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POLICY IMPACTS ON THE PRODUCTION STRUCTURE OF DAIRY FARMS IN THE 1980S

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Introduction

As in most developed countries, the dairy industry in the U. S. has been highly regulated. Government policies were designed to guarantee a regular and sanitary supply of milk to the consumer, and stable, adequate incomes to the producer. While these policies have achieved some of their goals, they have also been very costly to the treasury and taxpayer, and in addition have inefficiencies (Quiroga, Bravo-Ureta) which have led to higher consumer prices and a competitive disadvantage in the export market. Concern about these issues has generated many studies pertaining to the dairy industry's cost and production structure. On the policy level, many measures have been considered to alleviate unwanted effects and some of them have been implemented in recent years. In the light of the policy reorientation, it is appropriate to take a disaggregated look at structural aspects of dairy production so as to provide a framework in assessing the potential regional effects of policy changes.

Previous studies have used different conceptual frameworks. However, very few recent studies have analyzed the production structure of dairy farms across the whole country. Buxton, McGuckin, Selley, and Willett (1985) measured the profitability of typical farms in Minnesota, Washington, Arizona, and New Mexico, using an intuitive approach. Cilley and Blakley employed a single equation methodology in analyzing a data set that represents dairy farms from 25 states. Hammond (1974) and Buxton (1985) used regressions on production functions to estimate supply and demand elasticities for various states and aggregated the results by region.

The objective of this article is to analyze the dairy structure of the major milk producing regions of the U. S. and the impact of recent policy changes using duality theory. Duality theory offers a methodology that does not require the restrictive assumptions of previous studies, and can provide more theoretically-consistent results, which should be of great value to policy makers. Several aspects of production were analyzed to allow an interregional comparison and general conclusions regarding the production structure and the resulting adjustment behavior.

This paper reports portions of a more extensive study. Specifically, it presents and analyzes estimates of

1. short-run own-price elasticities of supply for the output milk;

2. returns to size; and

3. shadow prices for the aggregated quasi-fixed factor 'capital' and for fixed inputs other than capital.

Since government policies were considered to have had an influence on regional disparities, the regional effect of the dairy assessment, which was introduced in 1983, was captured through a special estimation procedure. The estimates indicate, how the assessment affected variable profits (revenues - cost of variable factors) on a regional level.

The following methodology section will outline the approach, present the functional form,

and the estimation formulas. In addition, it will provide a brief description of the data base chosen. Selected regional results will be presented in the next section, which will be followed by their implications for regional development and policy decisions.

Methodology and Data Description

It was hypothesized that due to variation in natural, historical, economical, and political factors, significant differences exist in the production structure of different regions across the U.S. The hypothesis was tested through a log-likelihood-ratio test and accepted ($\chi^2 = 567.2$). This finding implies that a national production function describing the U.S. dairy industry as a whole is incorrectly specified. Hence, a regional approach was taken using binary variables to distinguish between regions.

The aggregate dairy production in the U.S.A. can be described by a transformation function

$$F\ (Y, X, Z) \ = \ 0, \tag{1}$$

where F = transformation function,
Y = vector of outputs,
X = vector of variable inputs, and
Z = vector of quasi-fixed inputs and other exogenous variables.

The transformation function F relates all outputs Y with the chosen levels of variable inputs X, given resource constraints, as represented by the quasi-fixed inputs. Duality theory has established the relationship between transformation functions and profit functions that allows using a profit function of certain characteristics in place of the transformation function. The regularity conditions of duality theory require that the profit function be finite, nonnegative, real valued, continuous, smooth, monotonic, convex in prices, twice differentiable, bounded, and linear homogeneous in all prices (McFadden,1978).

This study employed a restricted translog variable profit function:

$$
\begin{aligned}
ln\,\pi^* \;=\; & \alpha_0 + \sum_{s=1}^{5} \alpha_s D_s + \sum_{i=1}^{2} \beta_i \, ln\, P_i^* \\
& + \sum_{j=1}^{3} \chi_j \, ln\, R_j^* + \sum_{z=1}^{2} \delta_z \, ln\, Z_z + \tau T \\
& + \frac{1}{2} \sum_{i=1}^{2}\sum_{h=1}^{2} \beta_{ih} \, ln\, P_i^* \; ln\, P_h^* + \sum_{j=1}^{3}\sum_{k=1}^{3} \chi_{jk} \, ln\, R_j^* \; ln\, R_k^* \\
& + \sum_{z=1}^{2}\sum_{t=1}^{2} \delta_{zt} \, ln\, Z_z \, ln\, Z_t + \sum_{i=1}^{2}\sum_{j=1}^{3} \epsilon_{ij} \, ln\, P_i^* \; ln\, R_j^* \\
& + \sum_{i=1}^{2}\sum_{z=1}^{2} \phi_{iz} \, ln\, P_i^* \; ln\, Z_z + \sum_{i=1}^{2}\sum_{s=1}^{5} \gamma_{ig} \, ln\, P_i^* \, D_s \\
& + \sum_{i=1}^{2} \mu_i \, ln\, P_i^* \, T + \sum_{j=1}^{3}\sum_{z=1}^{2} \eta_{jz} \, ln\, R_j^* \; ln\, Z_z \\
& + \sum_{j=1}^{3}\sum_{s=1}^{5} \psi_{js} \, ln\, R_j^* \, D_s + \sum_{j=1}^{3} \nu_j \, ln\, R_n^* \, T \\
& + \sum_{z=1}^{2} \varsigma_z \, ln\, Z_z \, T + \sum_{z=1}^{2}\sum_{s=1}^{5} \kappa_{zs} \, ln\, Z_z \, D_s + \sum_{s=1}^{5} \omega_s \, T D_s .
\end{aligned}
\tag{2}
$$

where π^* = normalized expected variable profits (= revenues - cost of variable factors),

D_s = binary variable indicating the region,

P_i^* = vector of normalized output prices,

R_j^* = vector of normalized input prices,

Z_z = vector of quantities of quasi-fixed inputs and other exogenous variables,

T = binary variable referring to the dairy assessment,

ln = the natural logarithm.

The translogarithmic functional form was originally proposed in the late 1950s by Halter, Carter, and Hocking. It was developed in this specific form by Christensen, Jorgenson and Lau. This form has the advantage that – by the envelope theorem (Beattie and Taylor: 227.) – the first derivatives of the profit function (2) with respect to the normalized product and factor prices represent the product supply and input demand share equations. The share equations are linear in

the logarithms of normalized prices and quantities of fixed inputs. This feature increases the ease of empirical estimation of the model. The input and output share equations were derived employing Hotelling's Lemma:

$$\frac{\delta \ln \pi^*}{\delta \ln P_i^*} = \beta_i + \beta_{ii} \ln P_i^* + \beta_{ij} \ln P_j^* + \sum_{j=1}^{3} \epsilon_{ij} \ln R_r^* + \sum_{z=1}^{2} \phi_{iz} \ln Z_z + \mu_i T \tag{3}$$

$$+ \sum_{s=1}^{5} \gamma_i D_s$$

$$\frac{\delta \ln \pi^*}{\delta \ln R^*_i} = \chi_j + \chi_{jj} \ln R_j^* + \chi_{jk} \ln R_j^* + \chi_{jr} R_r^* + \sum_{i=1}^{2} \epsilon_{ij} \ln P_i^* \tag{4}$$

$$+ \sum_{z=1}^{2} \eta_{jz} \ln Z_z + \nu_j T + \sum_{s=1}^{5} \psi_{js} D_s$$

Since, by Young's Theorem, (Beattie and Taylor: 122.) a cross-partial derivative is invariant with respect to the order of differentiation, symmetry between the interaction parameters was imposed. This property also reduced the number of parameters to be estimated. Fifteen symmetry restrictions were imposed on the coefficients: $\beta_{ij}=\beta_{ji}, \chi_{jk}=\chi_{kj}, \epsilon_{ij}=\epsilon_{ji}, \phi_{iz}=\phi_{zi}$.

To assure linear homogeneity of the profit function, both the profit function (2) and the share equations (3 and 4), were normalized, using one of the variable inputs, hired labor, as a numeraire. Imposing linear homogeneity, the share equation for the numeraire variable was dropped in the estimation procedure to avoid singularity in the variance-covariance matrix.

The following variables were included in the profit function: variable profits, milk and livestock prices, factor prices for concentrate, roughage, hired labor, and 'miscellaneous inputs'; and the total expenditures for capital and for other quasi-fixed inputs, such as land, family and operator labor, and general farm overhead. These represented the major input costs and output revenues on a specialized dairy farm.[1] In addition to the regular variables, six binary variables were incorporated into the model. A binary variable was also used to account for the introduction of the dairy assessment in 1983; the others were to distinguish between six regions coinciding with to the USDA's regional delineation.[2]

The system of one profit and five share equations were estimated simultaneously using Zellner's Iterative Seemingly Unrelated Regression method which is equivalent to the maximum likelihood procedure and ensures that the parameter estimates are invariant to the numeraire variable selected. The resulting 89 parameters – of which 45 were significant at the .10 level (a one-tailed t-test) – and the predicted shares were used to calculate elasticity and returns to size estimates, as well as shadow prices.

The <u>own-price supply elasticity</u>, was estimated as

$$E_{ii} = \beta_{ii} \cdot \frac{1}{SP_i} + SP_i - 1 . \tag{5}$$

The returns to size measures were obtained by using the formula

$$RTSZ = \frac{\sum_{i=1}^{n} \frac{R_i X_i}{\pi}}{\sum_{j=1}^{m} \frac{P_j Y_j}{\pi}} \tag{6}$$

Then, regional estimates were calculated using regional weights.

The shadow prices λ_l for the fixed factors Z_l can be obtained by using the formula

$$\lambda_l = \frac{\delta \ln \pi}{\delta Z_l} \cdot \frac{\hat{\pi}}{Z_l}$$

Weighted regional shadow prices were estimated for two quasi-fixed factors: Capital, consisting of machinery and equipment capital and livestock capital, and an aggregate of land, family and operator labor and general farm overhead.

The binary variable accounting for the dairy assessment was set to zero for the years 1981 and 1982, and to one for 1983, 1984 and 1985, the years, when the farmers were subjected to the assessment. Due to this procedure, the implementation of the assessment in 1983 to 1985 will shift the position of the profit function, as well as the position of the share equation. More specific calculations were done in order to gain some insights into the actual impact and the regional effect of the dairy assessment. First, the derivative of the dairy assessment variable, called 'T', was taken with respect to variable profits π^*:

$$\begin{aligned} r = \frac{\delta \pi^*}{\delta T} = \lambda &+ \mu_1 \ln P_1^* + \mu_2 \ln P_2^* + \nu_1 \ln R_1^* + \\ &\nu_2 \ln R_2^* + \nu_3 \ln R_3^* + \theta_1 \ln Z_1 + \theta_2 \ln Z_2 + \\ &\omega_1 D_1 + \omega_2 D_2 + \omega_3 D_3 + \omega_4 D_4 + \omega_5 D_5 \end{aligned} \tag{7}$$

The result, called 'r', represented the rate of change in profits given a change in the dairy assessment. Yearly estimates were obtained by calculating the means of the values for 'r' for each region and each year. These regional values can be interpreted as measures of the regional impact of the assessment.

The data set consisted of pooled cross-sectional time series data that was derived from the Firm Enterprise Data System (FEDS), a data base in budget form that is compiled annually by the Economic Research Service/USDA. The data set contained information on representative farms for twenty states for the time period from 1981 through 1985. This information was aggregated into nine variables for the use in our model.

Empirical Results

The own-price elasticity of the milk supply, as well as supply elasticities for livestock demand elasticities for concentrate feed, varied significantly across the U.S. (table 1). The extreme values are found in the Upper Midwest (-0.29 in 1981 and 1982) and in the Southern Plains (0.88 in 1984). The negatives estimates for the Upper Midwest region reveal a response behavior that farmers themselves might not be aware of. The negative elasticities imply that farmers decrease their milk supply at rising prices and increase it when prices decline. Thus, they do not display rational profit-maximizing behavior. The values for the Northeast and the Corn Belt range between roughly 0 and 0.21 and indicate an inelastic short-run response in milk production with respect to milk price changes. In these traditional milk-producing regions, few profitable alternatives to dairy farming can be found. This, together with a diversified family farm structure, might contribute to a minimal response to milk price changes. In addition, a farming structure that relies heavily on family labor and on feed produced on the farm does not seem to allow for quick and significant adjustments in milk production in the case of a milk price change.

A very different picture emerges when analyzing the elasticity estimates for the Southern Plains and the Pacific region. Values between 0.67 (1982) and 0.88 (1984) for the Southern Plains and between 0.57 (1982) and 0.73 (1985) for the Pacific region show a much less inelastic production response to milk price changes. This behavior reflects a very different production structure: In contrast to the Upper Midwest family-farms, for example, the Southern and Western farms show greater commercialization. Operating on a much larger scale with average herd sizes above 125 head (Buxton: 5.), they are highly mechanized and appear capable of reacting to price changes in a similar fashion as other farm enterprises not saddled with a preponderance of fixed assets. Appalachia takes on an intermediate position between the regions mentioned so far. Though the milk supply response in Appalachia is still inelastic with values ranging between 0.51 (1982) and 0.64 (1984), the sensitivity to price changes is much higher in Appalachia than in the traditional Northern and Central dairy regions.

In general, a tendency over time to increasing price elasticities for milk can be observed for all, but the Appalachia region. Hence, U. S. dairy farms in most regions have become more responsive to milk price changes in the first half of the 1980s. This development was not continuous, though: while the estimates for 1981 and 1982 actually indicate a decline in responsiveness in the early 1980s, this tendency is reversed in 1983. An explanation for this response change may lie in the implementation of the dairy assessment in 1983. By reducing the milk price received by farmers, the assessment might have induced farmers either not to replace resources or to take resources out of milk production. Thus, it appears that this policy measure, signaling to farmers the departure from the traditional price supports, was met by increasing adjustments. Interestingly, for the year 1985, in the first part of which the assessment ran out, the responsiveness declined again, especially in the Appalachia region. Hence, our results indicate that programs which are designed to control the milk supply through lowering of the support price will have regionally different effectiveness in reducing output.

The returns to size estimates (table 2) indicate that farmers across the U.S. have been operating in the increasing portion of their respective long-run average cost curves, at decreasing return to size. Thus, they have been producing inefficiently by producing more than would be optimal according to their respective cost structures. The degree to which farms overproduce varies significantly between regions. The farmers in the Upper Midwest were the least efficient in that respect, followed by farmers in the Northeast, the Corn Belt, and Appalachia. The farmers in the Southern Plains were operating most efficiently in this interregional comparison, closely followed by

the Pacific region. The returns to size estimates imply that high support prices have led farmers to produce in the increasing portion of their respective average cost curves. All regions showed a slight increase in the returns to size values over the years after 1982. It could be speculated that the dairy assessment might have affected this increase in efficiency.

The production structure of different regions was further investigated by estimating shadow prices (table 3 and 4) for two aggregated fixed factors: capital (comprising livestock, building, and equipment capital plus fixed operating expenses), and the remaining fixed factors. The fact that most of the shadow prices for capital were negative confirmed the finding that farmers have been overinvesting. The overinvestment into capital was greatest in the Southern Plains and the Pacific region. Increasing negative values were observed over the years, indicating that the investment situation was changing for the worse. These results suggest that farmers still considered dairying to be the most profitable among alternatives. Also, the fixity property of their assets would not allow immediate adjustments without unwarranted losses. A significant drop of the shadow prices for capital was noted after 1983. It was attributed to the dairy assessment that was introduced in 1983.

Contrasting results were found in the shadow prices for the remaining fixed factors (land, family and operator labor, and general farm overhead). The estimates generally showed positive and increasing values over the years. A disruption was observed between 1982 and 1983 -- possibly caused by the implementation of the dairy assessment -- this time in the form of a plunge (indicating the decapitalization of land), from which the shadow prices recovered in the following two years. In 1985, they were highest in the Pacific (1.06) and Appalachia region (1.03), suggesting to farmers in these regions that a further substitution of the factor "land/family and operator labor/general farm overhead" for capital would be advantageous.

The dairy assessment -- functioning like an excise tax -- was introduced in early 1983 as a 50-cent charge on every hundredweight of milk sold, thus lowering the actual milk price received by an average of 48 cents adjusted for the entire year. The objective was to reduce milk output and the cost of the supply surplus. In the following years, the assessment was continued after court challenges. In 1984, 50 cents were charged per hundredweight sold. The levy was continued into 1985, which is reflected in the data as an adjusted annual per hundredweight payment of 13 cents.

The analysis of shadow prices and the own-price supply elasticities of milk in particular indicated that the dairy assessment had disruptive effects on the behavioral patterns of producers. The estimates documented that a federal policy measure, such as the dairy assessment, can have remarkably differing effects on regions. The results presented in table 5 indicate the growth rate of farmers' variable profits due to a change in the dairy assessment. The estimates show that profits were affected minimally in 1983 in all regions but Appalachia. The minimal impact in 1983 is not surprising, since the program was in effect only part of the year due to court challenges and uncertainties associated with an actual enforcement of the levy and the fixity of assets obviously prevented speedy adjustments. In the following year, variable profits were adversely affected in all regions but the Northeast and the Upper Midwest. The negative effect was most pronounced in Appalachia, followed by the Southern Plains, while it was low in the Corn Belt and the Pacific region. In 1985, the effect of the assessment was negative in all regions. It was smallest in the Southern Plains region (10%) and highest in Appalachia (62%). The variable profits were affected to a similar degree in the Corn Belt, the Upper Midwest, and the Pacific region (21-29%); and in the Northeast, the effect was very pronounced with a reduction of variable profits by 36%. Overall, it seems that the dairy assessment does affect variable profits negatively, and therefore should eventually have a dampening effect on milk output. Analyzing the development over a period of three years, it can be concluded that the dairy assessment had a different impact on regions over time. For most regions,

the initial was positive; eventually, had negative effects on variable profits occurred in all regions.

Implications

The results of this study have several implications. It was found that a national production function describing the U.S. dairy industry as a whole does not exist, and therefore, a regional approach should be taken to present an appropriate picture of the dairy production situation in the U.S. Analyzing the production structure of six different regions within the U.S., the different production situation and potential could be captured. The specific results should be helpful in making appropriate policy decisions.

It was found that significant differences occur between regions with respect to price elasticities of output supply, returns to size, and shadow prices for capital and other fixed factors, reflecting differences in the production structure. All but the shadow price estimates were very similar for states within the regions, justifying the regionalization chosen. The analysis of the differing regional impact of the dairy assessment highlighted the importance of a regional perspective not only for researchers, but also for policy makers. It was obvious that a federal policy measure had significantly different effects on different regions. Since dairy farming plays an important role in the rural economies of some regions, its decline or prosperity will have substantial multiplier effects and economic as well as social consequences for these regions. In other regions, where dairy farming is not essential for the regional economy since more alternatives exist, its survival might not have serious economic consequences. This suggests that it might be more appropriate to employ a differentiated regional approach in place of a uniform federal policy to account for regional disparities. Additional supportive parallel measure should be taken to assist in the adjustment of particularly affected rural communities.

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Endnotes

[1]Farms obtaining over 50% of their revenues from the dairy enterprise are considered "specialized."

[2]Northeast (New England, New York, Ohio, Pennsylvania), Upper Midwest (Michigan, Minnesota, South Dakota, Wisconsin), Corn Belt (Illinois, Indiana, Iowa, Missouri), Appalachia (Georgia, Kentucky, North Carolina, Tennessee, Virginia), Southern Plains (Texas), and Pacific (California, Washington)

Table 1: Own-price supply elasticities for milk by regions for the U.S., 1981-1985.

Year	Northeast	Upper Midwest	Corn Belt	Appalachia	Southern Plains	Pacific
1981	0.076	-0.289	0.045	0.602	0.748	0.617
1982	0.061	-0.291	0.020	0.513	0.665	0.568
1983	0.095	-0.275	0.193	0.628	0.677	0.654
1984	0.159	-0.152	0.211	0.642	0.884	0.604
1985	0.103	-0.118	0.162	0.499	0.775	0.733

Table 2: Returns to size estimates by regions for the U. S., 1981-1985.

Year	Northeast	Upper Midwest	Corn Belt	Appalachia	Southern Plains	Pacific
1981	0.475	0.396	0.469	0.567	0.589	0.568
1982	0.467	0.391	0.460	0.551	0.573	0.558
1983	0.474	0.393	0.495	0.570	0.575	0.572
1984	0.486	0.423	0.497	0.570	0.605	0.565
1985	0.475	0.431	0.490	0.546	0.590	0.584

Table 3: Shadow prices of capital[1] for dairy farms in the U. S. by region, 1981-1985.

Year	Northeast	Upper Midwest	Corn Belt	Appalachia	Southern Plains	Pacific
1981	0.257	0.867	0.208	0.997	0.241	-0.854
1982	-0.743	-0.655	-0.394	-0.053	-0.920	-1.250
1983	0.148	0.193	0.032	0.145	0.170	-0.911
1984	0.197	-0.228	-0.306	-0.163	-3.849	-0.815
1985	-1.094	-0.779	-0.564	-0.308	-1.301	-1.933

[1]Livestock, machinery, and equipment capital.

Table 5: Change in variable profits due to the dairy assessment, by regions for the U.S., 1983-1985.

Year	Northeast	Upper Midwest	Corn Belt	Appalachia	Southern Plains	Pacific
			- in percent -			
1983	0.144	0.165	0.090	-0.210	0.047	0.012
1984	0.101	0.007	-0.121	-0.467	-0.241	-0.016
1985	-0.362	-0.262	-0.287	-0.615	-0.104	-0.207

Table 4: Shadow prices of fixed factors except capital[2] for dairy farms in the U. S. by regions, 1981-1985.

Year	Northeast	Upper Midwest	Corn Belt	Appalachia	Southern Plains	Pacific
1981	-0.310	-0.300	0.306	0.300	0.232	0.610
1982	0.158	-0.040	0.623	0.741	0.200	0.860
1983	-0.897	-0.887	-0.641	-0.193	-0.463	-0.033
1984	-0.577	-0.544	0.084	0.538	0.311	0.419
1985	0.216	0.175	0.638	1.033	0.864	1.059

[2]Land, family and operator labor, general farm overhead.