Regulation in a Dynamic Market: The U.S. Dairy Industry

Jeffrey T. LaFrance and Harry de Gorter

An econometric model of the U.S. dairy market is estimated for the period 1950–80. The economic costs of the dairy program for the period 1965–80 are calculated using *ex ante*, *ex post*, and long-run demand and supply functions. Results indicate that the costs of the dairy program averaged from 430 to 590 million 1980 dollars per year, depending upon the choice of economic surplus measure. The cost estimates depend only slightly on the year that the dairy program is assumed to have been terminated.

Key words: agricultural policy, dairy market, dynamic econometric models, economic surplus.

This paper presents an econometric analysis of U.S. federal dairy policies to estimate the annual economic costs of the joint marketing order and price support programs. The model focuses on the dynamic nature of demand and supply for farm milk over the period 1950–80 and on the costs of the dairy program over the period 1965–80. Three measures of the economic costs of the dairy program are developed and compared. The results obtained suggest that the dairy program has cost between \$430 and \$590 million per year in 1980 dollars. The costs of the dairy program are found to be dependent upon the choice of the economic surplus measure, but only slightly on the year in which it is assumed that the dairy program had been terminated.

The paper is organized as follows. Section two presents a dynamic econometric model of the U.S. dairy market. The third section develops the measures of economic costs associated with the *ex ante*, *ex post*, and long-run demand and supply functions, and presents and compares the measures of economic surplus and the direct government costs of the dairy program for the years 1965–80. The final section contains concluding remarks.

The Model

Though the federal dairy program has undergone several changes in its fifty-year history, the two basic aspects of federal controls are as follows: (*a*) in Grade A fresh fluid milk market areas with federal marketing orders, minimum prices for Class 1 (fresh fluid milk) and Class 2 (manufacturing milk) are set by an appointed U.S. Department of Agriculture (USDA) administrator; and (*b*) in the market for manufactured milk products, the farm price of Grade B milk and surplus Grade A milk is supported indirectly by Commodity Credit Corporation (CCC) purchases of butter, cheese, and nonfat dry milk at announced support prices and by government storage and disposal (through government sales and donations to domestic and foreign food aid programs) of government stocks of these products. There are normally no production controls, and Grade A producers do not directly receive either the Class 1 or Class 2 price but rather a uniform average "blend" price. The blend price is a weighted average of the Class 1 and Class 2 prices, with weights equal to the proportions of total milk sales in the market area that go into each class of use.

Local demand for fresh milk (hereafter Class 1 milk) is generally less price elastic than

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for manufacturing milk (hereafter Class 2 milk) largely because of the perishability and high transport costs of raw whole milk relative to manufactured products. This difference in price elasticities of demand for Class 1 and Class 2 milk is the basis for the classified pricing system of federal milk marketing orders. By raising the price of Class 1 milk relative to Class 2 milk, producers' incomes can be enhanced with a blend price that is higher than the competitive price because of the lower price elasticity of demand for Class 1 milk. Due to the efforts of the government to support both Class 1 and Class 2 farm milk prices without restrictions on milk production, private demand is less than supply. Therefore, government purchases of manufactured dairy products are necessary to clear the market.

These influences of the federal programs on farm-level milk prices suggest a convenient way to deal with the econometric problem of the simultaneous determination of market prices and quantities. The government sets the price support levels exogenously, but the price supports do not absolutely determine the market equilibrium because the CCC operations are at the wholesale level, not at the farm level. The actual Class 2 price seldom, if ever, equals the Class 2 support price because of the indirect nature of the CCC support operations, market conditions, measurement errors, and so forth. However, the actual Class 2 price should be closely related to the support price because of CCC support activities. This suggests that the predetermined and preannounced Class 2 support price should be a good instrumental variable for the actual Class 2 price for milk.

On the other hand, in federal marketing orders in the Grade A milk market, minimum Class 1 prices are aligned by transportation costs from Minnesota and Wisconsin (Ippolito and Masson) and determined by the Class 2 price plus a differential. Therefore, the Class 1 price should also be closely related to the Class 2 support price due to the price alignment in federal marketing orders and the strong influence of federal marketing orders on the Grade A milk market. This implies that the Class 2 support price is also a reasonable choice for an instrumental variable for the Class 1 price. That is, the federal support programs generate a means to deal with the simultaneity between prices and quantities demanded by introducing the exogenous Class 2 support price as an instrument for P_{1t} and P_{2t}, the average farm price for Class 1 and Class 2 milk in year t, respectively.

The per capita farm level demand equations for Class 1 and Class 2 milk consumption are

$$(1)\quad q_{1t} = \alpha_1 + \beta_{11}(P_{1t}/P_{NFt}) + \beta_{12}(P_{2t}/P_{NFt}) + \beta_{13}(P_{Bt}/P_{NFt}) + \beta_{14}AGE_t + \beta_{15}t + \delta_{11}q_{1t-1} + \epsilon_{1t},$$

$$(2)\quad q_{2t} = \alpha_2 + \beta_{12}(P_{1t}/P_{NFt}) + \beta_{22}(P_{2t}/P_{NFt}) + \beta_{23}(P_{FOt}/P_{NFt}) + \beta_{24}AGE_t + \beta_{25}t + \delta_{21}q_{2t-1} + \epsilon_{2t},$$

where q_{1t} and q_{2t} are per capita civilian consumption of Class 1 and Class 2 milk, respectively, P_{NFt} is the consumer price index (CPI, 1967 = 1.00) for nonfood items, P_{Bt} is the CPI for nondairy, nonalcoholic beverages, P_{FOt} is the CPI for fats and oils excluding butter, AGE_t is the average age of the U.S. population, t is a linear trend, and ϵ_{1t} and ϵ_{2t} are residuals. The CPI for nonfood items measures the cost of "other" goods; the CPI for beverages measures the cost of close substitutes for fluid milk; the CPI for fats and oils measures the cost of close substitutes for manufactured milk products.[1]

The basic reasons for a dynamic demand response for milk include uncertainty of future prices and incomes, habit formation and/or adjustment lags in consumption behavior, changing demographic characteristics of the population, and asset fixities and/or adjustment lags in the milk handling and processing sector. Some population effects are captured through the per capita specification, and some of the effects of the changing demographic makeup of the population through the average age variable. The linear trend is a proxy for smooth, systematic changes in the average margin received by the handling and processing sector.

In addition to private consumption of Class 1 and Class 2 milk, there are two other sources of removal of milk from the market, net government removals, NGR_t, and net commercial removals, NCR_t. Net government removals include net increases in government stocks, and foreign and domestic government sales

[1] It is assumed that the processing sector has a fixed coefficients technology, and each retail price for milk and milk products equals the farm price plus a margin. Income effects are constrained to zero because of the implied nonsubstitutability between Class 1 and Class 2 milk with nonzero income effects (LaFrance), and a statistical test of this hypothesis was not significant. The appearance of β_{12} in both demand equations indicates the symmetry condition for integrability and uniqueness of consumer's surplus measures.

and donations of manufactured dairy products. Net commercial removals include net increases in commercial stocks and net commercial export sales. Net government removals are set by the government in its efforts to obtain the Class 2 support price level and to clear the market for Class 2 milk. As government stocks increased 1950–80, commercially held stocks have declined. This suggests that government storage serves as a substitute for commercial storage. Also, net commercial exports are largely constrained at the margin by quotas.

Although net commercial removals constitute a very small share of the total disappearance of milk, it is desirable to obtain an instrumental variable predictor for NCR_t because of the definition of the average price of all milk,

$$(3)\quad P_t = [P_{1t}Q_{1t} + P_{2t}(Q_{2t} + NCR_t + NGR_t)]/(Q_{1t} + Q_{2t} + NCR_t + NGR_t),$$

where $Q_{1t} = q_{1t}POP_t$, $Q_{2t} = q_{2t}POP_t$, and POP_t is the U.S. population in year t. The equation that is employed for this purpose is[2]

$$(4)\quad NCR_t = \alpha_3 + \beta_{31}D_{66-80,t} + \beta_{32}D_{73-75,t} + \beta_{33}NGR_t + \delta_{31}NCR_{t-1} + \epsilon_{3t},$$

where $D_{66-80,t}$ is a dummy variable equal to zero in the years 1950–65 and one in the years 1966–80; $D_{73-75,t}$ is a dummy variable equal to one in the years 1973–75 and zero in all other years; NGR_t accounts for the gradual replacement of private storage with government storage; NCR_{t-1} accounts for the tendency for large (small) carryover stocks from the previous year to reduce (increase) growth in stocks this year, so that there will tend to be a negative correlation between net commercial removals in successive years. The dummy variables are structural change variables. The first one represents an apparent shift in commercial storage and export activity over the last half of the sample, while the second one represents the different structure of the market during the Nixon wage and price freeze, the OPEC oil embargo, and concurrent and subsequent disarray in the economy.

The demand equations (1) and (2) can be estimated consistently with two-stage least squares methods by utilizing the Class 2 support price and the dummy variable $D_{73-76,t}$ as instruments to predict P_{1t} and P_{2t}. As argued above, the period 1973–76 was significantly different in structure than the years prior to or after this period. The inclusion of the variable $D_{73-76,t}$ is a simple, parsimonious way of capturing this difference.

Once the demand equations have been estimated, a nonstochastic average farm price for all milk is defined by

$$(5)\quad \bar{P}_t \equiv [\hat{P}_{1t}\hat{Q}_{1t} + \hat{P}_{2t}(\hat{Q}_{2t} + \widehat{NCR}_t + NGR_t)]/ (\hat{Q}_{1t} + \hat{Q}_{2t} + \widehat{NCR}_t + NGR_t)$$

where ^ denotes the predicted values of the relevant variables. This price variable is a useful instrument for the average price of all milk defined in equation (3) and is used in the estimation of the supply of milk.

The milk supply model does not contain any short-run distinction between Grade A and Grade B milk producers. The interpretation of this approach is that the decision to switch from Grade B to Grade A production is an investment decision affecting mainly fixed inputs for the enhanced sanitary conditions and does not change the fundamental relationship between yield per cow and variable input use. As a result, the short-run marginal cost curve for Grade A farmers will be essentially the same as for Grade B farmers, even though total costs will be somewhat higher for Grade A producers.[3]

Total milk production is specified as the product of the stock of producing milk cows times yield per cow,

$$(6)\quad Q_{St} = C_t y_t$$

where Q_{St} is total milk supply, C_t is the stock of producing milk cows, and y_t is milk production per cow, each in year t. The yield-per-cow production function is specified as a quadratic function of grain and concentrated feed fed per cow, g_t, hay and other roughage fed per cow, h_t, and the quality of the typical dairy cow measured by the proportion of the total herd

[2] The net commercial removals model was estimated with separate price variables included for each of the periods 1950–80, 1966–80, and 1973–75. The joint influence of these price variables does not appear to be significant ($F_{3,20} = 1.46$). It is conjectured that import and export restrictions severely reduce any observable price response for net commercial removals.

[3] The differences in the costs of producing Grade A versus Grade B milk have been estimated to be as low as $0.15/cwt (Bartlett), although they could be as high as $0.50/cwt (Manchester). Use of a single supply function for milk has been criticized by Dahlgran (1981), but it will only result in a downward bias in the cost estimates since the costs of excess switching from Grade B to Grade A production are ignored. The bias should be small because developments in the sanitary regulation and in the handling of Grade B milk have greatly reduced the differences between Grade A and Grade B milk production.

that was on test in a dairy herd improvement association three years previously, $dhia_{t-3}$,[4]

(7) $$y_t = \alpha_4 + \beta_{41}dhia_{t-3} + \beta_{42}dhia_{t-3}^2 + \beta_{43}q_t + \beta_{44}dhia_{t-3}g_t + \beta_{45}h_t + \beta_{46}dhia_{t-3}h_t + \beta_{47}g_t^2 + \beta_{48}g_th_t + \beta_{49}h_t^2.$$

The most common feeding practice on dairy farms is to monitor the milk cow's concentrated feed ration and provide sufficient roughage for the animal to eat until full. This implies that the roughage intake of the typical dairy cow is related to the concentrated feed ration in a complementary manner. This complementarity is assumed to take the form

(8) $$h_t = \alpha_h + \beta_{h1}dhia_{t-3} + \beta_{h2}g_t.$$

The ability of the dairy farmer to substitute labor for cows or feed in the production of milk is extremely limited. Nevertheless, labor is an essential complementary input to the farming operation. In view of this, and the complementarity relationship (8) between roughage and concentrated feeds, it is assumed that labor per cow, l_t, satisfies the constraint

(9) $$l_t = \alpha_l + \beta_{l1}dhia_{t-3} + \beta_{l2}g_t.$$

For a given stock of milk cows, the representative dairy farmer is assumed to maximize net variable returns per cow

(10) $$\pi = P_ty_t - P_{gt}g_t - P_{ht}h_t - P_{lt}l_t$$

subject to (7)–(9), where P_{gt} is the price per hundred pounds for grain and concentrated feed, P_{ht} is the price per ton of hay, and P_{lt} is the farm wage. If dairy farmers are competitive price takers and the yield function (7) is strictly concave in (g_t,h_t), then upon adding a stochastic error term the optimal yield per cow equation is

(11) $$y_t = \alpha_y(t) - [\beta_y(t)^2/\theta_y] + [(P_{gt} + \beta_{h2}P_{ht} + \beta_{l2}P_{lt})^2/(\theta_yP_t^2)] + \epsilon_{4t},$$

where

$$\alpha_y(t) \equiv \alpha_4 + \alpha_h\beta_{45} + \alpha_h^2\beta_{49} + (\beta_{41} + \alpha_h\beta_{46} + \beta_{h1}\beta_{45} + 2\alpha_h\beta_{h1}\beta_{49})dhia_{t-3} + (\beta_{42} + \beta_{h1}\beta_{46} + \beta_{h1}^2\beta_{49})dhia_{t-3}^2,$$

$$\beta_y(t) \equiv \beta_{43} + \beta_{45}\beta_{h2} + \alpha_h\beta_{48} + 2\alpha_h\beta_{49}\beta_{h2} + (\beta_{44} + \beta_{46}\beta_{h2} + \beta_{48}\beta_{h1} + 2\beta_{49}\beta_{h1}\beta_{h2})dhia_{t-3},$$

and

$$\theta_y \equiv 4(\beta_{47} + \beta_{48}\beta_{h1} + \beta_{49}\beta_{h2}^2).$$

Therefore, y_t may be estimated as a function of an intercept, linear and quadratic terms in $dhia_{t-3}$, and a quadratic term in the composite input price $(P_{gt} + \beta_{h2}P_{ht} + \beta_{l2}P_{lt})/P_t$. Since the parameters β_{h2} and β_{l2} are unknown, they must be estimated simultaneously with the other parameters, and nonlinear estimation is required. Assuming that all prices are known to dairy farmers at the time of input decisions, that dairy farmers are competitive price takers, and that the small relative share of the dairy sector in the markets for grain and feed concentrates, hay and other roughage, and farm labor minimizes simultaneity problems with respect to yield per cow and these price variables, nonlinear two-stage least squares can be applied to (11) to deal with the simultaneity of P_t with y_t.

The milk cow herd response is an inventory adjustment equation with the real input prices, P_{gt}/P_t, P_{ht}/P_t, and P_{lt}/P_t, and the relative price of utility slaughter cows to the price of corn lagged one year, P_{UCt-1}/P_{Ct-1}, as explanatory variables. The real input prices for grain, hay, and labor are an indication of the profitability of milk production. The real price of utility slaughter cows provides a measure of the opportunity cost of keeping a milk cow in production versus culling for slaughter. The inventory response for the number of producing milk cows is specified as[5]

(12) $$C_t = \alpha_5 + \beta_{51}(P_{gt}/P_t) + \beta_{52}(P_{ht}/P_t) + \beta_{53}(P_{lt}/P_t) + \beta_{54}(P_{UCt-1}/P_{Ct-1}) + \delta_{51}C_{t-1} + \delta_{52}C_{t-2} + \delta_{53}C_{t-3} + \epsilon_{5t}.$$

The aggregate dairy herd constitutes less

[4] The specification of a quadratic yield production function for dairy cows has been used by Heady et al. (1960), Heady et al. (1964), and Hoover et al. Also, see Dahlgran (1981, pp. 6–7) for a summary and critique of these earlier studies.

[5] The third-order difference equation in cow numbers may be interpreted as a combination of adaptive expectations, partial adjustment, and capital depreciation. Let x_t denote the vector of real price variables plus a constant, θ the vector of slope parameters for these variables, and C^*_t the desired equilibrium number of producing milk cows. The adaptive expectations component may be written as

$$C^*_t = \theta' x_t/(1 - \Phi_1L),$$

where Φ_1 is the rate of geometric decline on the influence of past prices on expectations formation and L is the lag operator. The generalized partial adjustment/capital depreciation component may be written as

$$C_t - C_{t-1} = \Phi_2(C^*_t - C_{t-1}) + \Phi_3(C_{t-1} - C_{t-2}).$$

The coefficient Φ_2 is the partial adjustment parameter. The term $\Phi_3(C_{t-1} - C_{t-2})$ reflects the tendency for the herd size to be greater this year if there was an increase last year due to the addition of new heifers into the aggregate herd, or, conversely, their absence if the herd was reduced. The authors are thankful to Oscar Burt for this interpretation of the herd response equation.

than 10% of total cattle numbers in the United States. This factor, and the appearance of the lagged price of utility beef cows in (12) should minimize any simultaneity problems with C_t and the real price of utility cows. Therefore, consistent estimates of the parameters in (12) can be obtained with a two-stage least squares procedure to deal with the simultaneity of P_t with C_t.

Table 1 presents the estimated equations for the model of the dairy sector for the years 1950–80. The estimation procedure for the three price equations is ordinary least squares.[6] The estimation procedure for the per capita Class 1 demand equation is linear two-stage least squares. In all other equations, the estimation procedure is nonlinear two-stage least squares.[7]

Numbers in parentheses are asymptotic t-ratios in absolute value; R^2 is the coefficient of determination; $\bar{R}^2$ is the adjusted coefficient of determination, $d.f.$ is the number of degrees

[6] The estimated price equations are reported to permit the reader to judge the instrumental variables used for the two-stage estimation procedures. However, a structural interpretation need not be attached to these equations.

[7] The Class 1 demand equation appears to exhibit white noise residuals with the observed value of the lagged dependent variable as a right-hand-side regressor. Therefore, linear two-stage least squares is consistent for this equation. In the Class 2 demand, net commercial removals, and cows equations the residuals appear to exhibit serial correlation with the observed values of the lagged dependent variables included as right-hand-side regressors, and linear two-stage least squares is not consistent. In these equations the unconditional expectations of the lagged values of the dependent variables are estimated simultaneously with the model parameters using nonlinear least squares. See Burt for a detailed discussion of this method.

Table 1. Estimated Equations for the Dynamic Dairy Model

Per Capita Class I Demand

$$q_{1t} = .167 - .00287(P_{1t}/P_{NFt}) + .00852(P_{Bt}/P_{NFt}) - .00214t + .562q_{1t-1}$$
(3.21) (1.63) (2.83) (3.64) (4.53)

$R^2 = .994$, $\bar{R}^2 = .994$, d.f. = 25, D = 1.92 (Durbin's H = .303), s.e.e. = .0033, s.e.e./(mean dep. var.) = .011

Per Capita Class 2 Demand

$$q_{2t} = -.476 - .0150(P_{2t}/P_{NFt}) + .0286(P_{FOt}/P_{NFt}) - .000712t + .0179AGE_t + .793E(q_{2t-1})$$
(5.31) (4.62) (3.26) (2.31) (4.80) (12.7)

$R^2 = .975$, $\bar{R}^2 = .968$, d.f. = 23, D = 1.91, s.e.e. = .0046, s.e.e./(mean dep. var.) = .015

Net Commercial Removals

$$NCR_t = 5.01 - 3.35D_{66-80,t} - 1.55D_{73-75,t} - .187NGR_t - .447E(NCR_{t-1})$$
(8.28) (5.93) (2.70) (3.18) (3.57)

$R^2 = .818$, $\bar{R}^2 = .771$, d.f. = 24, D = 1.91, s.e.e. = .74, s.e.e./(mean dep. var.) = .48

Milk Production per Cow

$$y_t = 5.12 - 5.65(P_{gt} + .0250P_{ht} - 2.39P_{1t})^2/P_t^2 + 31.4dhia_{t-3} - 12.7dhia_{t-3}^2$$
(28.1) (4.34) (1.36) (5.95) (14.0) (1.86)

$R^2 = .999$, $\bar{R}^2 = .998$, d.f. = 22, D = 1.96, s.e.e. = .0724, s.e.e./(mean dep. var.) = .008

Stock of Producing Dairy Cows

$$C_t = 3.77 - (2.05P_{gt} - .136P_{ht} + 9.62P_{1t})/P_t + .0115(P_{UCt-1}/P_{Ct-1}) + 2.27E(C_{t-1}) - 1.96E(C_{t-2}) + .627E(C_{t-3})$$
(20.2) (3.05) (1.98) (15.1) (4.73) (44.8) (22.3) (14.7)

$R^2 = .9996$, $\bar{R}^2 = .9994$, d.f. = 18, D = 2.04, s.e.e. = .096, s.e.e./(mean dep. var.) = .006

Class 1 Milk Price

$$P_{1t} = 1.77 + .789D_{73-76,t} + 1.06P_{2t}^{sup}$$
(21.3) (6.79) (66.9)

$R^2 = .995$, $\bar{R}^2 = .994$, d.f. = 28, D = 1.50, s.e.e. = .207, s.e.e./(mean dep. var.) = .029

Class 2 Milk Price

$$P_{2t} = .077 + .514D_{73-76,t} + .997P_{2t}^{sup}$$
(1.04) (5.01) (71.2)

$R^2 = .995$, $\bar{R}^2 = .995$, d.f. = 28, D = 1.88, s.e.e. = .183, s.e.e./(mean dep. var.) = .036

Average Farm Price for All Milk

$$P_t = .00311 - .200D_{73-76,t} + 1.04\bar{P}_t$$
(.045) (2.36) (90.1)

$R^2 = .997$, $\bar{R}^2 = .997$, d.f. = 28, D = 1.96, s.e.e. = .072, s.e.e./(mean dep. var.) = .024

of freedom for the equation; D is the Durbin-Watson statistic for serial correlation, and *s.e.e.* is the standard error of the estimate. In the per capita Class 2 demand, net commercial removals, and cows equations, initial conditions parameters for the expected values of the dependent variable at the beginning of the sample were estimated simultaneously with the other parameters. Since these parameters are not of direct interest per se, they are not reported. However, in all cases the estimates of the initial conditions are within two standard errors of the actual values of the dependent variables for the relevant years.

The cross-price effect is constrained to zero in the demand equations. This restriction is imposed because the asymptotic t-ratio for the parameter β_{12} is 0.61 when the two demands are estimated jointly with the symmetry condition imposed. This result could be because of the high degree of collinearity between the Class 1 and Class 2 milk prices. It could also be because many people who can digest cheese cannot digest milk, so that the demands are independent. It is assumed that the demands are independent because this simplifies the analysis without changing the qualitative results.

Costs of the Dairy Program

This section contains results of a simulation of the dairy market for the years 1965–80 under the assumptions that the dairy program had not been active from 1953 on and that the resulting year-to-year equilibrium in the dairy market would be characterized by competition. Based on the prices and quantities that result from this simulation, three possible estimates for the annual costs of the dairy program over the period 1965–80 are presented and their respective strengths and weaknesses discussed. Intuitively, the differences between the measures of economic surplus that are considered result from the dynamic nature of the demand and supply functions estimated for the model of the dairy industry. When the quantity demanded (supplied) in year t depends on the quantity demanded (supplied) in previous years, the demand (supply) curve is a function of current and all past values of the prices and other explanatory variables. For example, iterating the difference equation for per capita Class 1 demand,

$$(13)\quad E(q_{1t}) = \sum_{j=0}^{\infty} \delta_{11}{}^{j}[\alpha_1 + \beta_{11}(P_{1t-j}/P_{NFt-j}) + \beta_{13}(P_{Bt-j}/P_{NFt-j}) + \beta_{15}(t-j)].$$

This dependence upon past prices creates some difficulty with respect to the measurement and interpretation of economic surplus. The source of the difficulty is the dependence of current, short-run demand and supply curves, hence preferences and production technologies, on previous prices and policies.

It is assumed that the marginal value of government purchases of manufactured dairy products for the purpose of domestic donations is the support price for each product. It is also assumed that the federal government will transfer the same dollar amount to the recipient groups in the event that the dairy support programs are terminated. This implies that those groups will be no worse off (in terms of their own preferences) if the dairy program were eliminated since actual income is in general preferred to income in kind. The direct costs of the government's operation of the dairy program are then defined by net CCC expenditures less domestic CCC donations valued at the support price for each donated commodity plus federal marketing order administration costs. Estimates of these direct costs and historical data on prices and quantities for the period 1965–80 are presented in table 2.

The year-to-year market-clearing equilibrium resulting from the elimination of the dairy program requires

$$(14)\quad Q_{1t}(P^*_t) + Q_{2t}(P^*_t) + NCR_t = Q_{St}(Q^*_t)$$

to determine the competitive price, P^*_t, where NCR_t is such that net government removals are equal to zero. The left-hand side of (14) is a linear function of P^*_t, while (6), (11), and (12) imply that the right-hand side of (14) is a third-order polynomial in $(1/P^*_t)$. A Newton-Raphson iteration, started by linearizing the supply function at the historical supply price for each year and solving for the linearized competitive equilibrium is used to solve (14). Table 3 presents the prices and quantities that the econometric model predicts would have occurred for the years 1965–80 under the assumptions that the dairy program had been eliminated in 1953 and that the decontrolled market would be characterized by competition.

Figure 1 pictures two short-run measures of

Table 2. Historical Prices, Quantities, and Net Government Costs of the Dairy Program

Year	Prices: Class 1	Class 2	Supply	Consumption: Class 1	Class 2	Production: Yield	Cows	Net CCC Exp.[a]	Dom. CCC Don.[b]	Admin. Costs[c]	Total Govt. Costs[d]
	($/cwt)			(lbs/person)		(lbs)	(10^6)	(10^6 $/calendar year)			
1965	5.22	3.34	4.23	303	302	8,305	14.95	268.4	117.4	19.9	170.9
1966	5.66	3.94	4.78	298	303	8,522	14.07	185.4	93.7	14.5	106.2
1967	6.07	4.06	5.02	286	280	8,851	13.42	356.0	116.9	15.6	209.7
1968	6.34	4.22	5.24	281	276	9,135	12.83	351.6	208.1	16.8	106.3
1969	6.63	4.45	5.49	273	273	9,434	12.31	287.2	196.1	17.4	108.5
1970	6.88	4.70	5.71	265	276	9,751	12.00	356.0	223.0	19.1	152.1
1971	7.08	4.86	5.87	260	276	10,015	11.84	373.3	215.7	21.3	178.9
1972	7.23	5.08	6.07	264	278	10,251	11.70	290.9	172.4	20.8	139.3
1973	8.18	6.20	7.14	260	278	10,119	11.41	123.9	106.5	20.2	37.6
1974	9.79	7.13	8.33	246	290	10,293	11.23	258.3	132.3	20.9	146.9
1975	10.10	7.62	8.75	246	288	10,360	11.14	273.9	94.1	21.7	201.5
1976	11.06	8.56	9.66	246	299	10,894	11.03	291.5	120.1	24.9	196.3
1977	11.07	8.70	9.72	243	293	11,206	10.95	611.5	209.5	24.0	426.0
1978	11.85	9.65	10.60	239	304	11,243	10.80	401.2	216.1	23.4	208.5
1979	13.22	11.10	12.00	238	311	11,488	10.74	507.9	267.3	23.8	264.4
1980	14.55	12.00	13.00	233	322	11,875	10.82	1453.5	404.5	25.2	1074.2

[a] CCC expenditures less sales of manufactured dairy products for the calendar year.
[b] CCC domestic donations of manufactured dairy products valued at the support price.
[c] Total federal marketing order assessments of products for administration costs.
[d] Net CCC expenditures plus marketing order administration costs less domestic donations.

economic surplus changes that could be used to estimate the annual costs of the dairy program: (*a*) the areas under the *ex ante* demand curves and above the *ex ante* supply curve, depicted in figure 1 as areas $CS_1^0 = A_1$, $CS_2^0 = A_2 + B_2$, and $PS_S^0 = A_S + B_S$; and (*b*) the areas under the *ex post* demand curves and above the *ex post* supply curve, depicted in figure 1 as areas $CS_1^N = A_1 + B_1$, $CS_2^N = A_2$, and $PS_S^N = A_S$. The development of the formal definitions of these measures focuses on the mean demand for Class 1 milk and expression (13) for this demand function. Arguments and derivations for the demand for Class 2 milk and the supply of milk are completely analogous and, hence, are omitted here. It is assumed throughout this discussion that $t = 1$ (e.g., 1953) is the first period that a change in policy

Table 3. Simulation of Competitive Equilibria, 1965–80

Year	Competitive Price	Consumption: Class 1	Class 2	Production: Yield/Cow	Milk Cows
	($/cwt)	(lbs/person)		(10^3 lbs)	(10^6 head)
1965	4.34	327	322	8.23	15.60
1966	3.90	314	308	8.46	14.48
1967	5.35	301	278	8.74	13.34
1968	4.88	293	265	9.23	12.23
1969	5.69	284	248	9.44	11.56
1970	5.40	279	244	9.72	11.14
1971	5.65	275	243	9.98	10.85
1972	5.98	269	242	10.19	10.59
1973	6.87	263	239	10.10	10.42
1974	8.25	256	241	10.81	10.37
1975	8.57	252	250	10.44	10.25
1976	9.12	248	254	10.92	10.04
1977	10.08	248	258	11.26	9.84
1978	11.26	245	261	11.36	9.86
1979	11.40	242	274	11.43	10.04
1980	11.40	239	291	11.80	10.11

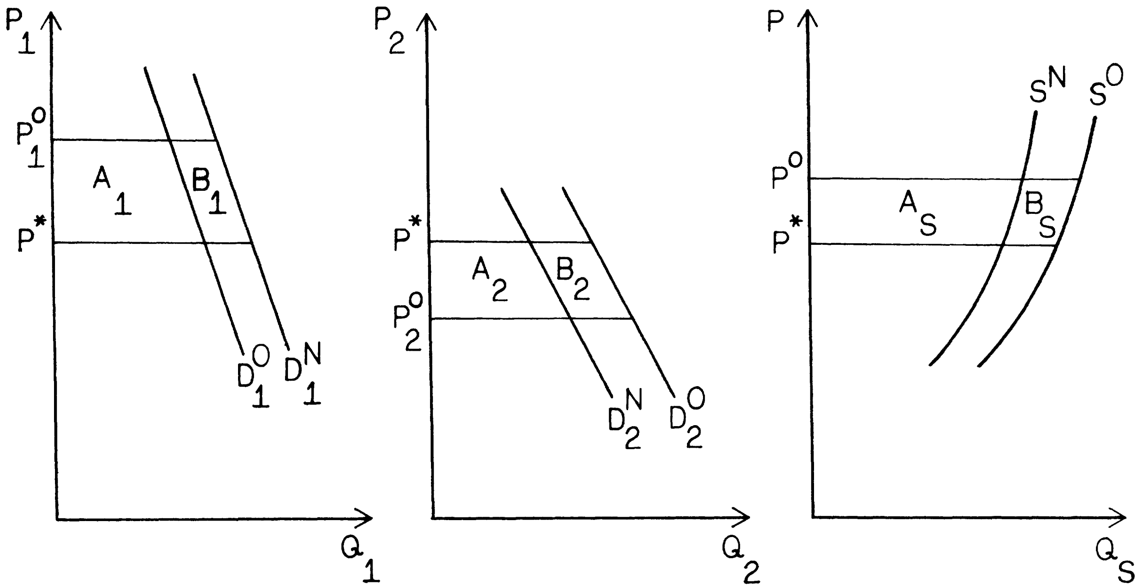

Figure 1. Short-run economic surplus gains and losses for the U.S. federal dairy program

to a competitive market occurs. The *ex ante* consumer's surplus is defined by the integral of (13) with respect to P_{1t} from P^*_t to $P_{1t}{}^o$, holding all past prices constant at the original levels under the historical dairy program,

$$(15)\ CS_{1t}{}^0 = \sum_{j=0}^{\infty} \delta_{11}{}^j[\alpha_1 + \beta_{11}(P_{1t-1-j}{}^o/P_{NFt-1-j}) + \beta_{13}(P_{Bt-j}/P_{NFt-j}) + \beta_{15}(t-j)](P_{1t}{}^o - P^*_t) + \frac{1}{2}\beta_{11}[(P_{1t}{}^o)^2 - (P^*_t)^2].$$

This measure of economic surplus gives a static, short-run estimate of the gains and losses from the dairy program at the *ex ante* levels of the demand and supply curves. That is, the demand and supply curves are presumed to be unchanged, as though the dairy program had been operating in all previous years. Alternatively, consumers and producers are presumed not to have adjusted over time to any previous price differences that resulted from competitive equilibria in order to calculate this measure of economic surplus. This estimate is not consistent with the simulation procedure, which presumes that the market is characterized by competition from 1953 through 1980. It is also inconsistent with the empirical model, which posits time lags in adjustment of quantities and/or price expectations on the part of consumers and producers. However, this estimate should be the most precise (in terms of size of the standard errors of the economic surplus estimates) because it is based upon the levels of the demand and supply functions associated with the actual data points for past prices and quantities.

The *ex post* consumer's surplus is defined by the integral of (13) with respect to P_{1t} from P^*_t to $P_{1t}{}^0$, with past prices $\{P_{11}, \ldots, P_{1t-1}\}$ constant at the levels for the competitive solution, $\{P^*_1, \ldots, P^*_{t-1}\}$,

$$(16)\ CS_{1t}{}^N = \left\{\sum_{j=0}^{t-1} \delta_{11}{}^j[\alpha_1 + \beta_{11}(P^*_{t-j-1}/P_{NFt-j-1}) + \beta_{13}(P_{Bt-j}/P_{NFt-j}) + \beta_{15}(t-j)] + \delta_{11}{}^t q_{10}\right\}(P_{1t}{}^0 - P^*_t) + \frac{1}{2}\beta_{11}[(P_{1t}{}^0)^2 - (P^*_t)^2].$$

This measure of economic surplus gives a static, short-run estimate of the gains and losses from the dairy program at the *ex post* levels of the demand and supply curves. That is, the demand and supply curves are presumed to be at the levels associated with competition, as though the dairy program had not been in operation in the previous years. This measure is consistent with the simulation procedure and at least partially accounts for the adjustments that would have been made by producers and consumers in response to changes in past prices through the inclusion of area B_1 for Class 1 demand and the exclusion of areas B_2 and B_S for Class 2 demand and supply, respectively. However, it is not associated with actual data for past milk prices and quantities but rather predicted values from previous stages of the iterative solution for the competitive equilibria, and it is likely to be less precise than the *ex ante* measure.

It is clear from table 3 that the competitive price is generally lower than the Class 1 and supply prices and higher than the Class 2 price from year to year. Under these conditions the sum of the *ex post* changes in economic surplus will be greater than the sum of the *ex ante* changes. This can be seen clearly in figure 1. When previous competitive prices satisfy this condition, the new Class 1 demand curve in the current period will be farther to the right than the old curve, while the new Class 2 demand and supply curves will be farther to the left than their old counterparts. Therefore, the *ex post* change in economic surplus will exceed the *ex ante* change by the sum of areas $B_1 + B_2 + B_S$.

Both the *ex ante* and *ex post* measures of economic surplus are dependent upon the market structure in previous years. That is, the short-run preferences of the representative consumer and the short-run technology of the representative dairy farmer are dependent upon the policies and price levels that were in existence in the past.

The long-run economic surplus measures depicted in figure 2 are defined in terms of the long-run mean demand and supply functions. For Class 1 milk the long-run per capita demand function satisfies the equation,

$$(17)\quad q_{1t}^{lr} = [\alpha_1 + \beta_{11}(P_{1t}/P_{NFt}) + \beta_{13}(P_{Bt}/P_{NFt}) + \beta_{15}t]/(1 - \delta_{11}).$$

From (17), it is clear that the long-run Class 1 demand function, and hence long-run preferences are not policy nor market structure dependent. A similar argument holds for the long-run Class 2 demand function and the long-run supply function. However, one implication of measuring economic surplus with long-run demand and supply functions is that the adjustment by consumers and producers to changing prices is presumed to be completed in the current period without any lags. This is inconsistent with the empirical specification of partial adjustment and/or adaptive price expectations in the econometric model. Nevertheless, the long-run measure is a useful way of overcoming the short-run dependence of dynamic demand and supply functions on past policies and the structure of the market. Also, if the competitive price is less than the Class 1 and supply price and above the Class 2 price from year to year (as is generally true for the model simulation in table 2) then figure 2 illustrates the property that the long-run measures will tend to lie between the *ex ante* and the *ex post* measures. Therefore, the long-run eco-

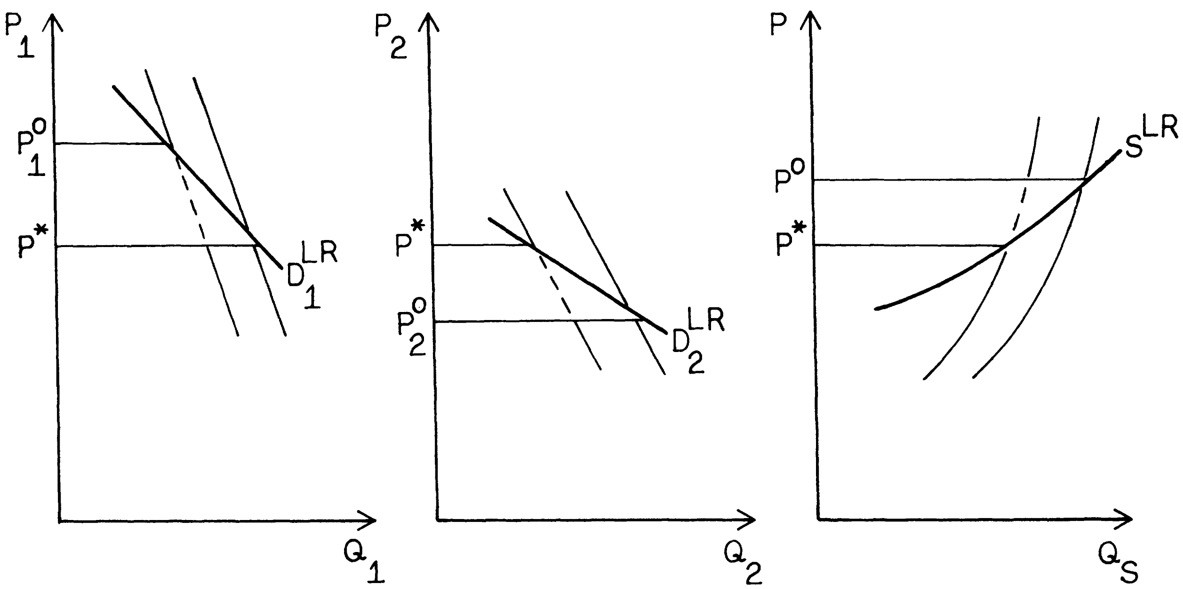

Figure 2. Long-run economic surplus gains and losses for the U.S. federal dairy program

nomic surplus represents a reasonable middle ground that can be used to judge the viability of the two short-run measures.

For the Class 1 milk demand function, the long-run consumer's surplus measure is defined as the integral of equation (17) with respect to P_{1t} from P^*_t to P_{1t}^0,

$$(18)\quad CS_{1t}^{lr} = \{[\alpha_1 + \beta_{13}P_{Bt}/P_{NFt} + \beta_{15}t](P_{1t}^o - P^*_t) + \frac{1}{2}\beta_{11}[(P_{1t}^o)^2 - (P^*_t)^2]\}/(1 - \delta_{11}).$$

The long-run surpluses for Class 2 demand and for supply are defined in an analogous way.

Table 4 presents the year-to-year estimates of the economic surplus changes for Class 1 and Class 2 consumers and for dairy producers resulting from a competitive equilibrium rather than the historical dairy support program and the sum of these surplus changes plus net government costs of operating the dairy program for the years 1965–80. With the exceptions of 1966 and 1979, the three measures of the economic costs of the dairy program for each year are similar, with the long-run estimate tending to fall between the *ex ante* and the *ex post* estimates.

The consumer price index (1967 = 1.00) is used to bring each year's estimates of the total changes in economic surplus plus the net government costs of the dairy program up to 1980 dollars. The resulting average annual cost estimates, in millions of 1980 dollars per year, are 430 for the *ex ante* measure, 590 for the *ex post* measure, and 560 for the long-run measure.

The estimated economic costs of the dairy program for the year 1980 are $1.4 billion. This is 8% of the total value of all milk produced in that year. The average annual cost to Class 1 consumers is from 1.9 to 2.0 billion 1980 dollars per year. The cost estimate of $1.7 billion in 1980 for Class 1 consumers represents 22% of total expenditures on Class 1 milk in that year. The average annual gain to Class 2 consumers is from 1.0 to 1.2 billion 1980 dollars per year.

The dairy program appears to be so far out of line with the competitive equilibrium in 1980 that even Class 2 consumers are worse off in that year under the dairy program than they might have been in a competitive scenario. The cost to Class 2 consumers of from 0.5 to 0.6 billion dollars represents slightly more than 19% of total expenditures on Class 2 milk in that year. Nevertheless, Class 2 consumers appear to have gained on average approximately 14% of the average annual expenditure on Class 2 milk from the dairy program 1965–80. The average annual gain to milk producers from the dairy program is from 0.5 to 0.6 billion 1980 dollars per year. The gain of from $1.9 to $2.0 billion in 1980 represents 11% of total farm receipts for milk in that year.

Table 4. Economic Surplus Changes 1965–80 from Eliminating the Dairy Program in 1953

	Class 1 Demand			Class 2 Demand			Supply			Total Economic Surplus + Net Government Costs		
Year	*Ex Ante*	*Ex Post*	Long-Run	*Ex Ante*	*Ex Post*	Long-Run	*Ex Ante*	*Ex Post*	Long-Run	*Ex Ante*	*Ex Post*	Long-Run
	($ millions per calendar year)											
1965	494	499	486	−595	−477	−515	171	177	125	242	370	268
1966	1,041	1,049	1,022	−83	−67	−75	−1,089	−1,173	−683	−25	−84	370
1967	380	384	369	−705	−580	−540	408	394	436	293	408	475
1968	776	785	761	−331	−266	−284	−426	−423	−351	125	203	232
1969	347	352	340	−733	−597	−614	432	393	410	155	257	245
1970	683	694	677	−425	−341	−394	−209	−194	−156	202	311	278
1971	705	721	701	−412	−336	−392	−175	−162	−133	297	402	354
1972	757	776	751	−367	−303	−347	−342	−317	−305	188	295	238
1973	777	790	760	−502	−422	−465	−220	−201	−211	93	205	122
1974	551	555	535	−793	−672	−797	288	256	243	183	284	129
1975	978	993	962	−359	−303	−372	−603	−568	−525	217	323	266
1976	1,043	1,060	1,032	−302	−260	−294	−719	−667	−685	219	328	249
1977	557	563	560	−768	−676	−786	337	299	283	552	612	483
1978	267	270	265	−1,176	−1,035	−1,209	900	807	897	200	251	162
1979	902	912	890	−455	−397	−484	−714	−683	−789	−3	96	−118
1980	1,709	1,728	1,687	567	505	613	−1,926	−1,859	−1,988	1,425	1,448	1,386

Summary and Conclusions

All of the measures considered in this study suggest strongly that the economic costs of the dairy program have averaged over 400 million 1980 dollars per year during the period 1965 to 1980, and these costs appear to be more than triple that amount for the year 1980.

There is some reason to believe that the results obtained in this study are fairly robust. First, they compare reasonably well with several other attempts to estimate the economic costs of government regulation of milk (see, e.g., Buxton, Buxton and Hammond, Dahlgren 1980, Heien, and Ippolito and Masson). Second, the simulation of the dynamic path of competitive equilibria appears to result in a very stable long-run equilibrium. In an effort to consider the sensitivity of the results with respect to the date of elimination of the dairy program, the dynamic competitive equilibrium path was obtained under the assumption that the dairy program had been terminated at the beginning of each year from 1953 to 1965. Each of the dynamic simulations starting in the years 1953 to 1965 results in virtually the same competitive price (within \$0.01/cwt) for each year from 1974 to 1980, and prices that are nearly equal for each of the years from 1965 to 1973. Consequently, the quantities consumed and produced under the competitive scenario are also stable over this period, and the estimates of the costs of the dairy program are only slightly sensitive to the date that we assume that the dairy program was terminated. The 1953 starting date for the competitive simulation is reported here because it generates the smallest estimates of the economic costs of the dairy program.

This paper has not dealt with some interesting aspects of the dairy market. For example, the simulated competitive prices appear to see-saw up and down over the period 1965–71, suggesting a short-run cobweb type instability in the dairy market. If consumers and/or producers are risk averse, then the stabilizing effects of the price support programs could mitigate the negative effects on the gains from trade somewhat, and a model that incorporated risk attitudes of producers and consumers explicitly would be useful in dealing with this question.

A further question of interest is the relationship between profitability of the dairy industry and the rate of participation in dairy herd improvement activities. If dairy herd improvement association participation rates are positively related to rates of return in the dairy market, then the resulting outward shift in the supply curve from additional research and development could lead to some beneficial outcomes from the dairy programs. The analysis of this question would call for a model of technological adoption among dairy farmers and the resulting influence on productivity of dairy cows.

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