Structural Change in U.S Cheese Manufacturing: A Translog Cost Analysis of a Panel of Cheese Plants

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Abstract

Over the last 20 years the cheese manufacturing sector has become the most important market for U.S. farm milk. Using a plant-level dataset encompassing the 1972-1997 period we examine the production characteristics of this industry. Using the results obtained from our cost function we estimate a series of measures of input substitutability and scale economies.

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Introduction

The consumption profile of dairy products in the U.S has been undergoing a dramatic change over the last 20 years. First, consumption of cheese has increased from 8.3 lbs/capita in 1960, to 17.5 lbs. in 1980 and then to 30.6 lbs. in 2002. Between 1980 and 2002 this represents a 75% increase in per capita cheese consumption. This increase in cheese consumption has been occurring while the consumption of fluid milk has been declining from 291.6 lbs/capita (product weight) in 1960, to 237.4 in 1980 and then to 206.0 lbs/capita in 2002. The 2002 value represents a 13% decrease in milk consumption.

With increased cheese demand, annual production of cheese in the U.S. has increased from 1.5 billion lbs. in 1960 to 8.6 billion lbs. in 2003. This increase in production has occurred at the same time that the number of cheese plants in the U.S. has declined. Figure 1 portrays this trend showing the number of natural cheese-producing plants and the average production per-plant over the 1960-2003 period. In 1960 there were more than 1,400 cheese plants producing an average 1 million lbs of cheese. This compares to 2003 where there are an estimated 399 cheese plants producing an average 21.5 million lbs.

The dramatic increase in cheese production coupled with the decline in fluid milk consumption has resulted in the cheese manufacturing sector representing a much more important market for U.S. farm milk (Figure 2). In 1950, 47.0% of the U.S. milk supply was used in the bottling of fluid milk, 10.1% for the manufacture of natural cheeses and 43.0% for the manufacture of other products, primarily butter. Between 1975 and 2003 the proportion of U.S. farm milk used for fluid purposes decreased from 44.2% to 32.3%, and the proportion used in the manufacture of natural cheeses increased from 20.7% to 37.6%.[1]

[1] This varies tremendously across state and region of the U.S. For example in Wisconsin, 85-90% of farm milk is used for cheese manufacture. In California, the largest milk producing state, 42.1% of the milk was used to manufacture cheese in 2002 (California Dept. of Food and Agriculture, 2003). For the Upper Midwest marketing order, 76% of

The reduction of the number of cheese plants has important public policy implications with respect to industry concentration and market power both for the consumer and dairy farm operator. For the dairy farm operator, fewer cheese plants may mean that at the local level there is less choices available to market their output.

Table 1 compares a series of concentration ratios (CR) and an aggregate Herfindahl-Hirschman Index (HHI) for a number of food processing sectors using data obtained from the 1997 Census of Manufacturers.[2] Regardless of measure used, the cheese manufacturing sector is much more concentrated than food manufacturing in general. In 1997 the CR4 value in terms of gross value of sales was 14.3 for U.S. food manufacturing compared to 34.6 for cheese manufacturing. When examining concentration of industry contributed value-added a similar pattern is displayed. The HHI-50 values show an interesting pattern.[3] In terms of the concentration of the gross value of sales, the cheese industry is much less concentrated than the meat processing sector. In contrast, the HHI-50 value when calculated for value added shows much more concentration in the cheese industry and much less in the meat processing sector. This is significant given the public policy concerns recently expressed with respect to the animal processing sectors (MacDonald and Ollinger, 2002; Rogers, 2001; Xia and Bucolla; 2002).[4]

In the present analysis we undertake an analysis of the cheese manufacturing sector to determine the role played by changes in the underlying technology in the consolidation

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milk was used in the manufacture of Class III (cheese) products. In the Northeast, 31% of the milk in 2002 was used in Class III products while in the Southeast order 21% of farm milk was used for Class III (USDA,AMS). Note, we do not report the 2003 values due to the significant amount of depooling that occurred during that year and would generate a biased the representation of actual milk utilization in some areas.

[2] For a review of changes in the concentration in food manufacturing, refer to Rogers (2001).

[3] Markets in which the HHI is between 1000 and 1800 points are considered by the U.S. Dept. of Justice to be moderately concentrated, and those in which the HHI is in excess of 1800 points are considered to be concentrated. Transactions that increase the HHI by more than 100 points in concentrated markets presumptively raise antitrust concerns under the Horizontal Merger Guidelines issued by the U.S. Department of Justice and the Federal Trade Commission.

[4] For a review of the structure of the U.S. dairy industry from the farm gate to the retail outlet refer to Manchester and Blayney (1997).

in this sector over a recent 25 year period. To accomplish this goal we use the Longitudinal Research Database (LRD) maintained at the Center for Economic Studies of the U.S. Census Bureau. This data contains production related information for all manufacturing plants (including cheese) within the U.S. Census of Manufacturers over the 1972-1997 period. We adopt a translog cost function approach to characterize the structure of cheese production over this 25 years period.

Any analysis of the cheese manufacturing industry needs to partition this industry into two sub-sectors, natural and processed, given the unique characteristics of the production processes. The production of natural cheeses such as cheddar, mozzarella, swiss, etc., is based on the curdling of raw farm milk. First, milk is carefully selected to make sure there are no antibiotics or harmful agents that could affect the manufacture process. This milk is then pasteurized to destroy any harmful bacteria. Special starter cultures are then added to the warm milk to change a very small amount of the milk sugar into lactic acid. Rennet is then added to the milk and within a short time a curd is produced. The resulting curd is then cut into small cubes, and heat is applied to start a shrinking process which, with the steady production of lactic acid from the starter cultures, will change it into small rice-sized grains. At a carefully chosen point the curd grains are allowed to fall to the bottom of the cheese vat, the left-over liquid, which consists of water, milk sugar and albumen (now called whey) is drained off and the curd grains allowed to mat together to form large slabs of curd. The slabs are then milled, and salt is added to provide flavor and help preserve the cheese. Later, it is pressed, and subsequently packed in various sized containers for maturing. For natural cheese manufacturers, 75-90% of the total cash costs are related to the purchase of this raw milk (Carlson and Gould, 1995).

The above production process differs significantly with the manufacture of process cheese. Process cheeses are a blend of fresh and aged natural cheeses that have been shredded, mixed, and heated (cooked) with an addition of an emulsifier salt, after which no further ripening occurs. Typically no raw farm milk is used in the production process. As a result process cheeses typically have a longer shelf life than most natural cheeses.

Given the differences in technologies most cheese plants produce either natural or process cheese but not both. Not only are there differences in the technology used in the manufacture of the final product, the scale of manufacture also differ. In 2003, USDA reports that there were 399 plants in the U.S. producing natural cheese with an annual output of 21.5 million lbs (USDA, 2004). This compares to 54 plants producing process/cheese foods or spreads with an annual output of 44.6 million lbs. For the present analysis we limit our analysis to natural cheese manufacturers given these are the plants purchasing the raw farm milk.

The remainder of this paper describes the methodology used to quantify the structure of the industry over the 25 year study period. The next section provides an overview of the econometric model that forms the basis of our evaluations. This is followed by a brief description of the panel data used in the empirical implementation of the above model. This is then followed by an overview of our econometric results and some concluding comments.

Description of the Translog Cost Model

The model used in our analysis follows very closely the methodology presented by Ball and Chambers (1982) in their analysis of the U.S. meat products industry. Let $x=(x_1,x_2,\ldots x_J)'$ be a vector of non-negative inputs and F(x) be a well-behaved production function. The dual cost function to F(x) can be represented as:

$$(1) \qquad C(y,w) = \underset{x}{Min}\,[w'x : F(x) \geq y]$$

where y is a single measure of output and w is a vector of input prices (all non-negative). Applying Sheppard's lemma to (1), the ith input demand curve can be represented as:

$$(2) \qquad \frac{\partial C(y,w)}{\partial w_i} = x_i(y,w)$$

where x_i(?) is the ith input cost minimizing input demand.

As in Ball and Chambers (1982) we quantify the substitutability of inputs i and j in the production function via a number of alternative measures. First, the Allen partial elasticity of substitution can be represented as:

(3) $$s_{ij} = \frac{CC_{ij}}{C_i C_j} = \frac{e_{ij}}{S_j}$$

where $C_i = \partial C(y,w) / \partial w_i$,$C_{ij} = \partial^2 C(y,w) / \partial w_i \partial w_j$, e_{ij} is the i^{th} input demand elasticity with respect to a change in the j^{th} input's price and S_j is the jth cost share (i.e., $w_j x_j/C$). Related to the Allen partial elasticity, an additional measure of substitutability can be represented by the Morishima elasticity of substitution:

(4) $$s_{ij}^{M} = Sj(s_{ij} - s_{jj}) = e_{ij} - e_{jj}$$

(Blackorby and Russell, 1988). A third measure of input substitutability can be represented by the shadow elasticity of substitution (evaluated at the constant average cost) is given by:

(5) $$s_{ij}^{S} = \frac{S_i S_j}{S_i + S_j}(2s_{ij} - s_{ii} - s_{jj})$$

The Allen partial elasticities (s_{ij}) measure is a one-factor/one-input elasticity of substitution measure used to evaluate how the use of a single input is impacted by the change of a particular input's price. In contrast the Morishima elasticity (s^{M}_{ij}) is a two-factor one price elasticity measure and as such measures *relative* adjustment of two factors to a single input's price change. The shadow elasticity of substitution measure is a two factor-two price elasticity statistic and provides an estimate of the percentage adjustment in input *ratios* to changes in factor price *ratios* (Ball and Chambers, 1982, p.704-705).

In our analysis of the natural cheese industry we assume that cheese plants use 5 inputs: labor (L), capital (K), purchased dairy-based inputs (D), energy (E) and an aggregate other materials (M) input to produce natural cheese (y). In addition we allow the production function F to include a set of plant characteristics (Z) (such as ownership type, geographic location, etc) and a time trend (t) used to capture non-neutral technological change. We represent this production function as:

(6) $$y = F(L, K, D, E, M, Z, t)$$

The dual cost function to (6) can be represented by the following translog function:

(7)

$$\ln C = a_0 + a_y \ln y + \sum_i a_i \ln w_i + ½ b_{yy} (\ln y)^2 + ½ \sum_i \sum_j b_{ij} \ln w_i \ln w_j + \sum_i g_{yi} \ln y \ln w_i$$

$$+ \sum_l \left(d_l z_l + d_{ly} z_l \ln y \right) + \sum_i d_{li} z_l \ln w_i + f_T t + ½ f_{TT} t^2 + f_{Ty} t \ln y + \sum_i f_{Ti} t \ln w_i$$

where a_0, a_Y, a_i, β_{yy}, β_{ij}, ?$_{yi}$, d_l, d_{ly}, d_{li}, f_T, f_{TT}, f_{Ty}, and f_{Ti} are parameters to be estimated. We impose symmetry via $\beta_{ij}=\beta_{ji}$ and linear homogeneity in input prices via the following:

(8) $$\sum_i a_i = 1 \sum_i b_{ij} = \sum_j b_{ij} = \sum_i g_{yi} = \sum_i f_{Ti} = \sum_i d_{li} = 0;$$

From (7) factor cost shares can be derived:

(9) $$\frac{\partial \ln C(y,w)}{\partial \ln w_i} = \frac{w_i x_i}{C} = S_i = a_i + \sum_j b_{ij} \ln w_j + g_{yi} \ln y + \sum_l d_{lj} z_l + f_{Ti} t$$

Obtaining estimates of the cost function's parameters allow us to characterize the existence of scale economies and the rate of technical progress in the cheese industry over the 1972-1997 period. The elasticity of scale (e) can be calculated as the inverse of the elasticity of cost (e_{Cy}) with respect to output along the expansion path:

(10) $$e = \left(e_{Cy}\right)^{-1} = \left(a_y + b_{yy} \ln y + \sum_i g_{yi} \ln w_i + \sum_l d_l z_l + f_{TY} t \right)^{-1}$$

(Ball and Chambers, 1982). If e < 1 this implies that the production function in (6) exhibits decreasing returns to scale and e > 1 implies increasing returns.

We can define the rate of technical progress (e_T) as the relative cost reduction resulting from technical progress, which from (7), can be calculated as:

(11) $$\begin{aligned} e_T &= -\partial \ln C(y,w) / \partial t \\ &= -(f_T + f_{TT} t + f_{TY} \ln y + \sum_i f_{Ti} \ln w_i) \end{aligned}$$

For the i^{th} input, technical change is input-saving, neutral or using if f_{Ti} is less than, equal to or greater than 0, respectively (Ball and Chambers, 1982 p.701).

From (3), input demand price elasticities (e_{ij}) can be calculated:

$$(12) \qquad e_{ij} = S_j s_{ij} = \frac{b_{ij} + S_i S_j}{S_i S_j} \text{ for } i \neq j \text{ and } e_{ii} = \frac{b_{ij} + S_i^2 - S_i}{S_i^2} \text{ for } i = j \; .$$

The parameters of the cost function can be obtained through the estimation of the share equations using an iterative SUR procedure. With adding up of the input cost-share equations, one of these equations can be omitted from the estimation process and the parameters for the omitted equation obtained from the parameter restrictions contained in (8). Following the procedure of Ball and Chambers (1982) we augment the share equation system represented in (9) with the underlying cost function in (7). Inclusion of this cost function allowed us to obtain estimates cost function parameters not contained in the cost share equations (i.e., a_0, a_Y, $ß_{yy}$, $ß_{ij}$, $?_{yi}$, d_l, d_{ly}, f_T, f_{TT} and f_{Ty}).

For this initial analysis we add to (7) and (9) additive disturbances which are assumed (i) jointly normally distributed, (ii) are non-autocorrelated and (iii) possess non-zero contemporaneous covariances. Given the above assumptions we obtain parameter estimates by maximizing the following log-likelihood function:

$$(13) \qquad L = \sum_{t=1}^{T} L_t = -\frac{MT}{2}\ln(2p) - \frac{T}{2}\ln|\Sigma| - \frac{1}{2}\sum_{t=1}^{T} e_t^{*\prime}\Sigma^{-1}e_t^{*}$$

where M-1 share equations are estimated along with the underlying cost function shown in (7), e_t^* is the [(M-1) x 1] error vector for the estimated share equations augmented with the error term from the cost function shown in (7), and S is the [M x M] error covariance matrix of these errors.

Overview of the Longitudinal Research Database

The data used in this study is a subset of the Longitudinal Research Database (LRD) maintained at the Center for Economic Studies of the U.S. Census Bureau. The LRD contains plant-level (versus firm-level) data collected via the 1972-1997 Census of Manufactures.[5] For each manufacturing plant in the U.S., Census of Manufacturers data for that plant are contained in the LRD for all years for which that plant was surveyed. As such, the LRD represents an unbalanced panel of manufacturing plants where each is

[5]Use of this data requires a lengthy security clearance process and the release of individual plant level information is prohibited given the confidential nature of the data.

identified by a permanent ID number that does not change with ownership which is important for the analysis of the cheese industry given the concentration/mergers that have occurred in the industry. For each Census year, the NAICS (SIC) code associated with the plant, its permanent identification number, location, current operational status, and legal form of organization are obtained. In terms of input use, the LRD contains information on: the number of production workers, hours worked by these production workers, number of white collar workers, total wage and non-wage labor costs, itemized materials costs detailed specifically to that NAICS sector, the quantity of the detailed material inputs consumed, the costs of services purchase, the amount and costs of energy used, beginning and ending primary product inventory values, the value of depreciable assets, and the level of capital expenditures during the previous year.[6]

The quantity and value of product shipments, interplant transfers and product used internally are recorded in the LRD according to a detailed NAICS product code specific to each sector.[7] Data are made available approximately 2 years after the survey period. Although the LRD contains information from both the Annual Survey of Manufacturers and the Census of Manufacturers, the limited number of cheese manufacturing facilities in the U.S. required that we limit our analysis to data contained in the Census portion of the LRD. We use data encompassing the 1972-1997 period.

As noted above, the focus of our analysis is on producers of natural cheese. We define a plant as a natural cheese producer if it identified itself as a cheese manufacturing plant (SIC 2022) and if the plant reports a positive amount produced of natural cheese or cheese not specified as to kind. After omitting plants from our sample due to missing data, the final number of observations in our combined pooled data set is 3,224 (Figure 3)

[6] For the cheese manufacturing sector specific information is collected with respect to cost and use of: whole milk, fluid skim milk, cream, butter, condensed, evaporated or dry milk, natural cheese (for use by processed cheese plants), dairy product mixes, fats and oils, sweeteners, whey (in all forms), casein and caseinates, chocolate, flavorings, plastic resins (for use in packaging), and other packaging materials.

[7] For the cheese manufacturing sector, detailed information is collected with respect to the manufacture of butter, butter/margarine blends, natural cheese, processed cheese, cheese substitutes, raw liquid whey, dry milk products, canned milk products, ice cream mixes, ice cream, fluid milk, cottage cheese, and yogurt.

The definition of the variables used in the estimation of the cheese industry cost function represent by (7) and the associated input share equations (9) are reported in Table 2.[8] Using the procedures outlined in MacDonald et al., (2000) we define capital input costs as the "opportunity cost of investing in plant and equipment". In the derivation of this cost item we use the rental price concept to derive input prices for buildings and equipment. Unpublished capital rental price data was obtained from the Bureau of Labor Statistics. The data used represent the rental price index of current dollar rent on one dollar's worth of constant (1996) dollar capital stock. Index values for each Census year for the Food and Kindred Products sector (SIC 20), which was the most detailed available, were used as proxies for the rental price of buildings and machinery. Separate index values were used for these two types of capital

Given that a set of diverse inputs comprise the aggregated dairy and energy input categories, we develop Tornqvist price indices for these inputs.[9] Our analysis includes some characteristics of the plants such as their location, type of organization and whether a particular plant is owned by a multi-plant firm. Additionally, following MacDonald et al. (2000) and MacDonald and Ollinger (2001) we include a time trend to estimate the rate of technical progress as noted above. Given our use of a pooled set of observations of natural cheese plants, all monetary values are expressed in real 1996 dollars via the use of the GNP deflator.

The Structure of Production in the U.S. Natural Cheese Industry

The primary goal of this research is to quantify the relationship between technological change and the structure of the U.S. natural cheese manufacturing sector. This is achieved by estimating a translog cost function and associated input cost shares based on a panel of U.S. cheese manufacturers. The maximum likelihood parameter estimates obtained from estimating this model are shown in Appendix A. Of the 78

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[8]The analysis presented here assumed a single output, natural cheese. Over the entire sample over 90% of the total value of output was from this commodity. An alternative version of the model was estimated where we allow account for multiple inputs via our use of a Tonrqvist output index. The conclusions reached did not change from that reported here.

[9] Refer to Coelli, Rao and Battese (2001) for an overview of the Tornqvist index used to create the dairy input price index..

estimated parameters, 48 had t-ratios that exceeded 2.0. Adjusted R^2 values for the share equations ranged from 0.075 for energy to 0.401 for the capital cost share. Given the technical relationships developed above, we use the SUR parameter estimates to evaluate the technological structure of this industry. [10]

From Appendix A we can directly interpret the f_{Ti} coefficients as to the impacts of technological change on input use. All of the estimated f_{Ti}'s coefficients were found to be significantly different from 0. Technological change was estimated to be dairy input and labor saving and energy, capital and material using. The result with respect to dairy inputs was surprising from the perspective that the cheese making process is almost Leontif with respect to how much milk is required per lb. of cheese. There may be some efficiency gains with respect to the adoption of automated systems that reduce "slippage" between the cheese vat and the selling of the product. There have also been some advances in the use of alternative dairy-based ingredients in the standardization of raw farm milk to improve cheese yield resulting in dairy-saving technological change..

Table 3 contains our estimates of the input demand elasticities evaluated at the overall sample mean of our exogenous variables. A majority of the input combinations exhibit a substitute relationship with estimated elasticities significantly different from 0. All of the own-price elasticitieis are significantly different from -1.0 with the exception of labor. Not surprising with more than 75% of total costs being dairy related, the own-price elasticity for the dairy input is the smallest of the 5 delineated in this study.

The top third of Table 4 presents the estimated Allen partial elasticities. The own-elasticities are negative and most of the inputs are complements. Note that the dairy inputs are inelastic as expected and that there is some substitution between dairy inputs and labor and between dairy inputs and capital. A complementary analysis of the price effects comes from the inspection of the Morishima elasticities reported in middle portion

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[10] In our estimation of the various elasticity measures discussed above we follow Greene (2003) and estimate asymptotic variances of these nonlinear functions. Let θ represent a nonlinear transformation of a vector of parameters, G where θ =g(G) and g(?) is a continuously differentiable function. Then var(θ)˜ $H'_G O H_G$ where H_G is the derivative of g(?) with respect to G and O is the variance-covariance matrix of these parameters (Greene, 2003 p.916-7).

of Table 4. Remember when interpreting individual elements, the values indicate the *relative* adjustment in input use with respect to the j^{th} inputs price change. For example the s^M value of 1.247 associated with a change in energy price implies a decrease in the energy-capital ratio. That is, from a percentage basis, an energy price increase results in larger decrease in energy usage than capital usage. Comparing the Allen to the Morishima elasticities we see that the Allen estimated complementary relationship between energy prices and dairy input use is a Morishima substitute. As noted above the Morishima elasticity matrix is not assumed to be symmetric as is the case in the derivation of the Allen substitution elasticity matrix. There are substantially different cross-elasticity values. For example, the elasticity of labor use to a change in the dairy input price (1.799) is much elastic than dairy input use to a change in labor price (0.308). Given that all inputs are estimated Morishima substitutes it was not surprising that all of the shadow substitution elasticities are also estimated to be substitutes.

Homotheticity requires all inputs to be normal and input ratios be independent of output. Ball and Chambers (1982) suggests to that to test for homotheticity, one can examine the elasticity of input demand with respect to scale, $?_{iY}$:

$$(14) \qquad x_{iy} = \frac{\partial \ln C_i(y,w)}{\partial \ln y}$$

where $C_i = \partial C(y,w)/\partial w_i$. Under homotheticity we should observe that $?_{iy} = ?_{jy} > 0$ for all i,j. In Table 5 we present $?_{iy}$ evaluated at year specific mean values of the exogenous variables. For all years and input levels, except for the 1992 and 1997 estimations for the energy input, all $?_{iY}$ values were estimated to be positive. For most inputs $?_{iY}$ remains relative constant. A cursory examination of the $?_{iY}$ values shows significant differences across commodity. For example, using the 1987 values, the range of elasticities is from 0.211 for energy and 0.724 for dairy products.

In Table 6 we report the elasticity of scale (e), its inverse, the elasticity of cost (e_{Cy}) and the rate of technological progress (e_t). Similar to the other elasticities we evaluate the scale elasticity at the mean value of the exogenous variables for each Census year. We find evidence of significant economies of scale. For each year we reject the null hypothesis that these elasticity values equal 1.0 . These results are not surprising given the trends in terms of the reduction in the number of plants and average plant size displayed in Figure 1. From this figure we see that the rate of growth in average size increases after the early 1970's the period encompassed by the present study. The elasticity values for 1972-1992 are not significantly different from each other. Though not large, the stability of these values suggests a continuation of the consolidation of the cheese industry displayed in Figure 1. To further illustrate this, Figure 4 shows estimated average cost curves for various years based on the parameter estimates shown in the Appendix. For 1972 our estimate is that the average cost curve was fairly flat for forms larger then the mean output of less than 8.4 mill. lbs. By 1997, there appears to be a shifting down of this average cost curve which continues the trend observed for 1982 and 1987.

Table 6 is also used to show that the rate of technological progress is positive in all years. Remember, the values in this column represent the percentage change in technology during that year. For example, the 1.6 observed in row 1, means that technology *improved* by 1.6% in 1972. The values for all years are significantly different from 0 except for 1982.

Summary

Concentration in the food manufacturing/processing industry has attracted considerable attention due to merger activity not only at this level of the marketing chain but also due to mergers at the food retailing level. Until recently the dairy sector has not been the subject of much scrutiny. However in 2002, the merger between the then two largest dairy companies, Suiza Foods Corp. and Dean Foods Co., resulted in considerable interest from public policy makers concerned with concentration in the food sector. To overcome U.S. Department of Justice concerns, Suiza and Dean Foods agreed to sell 11 dairy processing plants in eight states. Without these divestitures, it was felt that the merger would have reduced competition in markets for milk sold through schools and retail outlets in the areas around these plants.

There continues to be concern as to the growing concentration in the dairy industry given that the largest dairy cooperative, Dairy Farmers of American (DFA), which accounts for approximately 20% of U.S. farm milk, owns a controlling interest in

National Dairy Holdings which was created as the spin-off of the Dean Foods/Suiza Foods merger. DFA also has an exclusive supply agreement with post-merger Dean Foods Co. In summary, the dairy industry will continue to be the subject of considerable scrutiny as the number of dairy processing plants continues decrease and the remaining plants are owned by fewer and fewer firms.

This research is a first attempt at examining the characteristics of a major user of U.S. farm milk, natural cheese. Using plant level data from the U.S. Census of Manufactures we are able to estimates a flexible cost function (translog) for plants producing natural cheese over the 1972-1997 period. This data allowed us to determine the rate of technological change and more importantly, the existence of significant economies of scale. Our results show that in terms of cheese manufacturing there are significant economies of scale and these economies have existed since the beginning period of our analysis, 1972. These scale economies are higher compared to other industries such as hog and cattle slaughter (MacDonald et al., 2000).

Our results suggest that the pre-existing economic of scale might have led to concentration in the industry. The fact that these increasing returns were still relative high in 1997 gives strength to the argument that concentration in the natural cheese manufacturing sector will continue in the foreseeable future. Such concentration is significant at the local level given the nature of the primary raw product involved in the cheese manufacture, raw farm milk. Cheese manufacture concentration may limit a farm operator's ability to market milk in a competitive environment.

With the soon to be release 2002 Census of Manufacturers data, it will be interesting to determine the degree to which the above consolidation has impacted the structure of the dairy industry since 1997, the latest currently available data. Our intention is to add the 2002 data to the analysis and examine the impacts of the above concentration on the technological and cost structure of the remaining industry participants.

References

Ball, V.E. and R. Chambers, 1982. "An Economic Analysis of Technology in the Meat Products Industry", *American Journal of Agricultural Economics*, 64, November: 699-709.

Blackorby, C. and R.R. Russell, 1989. "Will the Real Elasticity of Substitution Please Stand Up, *American Economic Review*, 79, 882-888 (September).

California Department of Food and Agriculture, 2003. *California Dairy Industry Statistics and Trends: 2003*, www.cdfa.ca.gov/dairy.

Carlson, C. and B. Gould, 1995. *Results form the 1995 Wisconsin Small Cheese Plant Survey*, Phase II report for project: *A Comparative Analysis of Cheese Plant Operations*, Wisconsin Milk Marketing Board, June.

Coelli, T., D.S.P. Rao and G.E. Battese, 1998. *An Introduction to Efficiency and Productivity Analysis*, Kluwer Academic Publishers, Boston.

Greene, W., 2003. Econometric Analysis, 5th Ed., Prentice-Hall, New York.

MacDonald, J.; M. Ollinger; K. Nelson and C. Handy, 2000. *Consolidation in U.S. Meat Packing*, Food and Rural Economic Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 785.

MacDonald, J. and M. Ollinger, 2000. "Scale Economies and Consolidation in Hog Slaughter", *American Journal of Agricultural Economics*, 82, May: 334-346.

Manchester, A. and D. Blayney, 1997. *The Structure of Dairy Markets: Past, Present and Future*, Commercial Agriculture Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 757

Ollinger, M.; J. MacDonald and M. Madison, 2000. *Structural Change in U.S. Chicken and Turkey Slaughter*, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 787

Rogers, R., 2001. "Structural Change in U.S. Food Manufacturing, 1958-1997", *Agribusiness* 17(1): 3-32.

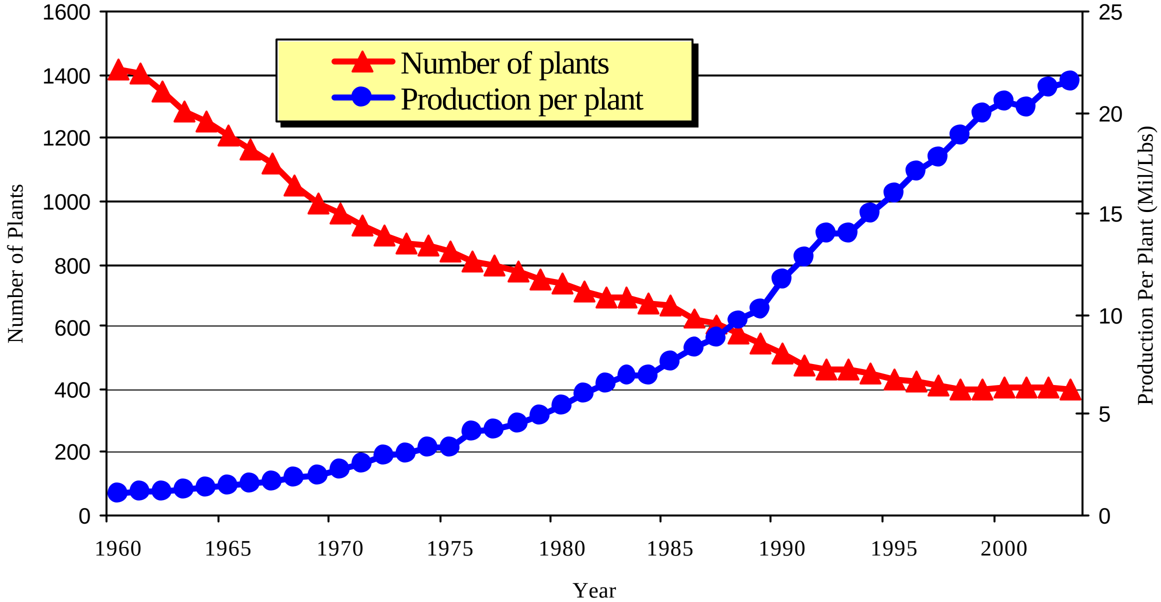
U.S. Census Bureau, 1997. “Concentration Ratios in U.S. Manufacturing”, U.S. Department of Commerce, Washington D.C.

U.S. Department of Agriculture, 2004. Dairy Products: 2003 Summary, National Agricultural Statistical Service, Washington, D.C., April.

U.S. Department of Agriculture, Agricultural Marketing Service, 2004. http://www.ams.usda.gov/dyfmos/mib/tbl_22_ann_2002.pdf

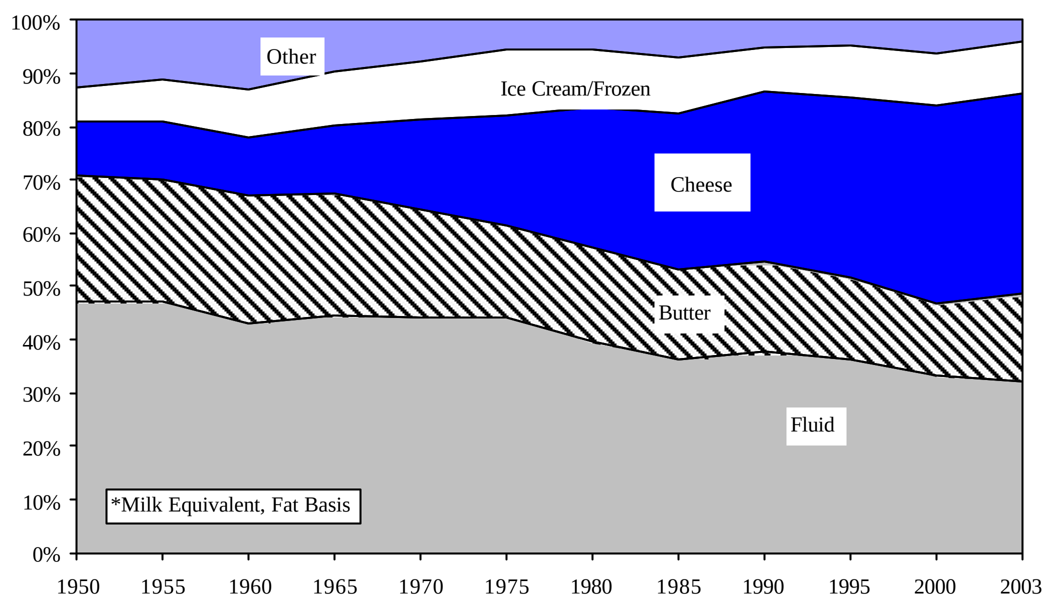
Xia, Y. and S. Buccola, 2002. "Size, Cost and Productivity in the Meat Processing Industries", *Agribusiness* 18(3): 283-299.

Figure 1 Number of Cheese Plants and Production Per Plant, 1960-2003



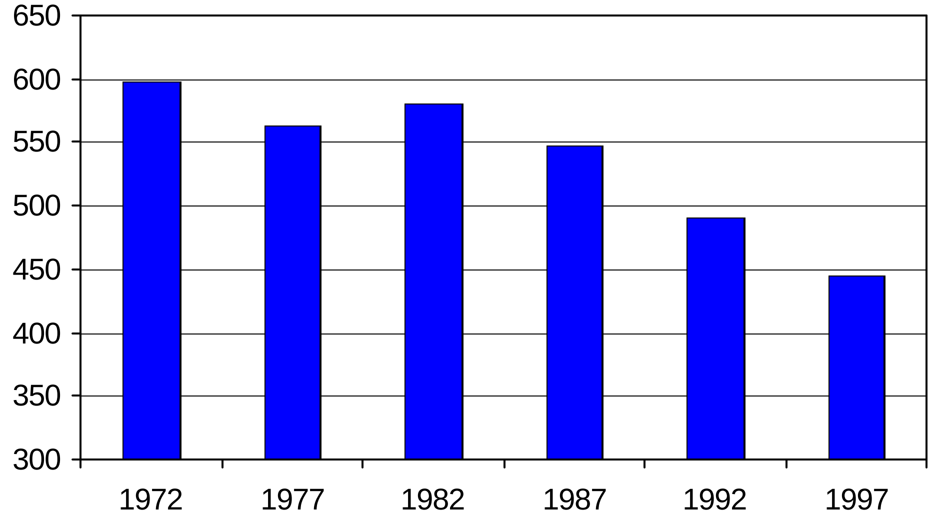
Source: USDA, Dairy Products, Various Years

Figure2. Allocation of U.S. Farm Milk to Various Dairy Products: 1950-2003



Source: USDA, Dairy Products, Various Years

Figure 3. Number of LRD Natural Cheese Plants Used in the Econometric Model



Note: The total number of plants across all years is 3,224

Figure 4. Estimated Average Cost Curves, Various Years

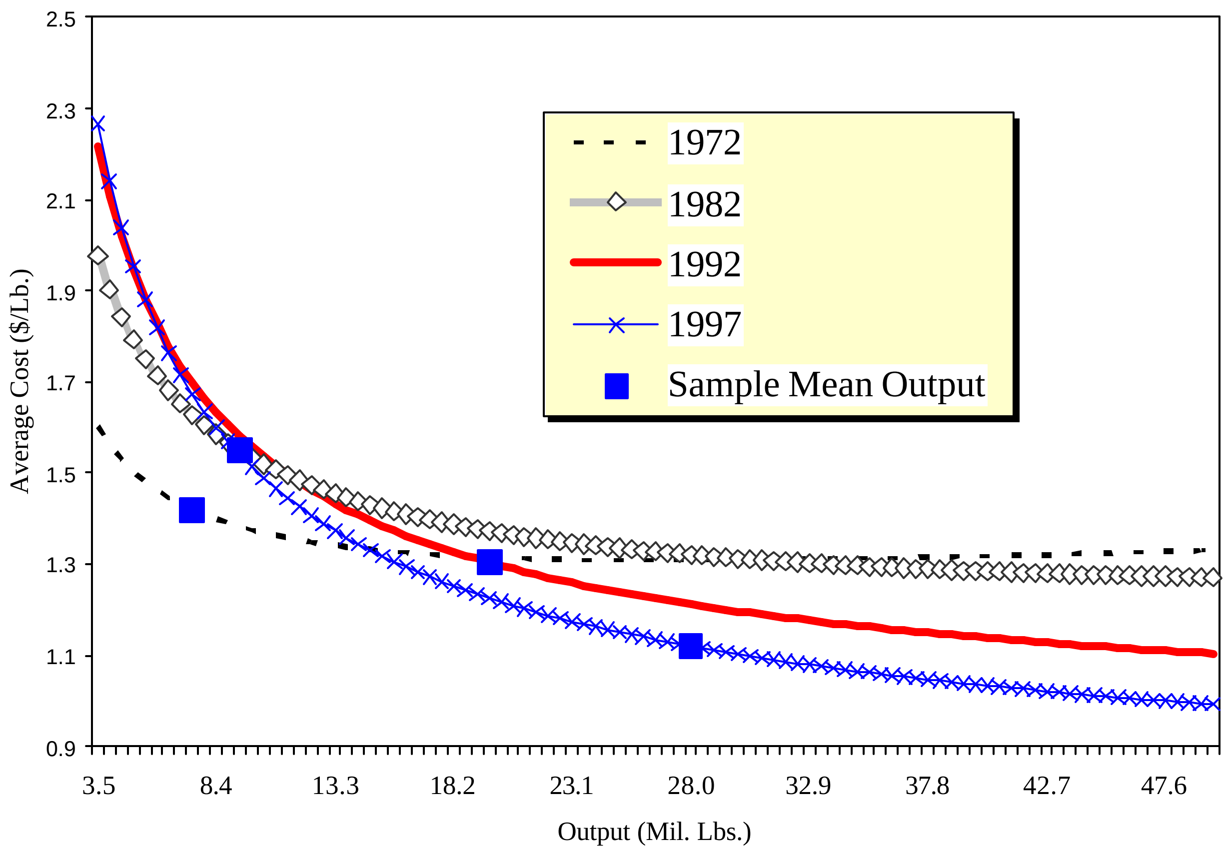


Table 1. Comparison of Concentration Ratios in the U.S. Cheese and Other Food Manufacturing Sectors, 1997

Manufacturing Sector	NAICS Code	Number of Largest Firms (CR-Values)				HHI-50
		Four	Eight	Twenty	Fifty	
		Gross Sales				
Cheese	311513	34.6	50.9	70.6	85.1	524.6
Fruit/Veg. Processing	3114	26.6	35.6	51.8	69.2	253.3
Bakeries	3118	28.6	40.1	55.5	68.1	281.2
Animal (ex. Poultry) Processing	31161	57.0	70.8	81.5	89.7	1069.1
Poultry Slaughter	311615	40.6	54.0	72.6	90.0	667.7
Food Manuf.	311	14.3	22.0	34.8	50.5	91.0
		Value Added				
Cheese	311513	43.4	55.1	74.1	86.8	921.4
Fruit/Veg. Processing	3114	31.5	40.8	57.1	73.3	353.5
Bakeries	3118	32.0	43.5	59.0	70.9	346.2
Animal (ex. Poultry) Processing	31161	42.5	65.8	78.3	87.3	639.6
Poultry Processing	311615	45.0	56.8	73.6	91.2	877.2
Food Manufacturing	311	10.9	20.0	37.4	53.4	87.0

Source: U.S Census Bureau (2001). HHI-50 represents the Herfindahl-Hirschman Index for the 50 largest firms.

Table 2: Variables Used in the Estimation of the Natural Cheese Cost Model

Variable	Description
Quantity produced	Pounds of Natural Cheese
Total Cost	Capital cost + Labor cost + Energy cost + Dairy input cost + Other material cost
Capital cost	Opportunity cost + New cost. Opportunity cost = building assets * building rental price + machinery assets* machinery rental price. New cost = Total cost of equipment / 2.
Labor cost	Hired labor cost + White collar labor cost. Hired labor= ww+(ww/sw)lc and White collar labor cost=ow+(ow/sw)*lc, where ww=wages of production workers, sw=total salaries and wages, lc=total supplemental labor cost; ow=other worker wages.
Energy cost	Cost of purchased electricity + cost of fuels
Dairy inputs cost	Sum of delivered cost of milk, butter, dry milk, dry mix, whey and casein. Milk includes whole milk, fluid skim milk and cream. Dry mix includes ice cream (normal and low fat), sherbet and yogurt mixes. Whey includes whey, liquid, concentrated, dried and modified whey products in terms of solids. Casein includes casein and caseinates.
Other material costs	Cost of materials - Energy cost – Dairy inputs cost
Input cost shares	Each input cost / Total cost
Price of capital	Cost of capital / Capacity. Capacity = (tab+tce-trt)/2 where tab=total assets beginning, tce=used capital expenditures + total new expenditures and trt=total retirements
Price of labor	Labor cost / Total labor hours. Total labor hours = hours of production workers + white collar workers*50*35. White collar workers=total employment- number of production workers.
Price of energy	Tornqvist index based the use and cost of electricity, natural gas, fuel oil, etc.
Price of dairy inputs	Tornqvist index based on the use of milk, natural cheese, butter, dry milk and dry mix. Natural cheese includes See definitions for dairy input costs.
Price of other materials	Other material costs / Quantity produced
Region of Location	Dummy variables identifying Northeast, South Central, West North and East North and West South regions
Single	1 if plant is the only plant of a firm, 0 otherwise
Cooperative	1 if plant's organization is a cooperative, 0 otherwise

Table 3. Estimated Input Demand Elasticities Evaluated at Overall Sample Means (e_{ij})

		Price Change				
		Labor	Capital	Dairy	Energy	Other
Quantity Change	Labor	-0.983* (0.006)	0.103 (0.007)	0.816 (0.012)	0.241 (0.003)	0.041 (0.003)
	Capital	0.094 (0.006)	-1.195* (0.029)	1.102 (0.032)	0.052 (0.008)	0.032 (0.003)
	Dairy	0.084 (0.001)	0.115 (0.004)	-0.224* (0.005)	-0.002 (0.001)	0.028 (0.001)
	Energy	0.144 (0.016)	0.342 (0.050)	-0.136 (0.065)	-0.369* (0.027)	0.019 (0.009)
	Other	0.102 (0.008)	0.087 (0.009)	0.680 (0.017)	-0.006 (0.004)	-0.877* (0.007)

Note: An * indicates own-price elasticities that are significantly different from -1.0. Note the formulas for these price elasticities are given in (12). Asymptotic standard deviations are presented in parentheses.

Table 4. Various Elasticity Measures of Input Substitution

Allen Partial Elasticities of Substitution (s_{ij})					
	Labor	Capital	Dairy	Energy	Other
Labor	-12.186 (0.074)	1.168 (0.074)	1.039 (0.015)	1.783 (0.203)	1.257 (0.100)
Capital		-13.516 (0.330)	1.295 (0.041)	3.871 (0.569)	0.988 (0.105)
Dairy			-0.285 (0.006)	-0.173 (0.083)	0.866 (0.022)
Energy				-27.299 (2.013)	-0.409 (0.291)
Other					-27.211 (0.227)
Morishima Elasticities of Substitution (s^{M}_{ij})					
	Labor	Capital	Dairy	Energy	Other
Labor		1.087 (0.007)	1.799 (0.017)	1.007 (0.006)	1.024 (0.007)
Capital	1.289 (0.029)		2.212 (0.060)	1.247 (0.030)	1.227 (0.030)
Dairy	0.308 (0.006)	0.338 (0.008)		0.222 (0.005)	0.252 (0.005)
Energy	0.513 (0.026)	0.711 (0.056)	0.233 (0.083)		0.387 (0.030)
Other	0.978 (0.010)	0.964 (0.012)	1.557 (0.022)	0.871 (0.008)	
Shadow Elasticities of Substitution (s^{S}_{ij})					
	Labor	Capital	Dairy	Energy	Other
Labor		0.563 (0.004)	0.968 (0.006)	0.162 (0.002)	0.310 (0.003)
Capital			1.177 (0.029)	0.204 (0.008)	0.343 (0.008)
Dairy				0.002 (0.001)	0.036 (0.001)
Energy					0.275 (0.020)
Other					

Note: All elasticities are evaluated at the mean values of the exogenous data. The formulas used to derive the Allen, Morishima and Shadow elasticities are given in equations (3)-(5). Asymptotic standard deviations are presented in parentheses.

Table 5. Elastiticity of Input Demand With Respect to Scale (?$_{iY}$)

Elasticity	Survey Year					
	1972	1977	1982	1987	1992	1997
Labor	0.565 (0.019)	0.523 (0.022)	0.517 (0.022)	0.550 (0.023)	0.552 (0.025)	0.572 (0.027)
Capital	0.521 (0.032)	0.511 (0.034)	0.524 (0.032)	0.656 (0.023)	0.675 (0.023)	0.710 (0.025)
Dairy	0.735 (0.016)	0.733 (0.016)	0.724 (0.017)	0.760 (0.019)	0.766 (0.021)	0.791 (0.023)
Energy	0.299 (0.031)	0.122 (0.042)	0.211 (0.036)	0.219 (0.039)	0.089 (0.048)	-0.006 (0.055)
Other	0.711 (0.040)	0.719 (0.071)	0.710 (0.068)	0.740 (0.061)	0.733 (0.032)	0.757 (0.035)

Note: The formula used to derive this elasticity is shown in equation (14). Asymptotic standard deviations are presented in parentheses.

Table 6. Elasticity of Scale (e) and of Cost (e_{CY}) and the Rate of Technical Change (e_T)

Year	Elasticity Measure			Technological Progress (%) (e_T)
	e		e_{CY}	
	Value	H_0:e=1		
1972	1.427 (0.032)	13.34	0.701 (0.016)	1.60 (0.58)
1977	1.428 (0.033)	12.97	0.700 (0.016)	1.71 (0.58)
1982	1.447 (0.036)	12.42	0.691 (0.017)	0.74 (0.59)
1987	1.380 (0.037)	10.27	0.725 (0.019)	1.58 (0.59)
1992	1.375 (0.040)	9.38	0.727 (0.021)	1.47 (0.60)
1997	1.333 (0.042)	7.93	0.750 (0.024)	1.77 (0.61)

Note: The formulas used to derive this elasticity is shown in (11). Standard deviations are presented in parentheses. The third column above displays the t-statistics under the null hypothesis.

Appendix A: SUR Parameter Estimates and Adjusted R^2 Values

Parameter	Estimate	Std. Dev.
α_0	2.985	0.267
α_y	0.258	0.053
α_d	0.731	0.019
α_e	0.055	0.004
α_k	0.029	0.010
α_l	0.184	0.008
α_m	0.001	0.010
β_{dd}	-0.007	0.004
β_{de}	-0.012	0.001
β_{dm}	-0.003	0.001
β_{ee}	0.008	0.000
β_{em}	0.000	0.000
β_{kd}	0.020	0.003
β_{ke}	0.003	0.001
β_{kk}	-0.025	0.003
β_{km}	0.001	0.001
β_{ld}	0.002	0.001
β_{le}	0.001	0.000
β_{lk}	0.001	0.001
β_{ll}	-0.005	0.000
β_{lm}	0.001	0.000
β_{mm}	0.003	0.000
β_{yy}	0.094	0.006
δ_1	0.160	0.151
δ_2	0.693	0.354
δ_3	0.397	0.196
δ_4	2.362	0.125
δ_c	0.374	0.202
δ_{d1}	-0.029	0.007
δ_{d2}	-0.011	0.011
δ_{d3}	0.006	0.008
δ_{d4}	-0.035	0.008
δ_{dc}	0.007	0.008
δ_{ds}	0.001	0.005
δ_{e1}	-0.001	0.002
δ_{e2}	-0.004	0.002
δ_{e3}	-0.005	0.002
δ_{e4}	-0.003	0.002
δ_{ec}	0.004	0.002

Parameter	Estimate	Std. Dev.
δ_{es}	0.004	0.001
δ_{k1}	0.008	0.004
δ_{k2}	0.002	0.005
δ_{k3}	0.000	0.004
δ_{k4}	0.010	0.004
δ_{kc}	-0.003	0.004
δ_{ks}	0.000	0.003
δ_{l1}	0.012	0.003
δ_{l2}	0.002	0.005
δ_{l3}	-0.004	0.003
δ_{l4}	0.017	0.004
δ_{lc}	-0.011	0.003
δ_{ls}	0.010	0.002
δ_{m1}	0.010	0.004
δ_{m2}	0.010	0.006
δ_{m3}	0.003	0.004
δ_{m4}	0.011	0.005
δ_{mc}	0.004	0.004
δ_{ms}	-0.014	0.003
δ_s	1.721	0.070
δ_{y1}	-0.003	0.019
δ_{y2}	-0.041	0.043
δ_{y3}	-0.024	0.022
δ_{y4}	-0.235	0.017
δ_{yc}	-0.012	0.023
δ_{ys}	-0.237	0.011
ϕ_T	0.097	0.010
ϕ_{Td}	-0.008	0.000
ϕ_{Te}	0.0005	0.000
ϕ_{Tk}	0.008	0.000
ϕ_{Tl}	-0.001	0.000
ϕ_{Tm}	0.002	0.000
ϕ_{TT}	-0.001	0.000
ϕ_{Ty}	-0.010	0.001
γ_{yd}	0.028	0.002
γ_{ye}	-0.007	0.000
γ_{yk}	-0.007	0.001
γ_{yl}	-0.013	0.001
γ_{ym}	0.000	0.001

Adjusted Equation R^2 Values
Obtained from SUR Estimation

Equation	Adj. R^2
Labor	0.137
Capital	0.401
Dairy Inputs	0.201
Energy	0.073
Cost Function	0.970