=4}^{n}\lambda_i Z_i + \xi_t$$

where Z_i is an as yet unspecified vector of variables determining the level of dairy capital stock along with milk price.

The exogenous policy variable in this equation is P^s_t , therefore, this equation, along with the forecast rule for P^s_t yields the basis for linking Cs_t to the policy parameter ϕ.

The LC/REH implications of a change in price support can be seen by examining the partial derivative of Cs_t with respect to $\hat{P}_t^s$.

This derivative is given by

(2.14) $\partial Cs_t = \lambda_2 \partial \hat{P}^s_t$, where the change in the anticipated support price is $\partial \mathcal{E}(P^s_t \mid \Omega_{t-1}) = \partial \hat{P}^s_t = \lambda_2 \phi P^s_{t-1}$,

so we have

$$(2.15) \quad \partial Cs_t = \lambda_2 \{\phi \partial P^s_{t-1} + P^s_{t-1} \partial \phi\},$$

$$= \lambda_2 \phi \partial P^s_{t-1} + \lambda_2 P^s_{t-1} \partial \phi .$$

The interpretation of this last equation is that the change in Cs_t with respect to $\partial \mathcal{E}(P^s_t \mid \Omega_{t-1})$ is given by $\{\lambda_2 \phi\}$ only as long as the $\{\partial \phi\} = 0$. Therefore, any change in the expected level of price-supports which implies a different ϕ, i.e., $\hat{P}_t = \bar{\phi} P^s_{t-1}$, is accounted for in the capital stock equation by both terms and not just the $\{\lambda_2 \phi\}$ term. This would manifest itself in the capital stock equation (2.13) by a change in the parameter $\{\lambda_2 \phi\}$. Suppose that the federal authority in charge of establishing the price support rule shifts from a policy of continually increasing price-supports, represented by

(2.16) $p^s_t = \phi_1 P^s_{t-1} + \varepsilon_t$ with $\phi_1 > 1.0$,

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

(2.17) $p^s_t = \phi_2 P^s_{t-1} + \varepsilon_t$ with $\phi_2 < 1.0$.

New levels of capital stock Cs_t would be determined by changes in both the level of price-supports over time and the value of the parameter $\{\lambda_2 \phi\}$. This would become $\lambda_2 \phi_2 \neq \lambda_2 \phi_1$ to reflect producer anticipation of the new "structure" of the price support policy.

In contrast to the more traditional models of policy impacts, which ignore the LC/REH critique when evaluating policy changes, not only does the exogenous variable P^s_t 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 LC/REH viewpoint. Having chosen a new value for the policy parameter ϕ, we are constrained to specify each new level of price-support P^s_{t+1} such that it is consistent with the policy rule as reflected in ϕ.

The Econometric Model and Policy Evaluation

The following simultaneous equation system has been shown to be a useful empirical characterization of the U.S. domestic dairy economy and is adopted here with some modification (Thraen and Hammond). The demand side of the model represents aggregate milk demand and is captured in a single equation rather than separate equations for fluid and manufacturing demand. The supply side is captured by a multiplicative stock of cows and yield per cow relationship which together give total domestic production. The model is closed by an equilibrium condition. Empirical definitions for each variable are considered in the subsequent section. The following equations characterize the aggregate U.S. dairy economy:

Stock of Dairy Cows

(3.1) $Cs(t) = h(\ \mathcal{E}\{EP^m(t)\},\ P^c(t-1),\ P^g(t),\ \sigma^r(t),\ Cs(t-2),\ u_1(t)),$

Yield per Cow

(3.2) $Y(t) = l(\ \mathcal{E}\{EP^m(t)\},\ Y(t-1),\ u_2(t)),$

Production

(3.3) $Q^s(t) = Cs(t) * Y(t),$

Aggregate Milk Demand

(3.4) $Q^d(t) = g(\ P^m(t),\ I(t),\ P^{sb}(t),\ u_3(t)),$

Net Commercial Removals

(3.5) $S^c(t) = k(\ P^m(t-1),\ S^c(t-1),\ S^c(t-2),\ u_4(t)),$

Market Equilibrium

(3.6) $Q^d(t) + S^c(t) + S^e(t) + R^g(t) + R^f(t) = Q^s(t)$

Optimal Forecast for Dairy Support Price

(3.7) $P^s(t) = l(P^s(t-1),\ u_5(t)),$

where: (the time reference is indicative of the period)

Cs(t) = average number of producing milk cows on dairy farms,

$EP^m(t)$ = effective market price of milk,

$\sigma^r(t)$ = a proxy for the level of 'risk' in dairy returns relative to crop production returns,

$P^g(t)$ = the nominal price of 16% dairy ration per cwt.,

$P^c(t-1)$ = the price of cull cows,

Cs(t-2) = the change in the number of dairy cows from period (t-2) to (t-1),

Y(t) = the U.S. average yield per dairy cow,

$Q^s(t)$ = the domestic production of milk in the United States on a fluid equivalent basis,

$Q^d(t)$ = the aggregate demand for milk in the U.S. on a fluid equivalent basis,

I(t) = the level of nominal disposable income in the United States,

$P^{sb}(t)$ = a Divisia price index, 1967=100 nonalcoholic beverages (excluding milk), non-dairy fats and oils, and meats, poultry and fish products,
$R^c(t)$ = the level of net commercial stocks,
$P^m(t-1)$ = the change in $P^m(t)$ from period (t-2) to (t-1),
$P^s(t)$ = Federal minimum market support price,
$u_i(t)$ = stochastic disturbance terms.

Expected market price, $\mathcal{E}\{EP^m\}$, in the stock of cows equation (3.1) and the yield per cow equation (3.2) is proxied by a two-step estimation procedure which replaces EP^m with the least squares estimate of the weighted effective milk price

(3.18) $EP^m(t) = (1 - \alpha_t)\ P^m(t) + \alpha_t\ P^s(t)$,

were the weight $\alpha(t)$ is the percent of milk marketed absorbed by the federal government for price support activities.[4] In the first stage this effective price is conditioned on the entire set of exogenous variables in the model (Turkington).

The high positive colinearity between the individual substitute price series, nonalcoholic beverages, non-dairy fats and oils, and meat, poultry, and fish, necessitates their combined effect be measured by a consumption weighted index of all the price series. A Divisia Index was constructed from the individual price and consumption series for nonalcoholic beverages, nondairy fats and oils, and meats, poultry and fish, and used as a proxy for changing substitute prices.[5] An empirical definition for the risk variable $\sigma^r(t)$ is presented in detail in Thraen and Hammond, and is summarized in appendix A.

The model is closed by the equilibrium condition setting domestic milk production $Q^s(t)$ equal to total commercial demand, $Q^d(t)$, plus net commercial stocks, $S^c(t)$, net commercial exports, $S^e(t)$, net government removals, $R^g(t)$, and on-farm use, $R^f(t)$. $R^e(t)$ and $R^f(t)$ are taken as being exogenously determined in this model. Net government removals becomes the residual after market demands are subtracted from domestic production.

Model Estimation and Statistical Results

The estimated model parameters and their related statistics are reported in Table 1. The derived supply and demand elasticities are given in Table 2. The use of a stock of cows equation and a yield equation introduces nonlinearity into the model (Kelejian). To obtain consistent parameter estimates the model was estimated by nonlinear two stage least squares. All price and income data are in nominal dollars.

Data on milk production, dairy cow stocks, milk prices, feed prices, cull cow prices, milk demand, and commercial milk stocks were obtained from Dairy Outlook and Situation Report, USDA, ERS, April and December issues, 1980 to 1986. Data on wholesale price indexes for nonalcoholic beverages, non-dairy fats and oils, and meats, poultry and fish, were obtained from Food Consumption, Prices, and Expenditures, USDA, ERS SB #713. Data on gross returns to dairy and crops and nominal disposable personal income were obtained from Agricultural Statistics, annual issues 1979 to 1986.

Table 1: Econometric Model of the U.S. Dairy Economy: 1964 - 1983
Nonlinear Two Stage Least Squares

U.S. Dairy Capital Stock:

$$
\begin{array}{llllll}
C(t) = & 11596.42 & + 7.04 & * \{(1-\alpha(t-1))*P^m(t-1)+\alpha(t-1)*P^s(t-1)\} & & \\
 & (10.33) & (2.98) & & & \\
 & - 13.077 * P^g(t) & - 3.115 * & C(t-1) & + 61.28 * \sigma^r(t) & \\
 & (-3.25) & (-3.08) & & (3.66) &
\end{array}
$$

Adj. $R^2 = 0.78$ DW = 1.46 SEE = 681.1

U.S. Dairy Output per Cow:

$$
\begin{array}{lllll}
Y(t) = & 1.706 & + 0.794 * Y(t-1) & + 0.000797 & * \{(1-\alpha)*P^m(t-1)+\alpha*P^s(t-1)\} \\
 & (3.41) & (11.27) & (2.70) &
\end{array}
$$

Adj. $R^2 = 0.99$ DW "h" = -0.38 SEE = 0.135

U.S. Dairy Production:

$$Q^s(t) = C(t) * Y(t)$$

U.S. Total Milk Demand:

$$
\begin{array}{lllll}
Q^d(t) = & 118083.8 & - 63.25 * P^m(t) & + 24.05 * I(t) & + 148.73 * P^{sb}(t) \\
 & (41.80) & (-5.05) & (3.07) & (2.51)
\end{array}
$$

Adj. $R^2 = 0.80$ DW = 1.64 SEE = 2639.85

U.S. Commercial Stocks Demand:

$$
\begin{array}{lllll}
S^c(t) = & -501.68 & + 12.20 * P^m(t) & - 0.693 * S^c(t-1) & - 0.655 * S^c(t-2) \\
 & (-3.95) & (6.15) & (-5.66) & (-5.12)
\end{array}
$$

Adj. R2 = 0.76 DW "h" = 0.16 SEE = 384.68

U.S. Dairy Price Support Forecasting "Rule": 1964-83

$$P^s(t) = 1.0675 * P^s(t-1)$$

Adj. R2 = 0.98

-t-values are in parentheses, "h" is the Durbin test for serial correlation with lagged dependent variables.
-SEE is the standard error of the regression.

Table 2: Estimated Supply and Demand Elasticities

Elasticities derived from the Dairy Model:

SUPPLY:	$\mathcal{E}\{EP^m(t)\}$	$\sigma^r(t)$	$P^g(t)$
Q^s:	(0.55)	(0.054)	(-0.56)
DEMAND:	$P^m(t)$	$I(t)$	$P^{sb}(t)$
Q^d:	(-0.44)	(0.22)	(0.22)

Elasticities derived at the means of the variables.

This model provides a good statistical explanation of the variability in the domestic supply of and demand for milk in the U.S. market. The estimated parameters exhibit the expected signs and are statistically significant at the 0.05 level in one tailed tests.

The supply and demand elasticities measured at the mean values of the data are given in Table 2. The elasticities are calculated relative to total milk production and total milk demand. The estimated supply elasticity with respect to expected milk price is +0.55. Feed price elasticity is -0.56 and the risk elasticity is +0.054. These estimates seem reasonable in comparison to estimates reported in previous studies (e.g., Chavas and Klemme, and Chen, et.al., Thraen and Hammond).[6] The demand elasticities are also reasonable, with own price, cross price, and income elasticities calculated at -0.44, +0.22, and +0.22 respectively.

Effective Price Support Analysis

The evaluation of the impact of price-supports on prices, production and consumption under the LC/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 new policy rule, i.e., an explicit form for equation (3.7). 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 $\phi = 1.067$ from the data on price supports 1964-1983, 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.

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 Cs(t) or yield Y(t).

By adopting the LC/REH perspective we are constrained, when making hypothetical policy evaluation, to alter, in a logical fashion, both the support rule parameter, ie., 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 reasonably forecasts off 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 1964 and maintain it there through 1983?" 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 1964 through 1983?" To answer this question, we would select a value of Φ such that the price-support declined rapidly, for example, from 1964 onward. We would then use the invariant estimate of B to calculate a new parameter for P^S (t-1). Using this in the capital stock equation we would estimate a new level of capital stock in each year consistent with the new price-support rule.[7] As an example of the implications of the LC/REH and the AR(1,0,0) forecasting rule for the period 1964-1978, consider the estimated parameters on Φ. With this estimated AR(1) forecasting "rule" the implied structurally invariant parameter is:

$B = 7.04/1.0675 = 6.594$

Any other historical time path of price-supports implies a different rule, i.e., AR (1) parameter Φ and hence a different value of B. For example, in 1984 the U.S. Congress reversed a policy of ever rising support levels and initiated a policy of declining support levels. To evaluate the implications of policy shift the new parameter in the capital stock equation would become $B = 6.594 * 0.975$ or 6.425 assuming a policy which sets the price-support at 97.5 percent of the previous period value.

Conclusions

The concept of policy evaluation and rationally formed Muthian expectations constitutes a phenomenon which is both logically appealing and empirically tractable. Its appeal lies in the fact that the development of economic expectations is consistent with the econometric model being used for evaluation of policy.

The intent of this paper was to develop and explore the conceptual and econometric implications of LC/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 useful policy models in dairy and elsewhere, if the econometrician's 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 policy variable, the more intricate and complex the econometric model becomes. Clearly additional research is needed on questions which concern the manner in which optimizing economic agents form "models" of social and political phenomena as well as the more traditional questions of economics.

Notes

1. The term 'rational' is used throughout the paper because of the wide acceptance of the term to describe the expectation process as defined by Muth. However, the term 'model-consistent' is probably more appropriate and less psychologically loaded (Simon, 1978).

2. Wallis (1981) in an unpublished paper points out that these models can in fact be considered "rational" expectations if in fact the implied restriction on the parameter space are valid.

3. Fluid milk prices in the U.S. are controlled under federally administrated marketing orders. Under these orders, minimum milk prices are set according to the distance that the market is from a basing point. This price differential Θ is set as a function of the distance from the base market.

4. The greater the proportion of milk required to be removed from the market $\alpha(t)$, the greater the influence of the minimum price support in establishing the effective market price. This weighted price has the desirable property that as the support price declines and less milk is absorbed by the support system, the greater the reliance on the market clearing price.

5. The Divisia index is a continuous time statistical index number. The index used in this analysis is a discrete-time approximation to the continuous case. As a chain-linked index it provides one of the best methods for aggregating price series for different commodities. The price and quantity components of the index constructed for this study are: i) fats and oils (nondairy), ii) citrus and non-citrus fruit juices (chilled and concentrate), iii) coffee, iv) soft drinks, and v) red meats, poultry and fish. The interested reader should consult Layard and Walters, pp.156-159 for more detail on the construction of indexes and the appropriateness of the Divisia index.

6. The long run supply elasticity of market supply Q^s with respect to the expected effective market price $\mathcal{E}EP^m$ is approximately one-half of that reported in Thraen and Hammond. This is most likely due to the respecification of the cow stock equation and the definition of the effective market milk price.

7. 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, o= 0 is econometrically equivalent to setting $P^s_{t=1} = 0$ for all ti. Note that the question of policy evaluation with with this type of policy change is difficult to address because the implications of the REH become indistinguishable from that of the naive models.

8. Gross income includes both cash farm receipts and government payments in the form of net loans and deficiency payments in the case of crops.

9. The weight structure reflects the assumption that the most recent information has the greatest influence on decisions and that the past information is totally discounted after three periods. Actual lag weights were arrived at by trying various lag structures and selecting that structure which performed the best statistically.

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Appendix A

Empirical Measurement of Uncertainty

Traditionally stochastic elements are introduced into theoretical economic models by specifying one or more of the driving variables to be represented by a random variable. The random variable is assumed to be known up to the central moments of it's underlying distribution. The conceptual economic model introduces uncertainty in the form of the expected value, variance and covariance of output prices. Higher moments of the price distribution do not enter into the conceptual model because of the assumption that this variable is distributed normally. Typically, this randomness imparted to the first and second order conditions for optimal behavior by the stochastic price variable is termed 'risk'. There is little agreement as to the appropriateness of this equivalence between uncertainty and 'risk'. While variance is perceived as 'risk', researchers have adopted either a distributed lag formulation or an adaptation of a moving average standard deviation in either output prices or gross returns as an empirical measure of 'risk' in applied research (e.g. Thraen and Hammond, 1987)

The definition adopted in this study is that uncertainty or 'risk', in an empirical sense, can be proxied as the error in forecasting the level and direction of gross returns in the next period. It is assumed that producers form an expectation of the level of next periods returns based on a moving average formulation involving past information. The concept also reflects the idea that recent information carries more weight that past information. To the extent that the actual returns next period deviates from that which was expected 'risk' is incurred.

The 'risk' variable, $\sigma^d(t)$, for dairy returns is measured as a weighted three period moving variance of past gross dairy returns deflated by the average gross returns over the preceding three periods. Deflating by average gross returns expresses the variance relative to the level of average gross returns. Because we are working with aggregate market data and are assuming that dairy producers know their individual levels of production, gross income to dairying is used as the indicator of variance or 'risk' and not market price alone.[8] Specifically this 'risk' proxy $\sigma^d(t)$ for dairy is derived as:

$$\overline{DR}(t) = 1/3 \sum_{i=1}^{3} DR(t-i) \tag{1}$$

$$\sigma^d(t) = 1/\overline{DR}(t) \; \{ \sum_{i=1}^{3} (DR(t-i) - \overline{DR}(t-i))^2 * \omega_i)\}, \tag{2}$$

(3) ω_i, for i = 1,2,3 are 1/2, 1/3, and 1/6 respectively.

where DR(t) is the moving average of cash returns over the last three periods, DR(t-i) is the gross returns to dairy in the period (t-i), $\sigma^d(t)$ is the weighted moving average variance of gross returns to U.S. dairying, and ω_i are the weights for each period.[9] An equivalently defined 'risk' variable $\sigma^c(t)$ is derived for U.S. crops as the alternative economic activity.

In order to capture the relative variation of dairy to crop returns, the 'risk' variable specified in the estimated econometric model is defined as the ratio of $\sigma^c(t)$ to $\sigma^d(t)$:

(4) $$\sigma^r(t) = \sigma^c(t) / \sigma^d(t)$$

As can be seen from (2) and (4), an increase in $\sigma^r(t)$ can come about by either a reduction in the variance of dairy returns relative to crops or an increase in dairy returns relative to crops, ceterus paribus. Either type of change would be expected to increase United States dairy output as resources are shifted to milk production.