Regional Adjustment Response in the U.S. Dairy Sector to Changes in Milk Support Price

Alfons Weersink and Wayne Howard

Milk production supply response at the regional level for the U.S. dairy sector is estimated through the use of dynamic dual models. Adjustment rates and elasticity measures are presented, and then the estimated parameter coefficients are used to stimulate shifts in production resulting from price changes. A drop in milk price designed to realign market conditions is projected to be borne largely by the Corn Belt and, to a lesser extent, the western states.

Key words: dynamic duality, milk support price.

The present U.S. government program for the dairy sector changes the value of the milk support price level based on the projected relationship between national milk supply and demand. In the case of predicted purchases by the Commodity Credit Corporation (CCC) of greater than 5 billion pounds, the support price is lowered by 50¢ per hundred weight (cwt.). CCC purchases of less than 2.5 billion pounds would prompt an increase in the support price of 50¢ per cwt. The support price remains unchanged if the surplus is predicted to be within this range.

A decrease in the support price of milk is expected to prompt an adjustment in the quantities supplied and demanded. However, a cut in milk price likely would not result in equal cuts of milk production across all regions. Instead, the desired reduction in quantities supplied would be achieved largely at the expense of regions with a relatively elastic supply function. Given the importance of dairy farming to certain regions of the country, changes in the pattern of regional production could have significant impacts on the viability of the agricultural sector in these regions. The net result of support price changes based on market conditions and differing regional adjustment responses could be large shifts in the regional production levels of the U.S. dairy sector. For example, if projected CCC purchases are greater than 5 billion pounds, then the subsequent lowering of the support price by 50¢ may reduce supply significantly in only several regions. However, this cutback may be sufficient so that no further changes in milk price are necessary which means most of the adjustment is borne by those several regions.

The purpose of this article is to examine milk production response relationships at the regional level for the U.S. dairy sector. These relationships are estimated through the use of dynamic duality models in order to account for the intertemporal linkages in a theoretically consistent manner. Adjustment rates and elasticity measures are presented, and then the estimates of the parameter coefficients are used in a simulation process to determine shifts in production structure resulting from price changes.

Methodology

The basis for the dynamic optimization models used recently in agricultural applications by

The authors are assistant professors in the Department of Agricultural Economics and Business, University of Guelph.

They thank three anonymous reviewers for their helpful comments.

Western Journal of Agricultural Economics, 15(1): 13–21

Howard and Shumway (1988 and 1989); Vasavada and Ball; and Vasavada and Chambers is the specification of a production function which includes investments as an argument,

$$(1) \qquad Y = F(X, Z, I, T),$$

where Y is the maximum output produced from combining the vector of m variable inputs, X, and the vector of n quasi-fixed inputs, Z, which are fixed in the short run according to the technology $F(\cdot)$. Gross investment, I, in the quasi-fixed inputs acts to reduce output because resources are used to change the stock of Z rather than to produce output. While investment is assumed to inversely affect production ($F_I < 0$), the increased stock level of Z resulting from investment serves to enhance ouput ($F_Z > 0$). A time trend, T, is included in the production function to represent disembodied technical change.

The presence of adjustment costs in the production function transforms a firm's static optimization problem into one where it is concerned with maximizing the present value of net receipts over time. Assuming static price expectations, this infinite horizon, nonautonomous problem can be written as:

$$(2) \qquad J(P, W, R, Z_0, t_0) = e^{-rt} V(P, W, R, Z_0, t_0)$$

$$V(P, W, R, Z_0, t_0) \equiv$$

$$\underset{X(t),\, I(t)}{\text{Maximize}} \int_{t_0}^{\infty} e^{-rt}\{PF(X, Z, I, t_0) - WX - RZ\}\, dt$$

$$\text{subject to } \dot{Z} = I - \delta Z$$

$$X(t), I(t) > 0,\ Z(0) = Z_0,$$

where $V(\cdot)$ is the optimal value function representing the discounted future stream of rents accruing to the quasi-fixed inputs at time t_0; r is the required rate of return; P is the price of output Y; W is a $(1 \times m)$ vector of prices for the variable inputs, X; R is the $(1 \times n)$ vector of rental prices for the quasi-fixed factors, Z; δ is the depreciation rate; and $\dot{Z}$ is net investment in Z.

The assumption of static price expectations implies that all relevant information is contained within the current price. Static price expectations for the dairy sector suggest that the firm expects the CCC's projections of surplus dairy products to remain within the range of 2.5 to 5 billion pounds. Since the government is adjusting price to lower surpluses to an acceptable limit and thus maintain a constant price level, it is not unrealistic to assume stable price expectations at the firm level. If prices do change from period to period, the firm will revise its expectations and resolve the optimization problem given by (2). Hence price expectations are static for a production period but subject to revision in subsequent production periods. Reasons why a firm that maximizes its value intertemporally may rationally choose to formulate expectations in this manner are discussed by Chambers and Lopez.

Although the assumption of static price expectations for milk may be realistic in the dairy sector, it can be argued that other price expectation models may be more appropriate especially with regard to prices other than milk. Karp, Fawson, and Shumway employ three different price expectations in a dynamic dual model. Their conclusions regarding various hypotheses about the adjustment matrix for the quasi-fixed inputs is the same under a static, perfect foresight, or adaptive price expectations model. However, the estimated elasticity measures do differ under the alternative assumptions on price. The relative robustness of their results under the alternative price expectations plus the simplification of the empirical estimation with static price expectations must be weighed against any loss in realism the assumptions impose. The final decision here on employing static price expectations was thus based on empirical tractability.

In contrast, expectations regarding technology are not static but instead are assumed to continuously evolve over time as indicated by T in the production function. The expectation of disembodied technical change implies the value function, $V(\cdot)$, is an explicit function of initial time, t_0.

For the value function to attain the required maximum in any period, it must satisfy the following Bellman equation (Kamien and Schwartz, p. 241):

$$(3) \qquad rV(P, W, R, Z_0, t_0) = \underset{X(t),\, I(t) > 0}{\text{Maximize}} \{P \cdot F(X, Z, I, T) - WX - RZ + V_Z \dot{Z} + V_{t_0}\},$$

where V_Z is the derivative of the value function with respect to the quasi-fixed input, which is also known as the shadow price of Z, and V_{t_0} is the partial of the value function with respect to time. The current value function now is defined as the maximum discounted value of current profits, plus the marginal benefit of an optimal adjustment in net investment, plus the marginal value of technical change in period t_0.

The Bellman equation transforms the dynamic optimization problem of (2) into a static form and in the process serves as a link between the production function and value function. Epstein has shown that a full dynamic duality exists between these two functions under certain regularity properties. The significance of the duality relationship is that it permits one to derive output supply and input demand equations without imposing restrictive assumptions on the firm's technology. Explicit solution of the behavioral equations for the intertemporal optimization problem is difficult without duality theory and generally involves a system of second-order nonlinear differential equations and nontrivial boundary solutions. However, equation (3) allows one to determine the following output supply (4), variable input demand (5), and net investment in the quasi-fixed inputs (6) equations directly through application of the dynamic analogue of Hotelling's lemma to the Bellman equation:

$$(4) \quad F(P, W, R, Z_0, t_0) = rV_P - V_{PZ}\dot{Z} - V_{Pt_0},$$

$$(5) \quad X(P, W, R, Z_0, t_0) = rV_W + V_{WZ}\dot{Z} + V_{Wt_0},$$

and

$$(6) \quad \dot{Z}(P, W, R, Z_0, t_0) = V_{RZ}^{-1}(rV + Z - V_{Rt_0}).$$

The parameters of the value function can be inferred from these equations to determine if the value function possesses the properties necessary to establish the duality relationship with the firm's technology. However, it should be emphasized that the duality relationship between the production function and the value function depends critically on the assumptions outlined, especially those regarding price expectations. Taylor has shown that a stochastic dynamic analogue of Hotelling's lemma does not hold if price expectations have a Markovian structure. In such a case, current and future prices are variables rather than parameters, and, consequently, equations (4), (5), and (6) will include a term to reflect the impact of price changes on expected future returns (Taylor).

Estimation Procedure

The first step in empirically determining the output supply and input demand equations through dynamic duality is to specify the functional form of the value function. Given the results of Howard and Shumway (1989) who compared alternative functional forms in an application to the aggregate U.S. dairy industry, a modified generalized Leontief (GL) (Vasavada and Chambers) is chosen which is linearly homogeneous in prices:

$$(7) \quad V(P, W, R, Z, t_0) = [PW]AZ + R'B^{-1}Z + [P^{.5}W^{.5}]CR^{.5} + R^{.5\prime}DR^{.5} + [P^{.5}W^{.5}]E[P^{.5}W^{.5}]' + t_0\, G[PWR]',$$

where P is the average blend price of milk, W is the price of feed concentrate, R is a (2×1) vector and includes the rental price of the quasi-fixed input milk cows (Rc) and the wage rate of farm labor (R_L), and Z is a (2×1) vector of the quasi-fixed inputs milk cows (Zc) and labor (Z_L).[1] A, B^{-1}, C, D, and E are conformable parameter matrices, and G is a (4×1) parameter vector. The actual form of the milk supply (8), feed demand (9), cow demand (10), and labor demand (11) equations using the GL functional form arcs are: (see p. 16)

The GL form of the value function is specified so that V_Z is linear in prices. This specification allows the necessary curvature properties of the production technology to be verified by the convexity of the value function without having to examine the third-order properties of the value function. Concavity of the quasi-fixed inputs is imposed by the GL form and cannot be examined. Convexity requires the parameters of the C matrix plus D_{CL}, D_{LC}, E_{MF}, and E_{FM} to be negative. Symmetry restrictions also can be imposed on the model such that $D_{CL} = D_{LC}$, and $E_{MF} = E_{FM}$. Monotonicity is tested after estimation by determin-

[1] Several reviewers questioned the model's specification. Costs of seed, fertilizer, machinery, and other operating costs as well as other quasi-fixed inputs such as land and buildings were not included in the model. Data limitations necessitated severe simplification of the model. However, misspecification due to simplification is held constant across the regions. Modeling labor as a quasi-fixed input also was questioned, but justification for this initial assumption has been provided by Gallaway and by Maddox. One feature of the dynamic dual model used in this study is that it allows one to test the degree of fixity of an input rather than to assume that an input is fixed or variable.

ing if $V_Z > 0$ when $I > 0$ ($V_Z < 0$ when $I < 0$); and $V_P > 0$; and V_W, $V_R < 0$.

Provided the value function satisfies the above properties, duality theory can be used to generate the producer core equations. However, the theory is based on micro-level optimizing behavior, and this study examines regional response rates through aggregate data rather than individual firm decisions. In order for the micro theory to be applied at the macro level, the value function must be specified so that it depends only on the aggregate stock of cows and labor in each region and not on their distribution across firms (Chambers and Lopez). The linear aggregation over firms to the aggregate level implies

$$V(P, W, R, Z, t_0) = \sum_i V(P, W, R, Z_i, t_0) \text{ and } Z = \sum_i Z_i,$$

where i represents the number of firms in a region. Theoretically consistent aggregation requires the aggregate value function to be affine in Z which means $V_{zz} = 0$. The GL form in (7) incorporates this restriction. However, empirical aggregation problems still may exist.

Equations (4), (5), and (6) represent the milk supply and input demand equations which form the producer core to be estimated. However, before the model can be estimated, several modifications are necessary. First, additive error terms assumed to be independently and identically distributed with a mean of zero are appended to each equation to reflect errors in measurement and optimization. The error term accounts for unobserved variables and/or variables not included in the simplified three-input model. Secondly, a discrete approximation of net investment is used so that $\dot{Z} = Z_t - Z_{t-1}$. Thirdly, the required real rate of return (r) is set at .03. Finally, milk price is lagged one period to proxy price expectations when production decisions are made.

Data

The data necessary for computation of the producer core equations involve prices and quantities for milk and the three inputs: feed, cows, and labor. Regional data on all these variables were not available so annual data for each of the 48 contiguous states from 1950 to 1986 were aggregated based on the 10 farm production regions as defined by the U.S. Department of Agriculture (USDA). The aggregation involved either averaging with weights based on

(8)
$$F(P, W, R, Z, t) = A_{MC}[(r + 1)Z_C^{t-1} - Z_C^t] + A_{ML}[(r + 1)Z_L^{t-1} - Z_L^t] + G_{TM}(rt - 1) + C_{MC}\left(\frac{r}{2}\right)\left(\frac{R_C}{P}\right)^{.5} + C_{ML}\left(\frac{r}{2}\right)\left(\frac{R_L}{P}\right)^{.5} + E_{MM}r + E_{MF}r\left(\frac{W}{P}\right)^{.5},$$

(9)
$$X(P, W, R, Z, t) = A_{FC}[Z_C^t - (r + 1)Z_C^{t-1}] + A_{FL}[Z_L^t - (r + 1)Z_L^{t-1}] - G_{TF}(rt - 1) - C_{FC}\left(\frac{r}{2}\right)\left(\frac{R_C}{W}\right)^{.5} - C_{FL}\left(\frac{r}{2}\right)\left(\frac{R_L}{W}\right)^{.5} - E_{FF}r - E_{FM}r\left(\frac{P}{W}\right)^{.5},$$

(10)
$$\dot{Z}_C(P, W, R, Z, t) = (r + B_{CC})Z_C^{t-1} + B_{CL}Z_L^{t-1} + [B_{CC}G_{TC} + B_{CL}G_{TL}](rt - 1) + \frac{r}{2}\left\{B_{CC}\left[C_{MC}\left(\frac{P}{R_C}\right)^{.5} + C_{FC}\left(\frac{W}{R_C}\right)^{.5}\right] + B_{CL}\left[C_{ML}\left(\frac{P}{R_L}\right)^{.5} + C_{FL}\left(\frac{W}{R_L}\right)^{.5}\right] + 2B_{CC}\left[D_{CC} + D_{CL}\left(\frac{R_L}{R_C}\right)^{.5}\right] + 2B_{CL}\left[D_{LL} + D_{LC}\left(\frac{R_C}{R_L}\right)^{.5}\right]\right\},$$

and

(11)
$$\dot{Z}_L(P, W, R, Z, t) = (r + B_{LL})Z_L^{t-1} + B_{LC}Z_C^{t-1} + [B_{LC}G_{TC} + B_{LL}G_{TL}](rt - 1) + \frac{r}{2}\left\{B_{LL}\left[C_{ML}\left(\frac{P}{R_L}\right)^{.5} + C_{FL}\left(\frac{W}{R_L}\right)^{.5}\right] + B_{LC}\left[C_{MC}\left(\frac{P}{R_C}\right)^{.5} + C_{FC}\left(\frac{W}{R_C}\right)^{.5}\right] + 2B_{LL}\left[D_{LL} + D_{LC}\left(\frac{R_C}{R_L}\right)^{.5}\right] + 2B_{LC}\left[D_{CC} + D_{CL}\left(\frac{R_L}{R_C}\right)^{.5}\right]\right\}.$$

milk production shares for the price variables or summing state totals for the quantity variables.

The price of milk for each state was estimated by the average blend price, and the quantity of milk supplied was measured by the combined marketings of milk and cream. Both variables were obtained from *Milk: Production, Disposition and Income* (USDA) and *Dairy Summary Statistics* (USDA). The amount of feed concentrate fed per cow and its value were from *Milk Production* (USDA). The rental price of milk cows represents the services provided by the asset during the year. It was computed by amortizing over a three-year period the cash purchase price for dairy cows obtained from *Agricultural Prices* (USDA). The discount rate used in amortizing cow price was the average interest rate on agricultural loans outstanding and was obtained from *Agricultural Statistics* (USDA).[2] The interest rate data were available by production region only, so average regional cow price first was calculated from state prices and then the regional rental price was determined using the described amortization procedure. The number of milk cows was provided by *Milk: Production, Disposition and Income.* The wage rate was estimated by the wages paid to all farm hired labor obtained from *Agricultural Statistics.* There was not sufficient information for all states through the 35-year time frame to derive a wage rate exclusively for the dairy sector. A proxy for the quantity of labor used was the number of hours required for milk cows which was provided by *Economic Indicators of the Farm Sector: Production and Efficiency Statistics* (USDA).

The data were not adjusted for quality since a consistent quality index was not available on a regional basis. Adjustment rates likely are overstated. However, the primary objective of the research was to examine regional differences in production responses. Assuming the quality indices would be similar across regions, the relative changes between regions in terms of milk supply would not be altered from the present results.

[2] A weighted average cost of capital would be the appropriate measure of the subjective rate of time preference if cow purchases were not assumed to be debt financed (Abel and Blanchard). The average interest rate used to amortize cow prices is distinct from the subjective real rate of time preference, *r*, which was used in the optimization procedure.

Results

The milk supply (8), feed demand (9), investment in milk cows (10), and labor (11) equations were estimated for each of the 10 production regions. The equations were first estimated with no restrictions on the parameters and then reestimated with symmetry imposed on the value function ($D_{CL} = D_{LC}$, $E_{MF} = E_{FM}$). The symmetry assumption was accepted for all regions using the Gallant-Jorgenson test statistic, T^0, which is an asymptotically distributed chi-squared test with the degrees of freedom equal to the number of restrictions.

The theoretical consistency of the dynamic dual model was evaluated by examining the regularity conditions of the value function. Convexity in prices was imposed by restricting the parameters D_{CL}, E_{MF}, and the elements of the matrix C to be negative. Convexity was rejected for all regions, however, convexity in prices was obtained if the unrestricted parameter estimates of concern were adjusted by one standard deviation.

The applicability of a univariate flexible accelerator then was tested by restricting $B_{CL} = B_{LC} = 0$. Such a restriction implies that net investment for each of the two quasi-fixed inputs does not depend on the stock level of the other input in the period. The assumption of independent adjustment rates was rejected. Instantaneous adjustment by cows, $B_{CC} = -1$ and $B_{CL} = 0$, and by labor, $B_{LC} = -1$ and $B_{CL} = 0$, also was rejected.

The accepted form of the model in all regions thus imposed only symmetry on the parameters.[3] Although not presented due to the number of parameters (22) and regions (10), approximately 65% of the estimated coefficients were significant at the 5% level for each region. Monotonicity was accepted for all but a few observations, since the partial derivation of the value function with respect to the quasi-fixed inputs was positive when investment was

[3] A reviewer was concerned about nonconvexity of the final model. Since the primary objective of this model was to project regional production responses, the lack of convexity was not considered sufficient to stop the study. There may be several reasons for nonconvexity, e.g., firms not optimizers, aggregation bias, wrong price expectations, but choice of functional form is an unlikely source of nonconvexity. Earlier estimation using a normalized quadratic yielded parameter estimates that rejected convexity, but the estimates were within one standard deviation of the convexity requirements.

Table 1. Regional Adjustment Rates in U.S. Dairy Sector

Region	Adjustment Rates[a] Milk Cows	Labor
Northeast	−.277 (.035)	−.036 (.011)
Lake States	−.282 (.053)	−.052 (.038)
Corn Belt	−.128 (.042)	−.060 (.022)
Northern Plains	−.172 (.053)	−.020 (.007)
Appalachian	−.069 (.066)	−.077 (.065)
Southeast	−.262 (.064)	−.025 (.013)
Delta States	−.141 (.265)	−.083 (.157)
Southern Plains	−.095 (.016)	−.043 (.059)
Mountain	−.188 (.032)	−.071 (.015)
Pacific	−.198 (.045)	−.040 (.010)

[a] Standard errors in parentheses.

positive. In addition, the estimated long-run equilibrium values for the quasi-fixed inputs were positive at all points indicating the existence of unique steady-state values for these variables. These equilibrium values will be stable given the stability of the adjustment matrix, *B*.

Significance generally was attained for the main diagonal elements of the *B* matrix which were used to calculate the adjustment rates presented in table 1.[4] The rates for milk cows ($B_{11} + r$) are highest in the traditional milk-producing regions of the Lake States (−.282) and Northeast (−.277), and slowest in the Appalachian region (−.069). The 9% value obtained by Howard and Shumway (1988) is close to the adjustment rates for the southern regions. However, the average across all 10 regions is more than double their value implying that full adjustment of milk cows to long-run optimum values will occur in approximately five years.

The adjustment rates for labor are within a smaller range than that exhibited by milk cows and do not display any clear regional tendencies. The average rate across all regions indicates that labor adjusts 4% of the way towards its equilibrium value in one year. This is close to the 7% value estimated by Vasavada and Chambers for total agricultural labor but much less than the 40% adjustment response given for dairy labor in Howard and Shumway (1988). Gunter and Vasavada disaggregated farm labor into family/operator, seasonal hired, and full-time hired labor. Their results indicated that both types of hired labor adjusted more rapidly than family labor. Similar results were obtained by Lopez. Thus, the use of aggregate labor data in this study does not distinguish possible differences in the adjustment response of various types of labor.

The responsiveness of regional milk supply to price changes is presented in table 2.[5] The own-price elasticity for milk is largest in the Corn Belt. A possible reason may be the availability of alternative farm enterprises. The relative attractiveness of these alternatives would increase with a drop in milk price leading to a proportionately large reduction in milk supply. The western regions of the Mountain and Pacific states have the next highest own-price elasticities for milk.

The responsiveness of milk supply for the remaining seven regions declines consistent with the region's ranking of national market share. The smaller regions based on ranking of market share may tend to have a more inelastic supply response since their production is generally just sufficient to meet their regional fluid milk requirements which varies little over time. The exception is the Lake States region which produces the largest percentage of national supply (28%) but has one of the most inelastic supply responses. This may be due to the lack of economic alternatives within and outside of the agricultural sector for the areas of the Lake States region where production is concentrated.

The Le Chatelier principle (Silberberg) is satisfied in all situations since the long-run elasticity is larger in absolute terms than its short-run counterpart. Although not evident

[4] The adjustment rates in the *B* matrix are assumed to be symmetric with regard to upward or downward changes in prices. Chang and Stefanou examined the effect of asymmetric adjustment on supply and factor demand.

[5] Rosen considered the effect of transitory and permanent shocks on supply response and showed that the sign and magnitude of the supply change depend on the type of stock.

here, dynamic models permit the possibility of negative own-price output supply elasticities in the short run due to the inclusion in the production function of quasi-fixed input investment. In the long run, net investment is zero as the quasi-fixed inputs reach their equilibrium value. Thus, milk own-price elasticities must be positive in the long run under the assumption of profit maximization.

A change in feed price has an inverse effect on milk supply in all regions except Appalachia and the Northern Plains. However, the measures are very inelastic and becoming more so over time. Similar values are obtained for cow price elasticities, and these are again negative except for Appalachia and the Mountain and Pacific regions. The result for the latter two areas may be explained by the large increase in cow numbers which has occurred in these regions over the last 20 years. Production has increased as a result and so has cow price due to the expansion in demand for milk cows by forces not adequately captured by the model. The direction of response also may be due to the incorporation of expected profits within the rental price of cows.

The cross-price elasticity of milk supply with respect to the wage rate varies across regions in a pattern similar to own-price elasticity. Except for the Corn Belt, an increase in the wage rate has the largest inverse effect in the western regions due to their well-established labor markets for the dairy sector (Putnam and Nowak). The elasticities given in table 2 are calculated for 1985 but measures obtained for earlier years indicate response is becoming more inelastic over time. The result is consistent with the concentration of production within each region as well as between them.

The effect of a change in milk price is reported in table 3 for milk supply and production shares and in table 4 for milk cows. The simulation process used the estimated parameter coefficients from the regression procedure. The first column of both tables contains actual 1986 values. The predictions in both tables are based on 1986 prices. The model appears to be able to forecast well given the low percentage error between the predicted and actual values.

Given the model's ability in an *ex post* forecast, an *ex ante* simulation was conducted in which each region's milk price was reduced an additional 50¢ per cwt. and then $1 per cwt. from the 1986 values. The 50-cent increment coincides with the possible change in support price under the present adjustment mechanism in the dairy price support program. The simulation procedure involved simultaneously determining the level of the quasi-fixed inputs and milk supply since the former are part of the production function for milk.

Table 3 shows that a reduction in milk price would be borne largely by the regions with the most elastic own-price supply elasticity. The largest absolute fall in quantity of milk supplied is in the Corn Belt even though it is only the fourth-largest producing region in the country. The result is an approximate .2% drop in national market share for each 50-cent decline in milk price. The Corn Belt's share of national milk supply fell from 21% in 1950 to approximately 12% in 1985, and the projected

Table 2. Regional Milk Supply Elasticities in U.S. Dairy Sector, 1985

	Elasticity with Respect to Price of			
Region	Milk	Feed	Milk Cows	Labor
Northeast				
Short Run	.314	−.012	−.033	−.269
Long Run	.324	−.017	−.033	−.274
Lake States				
Short Run	.174	−.015	−.027	−.131
Long Run	.258	−.008	−.042	−.209
Corn Belt				
Short Run	.639	−.023	−.003	−.613
Long Run	.664	−.024	−.032	−.672
Northern Plains				
Short Run	.243	.027	−.069	−.202
Long Run	.276	.030	−.084	−.221
Appalachian				
Short Run	.257	.009	.007	−.274
Long Run	.292	.009	.012	−.312
Southeast				
Short Run	.132	−.002	−.074	−.056
Long Run	.145	−.006	−.075	−.064
Delta States				
Short Run	.118	−.037	−.047	−.034
Long Run	.188	−.060	−.058	−.070
Southern Plains				
Short Run	.217	−.030	−.053	−.134
Long Run	.229	−.033	−.056	−.140
Mountain				
Short Run	.435	−.076	.106	−.465
Long Run	.482	−.082	.117	−.517
Pacific				
Short Run	.413	−.018	.056	−.450
Long Run	.419	−.014	.059	−.464

Table 3. Regional Effects on Milk Supply from a Drop in Milk Price

Region	Actual 1986 Milk Supply (mill. lbs.)	Actual 1986 Production Share (%)	Predicted 1986 Production Share (%)	% Error	50¢ Drop in Milk Price		$1 Drop in Milk Price	
					Production Share (%)	Supply Reduction (mill. lbs.)	Production Share (%)	Supply Reduction (mill. lbs.)
Northeast	28,835	20.14	21.41	6.34	21.50	305	21.59	629
Lake States	40,518	28.30	27.02	−4.52	27.17	326	27.33	671
Corn Belt	16,941	11.83	11.92	0.79	11.71	504	11.48	1,042
Northern Plains	5,447	3.80	3.84	0.89	3.85	60	3.86	126
Appalachian	8,769	6.12	6.23	1.67	6.25	93	6.27	192
Southeast	4,511	3.15	3.41	8.20	3.44	22	3.48	44
Delta States	2,483	1.73	1.92	10.69	1.94	13	1.96	26
Southern Plains	5,279	3.69	3.66	−0.79	3.70	11	3.75	24
Mountain	7,937	5.54	5.17	−6.68	5.13	158	5.08	325
Pacific	22,473	15.69	15.42	−1.74	15.32	428	15.21	884
Total	143,193	100.00	100.00		100.00	1,920	100.00	3,963

decline represents a continuation of this downward trend. The Mountain and Pacific regions also lose national market share due to the price decline but not to the same extent as the Corn Belt. Their shares fall by approximately .1% for each 50-cent drop in milk price. The absolute level of the reduction in milk supply from these three regions allows the other seven regions to increase market share despite their decline in actual milk supply. The relative increase is greatest for the Appalachians, the Southeast, the Delta states, and the Southern Plains which are smaller producing regions who largely supply just for their own fluid milk demand.

The total decline in milk supply is 1.9 and 4 billion pounds under the 50-cent and one-dollar price reduction scenarios, respectively. The present government policy is to reduce the support price by 50¢ if projected CCC purchases are greater than 5 billion pounds. These results indicate that under the present policy, a surplus greater than 7 billion pounds will not be lowered below the 5-billion-pound trigger level within a year. Either more time or a price drop larger than 50¢ will be required to realign market conditions.

Table 4 contains projected cow numbers under the two price scenarios. Total herd size falls slightly with the extent of the decline consistent with the earlier adjustment rates. The relative decline in cow numbers is smaller than that of milk supply leading to a drop in milk production per cow. The result implies that variable input use will be altered before changes in the capital stock are made.

Conclusions

Adjustments in the dairy support price are now based on projected market relationships rather than on a parity concept. The trigger mecha-

Table 4. Regional Effects on Cow Numbers (000s) from a Drop in Milk Price

Region	Actual 1986 Milk Cows	Predicted 1986 Milk Cows	% Error	50¢ Drop in Milk Price	$1 Drop in Milk Price
Northeast	2,185	2,155	−1.4	2,149	2,143
Lake States	3,123	3,096	−0.9	3,081	3,066
Corn Belt	1,367	1,357	−0.8	1,344	1,331
Northern Plains	472	461	−1.9	456	451
Appalachian	743	749	0.9	746	743
Southeast	379	371	−2.1	371	370
Delta States	243	260	7.3	259	258
Southern Plains	434	428	−1.3	428	427
Mountain	534	529	−0.9	527	525
Pacific	1,338	1,334	−0.3	1,330	1,327
Total	10,818	10,740	−1.4	10,691	10,641

nism means that short-run changes in milk supply likely will be the catalyst to alter prices given the relatively inelastic demand for dairy products. This article has shown that desired reductions in milk supply are borne largely by regions with a relatively elastic supply function. The decline in production is especially significant in the Corn Belt region where other farming alternatives exist. The Corn Belt also experiences the largest percentage decline in cow numbers, but the drop in herd size is small in absolute terms across all regions under both price scenarios. In contrast to the decline exhibited by the Corn Belt, Mountain, and Pacific regions, the Lake States are able to increase market share during a price decline due to their slow adjustment response which is due partially to limited alternatives. Milk production also falls by a relatively small amount in the smaller producing regions especially in the southern parts of the country. Their fluid demand cannot be supplied by other regions under present technology and policies and the result is the inelastic supply response noted for the smaller producing regions. Consideration of new technologies and policy modifications which could increase productivity at the farm level and alter fluid market conditions likely would have significant impacts on the results, especially in the western states which have a higher return on investment in the dairy sector.

[*Received April 1989; final revision received October 1989.*]

References

Abel, A. B., and O. J. Blanchard. "The Present Value of Profits and Cyclical Movements in Investment." *Econometrica* 54(1986):249–73.

Chambers, R. G., and R. E. Lopez. "A General, Dynamic, Supply-Response Model." *N. East. J. Agr. and Resour. Econ.* 13(1984):142–54.

Chang, C., and S. Stefanou. "Supply, Factor Demand and Asymmetric Adjustment." Selected paper presented at the Amer. Agr. Econ. Assoc. annual meeting, Knoxville TN, August 1988.

Epstein, L. "Duality Theory and Functional Forms for Dynamic Factor Demands." *Rev. Econ. Stud.* 48(1981):81–95.

Gallant, A. R., and D. W. Jorgenson. "Statistical Inference for a System of Simultaneous, Nonlinear, Implicit Equations in the Context of Instrumental Variable Estimation." *J. Econometrics* 11(1979):275–302.

Gallaway, L. E. "Mobility of Hired Agricultural Labor: 1957–60." *J. Farm Econ.* 49(1967):32–52.

Gunter, L., and U. Vasavada. "Dynamic Labour Demand Schedules." *Appl. Econ.* 20(1988):803–12.

Howard, W. H., and C. R. Shumway. "Dynamic Adjustment in the U.S. Dairy Industry." *Amer. J. Agr. Econ.* 70(1988):837–47.

———. "Non-Robustness of Dynamic Duality Models." *N. East. J. Agr. and Resour. Econ.* 18(1989):18–25.

Kamien, M. L., and N. L. Schwartz. *Dynamic Optimization: The Calculus of Variations and Optimal Control in Economics and Management.* Amsterdam/North Holland: Elsevier, 1981.

Karp, L. S., C. Fawson, and C. R. Shumway. "Impact of Expectation Formation on Dynamic Investment Decisions: An Application to U.S. Agriculture." Work. Pap. No. 343, California Agricultural Experiment Station, Giannini Foundation of Agricultural Economics, March 1985.

Lopez, R. E. "Estimating Substitution and Expansion Effects Using a Profit Function Framework." *Amer. J. Agr. Econ.* 66(1984):358–67.

Maddox, J. G. "Private and Social Costs of the Movement of People Out of Agriculture." *Amer. Econ. Rev.* 50(May 1960):392–402.

Putnam, J. N., and R. J. Nowak. *Dairy Farming in the Northeast: Trends for the Future.* Springfield MA: Federal Intermediate Credit Bank of Springfield, 1984.

Rosen, S. "Dynamic Animal Economics." *Amer. J. Agr. Econ.* 69(1987):547–57.

Silberberg, E. *The Structure of Economics.* New York: McGraw-Hill, 1978.

Taylor, C. R. "Stochastic Dynamic Duality: Theory and Empirical Applicability." *Amer. J. Agr. Econ.* 66(1984):351–57.

U.S. Department of Agriculture. *Agricultural Prices.* Washington DC. Various issues.

———. *Agricultural Statistics.* Washington DC. Various issues.

———. *Dairy Summary Statistics.* Washington DC. Various issues.

———. *Economic Indicators of the Farm Sector: Production and Efficiency Statistics.* Econ. Res. Serv., Washington DC. Various issues.

———. *Milk Production.* Statist. Rep. Serv., Washington DC. Various issues.

———. *Milk: Production, Disposition, and Income.* Statist. Rep. Serv., Washington DC. Various issues.

Vasavada, U., and V. E. Ball. "A Dynamic Adjustment Model for U.S. Agriculture: 1948–79." *Agr. Econ.* 2(1988):123–38.

Vasavada, U., and R. G. Chambers. "Investment in U.S. Agriculture." *Amer. J. Agr. Econ.* 68(1986):950–60.