WP 2008-11
May 2008

Working Paper

Department of Applied Economics and Management
Cornell University, Ithaca, New York 14853-7801 USA

Empirical Analysis of Stanchion and Parlor Milking Cost on New York Dairy Farms

Kentaro Katsumata and Loren W. Tauer

Empirical Analysis of Stanchion and Parlor Milking Cost on New York Dairy Farms

Kentaro Katsumata and Loren Tauer

Kentaro Katsumata is a researcher at the Policy Research Institute of the Ministry of Agriculture, Forestry and Fisheries of Japan. Loren Tauer is a professor, Cornell University. The authors thank David Just for his assistance and comments.

Short Abstract (50 words): Cost functions were estimated for stanchion and parlor dairy farms. Economies of scale were found to exist over the entire range of sample output. Stanchion technology cost was lower than that of parlor over the sample range of output levels of stanchion technology, but parlor farms eventually experienced lower costs.

Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Dallas, TX, February 2-6, 2008

Abstract

This paper empirically estimates cost functions for two milking technologies, stanchion and parlor, using farm level data from New York dairy farms for the years 1993 through 2002. A translog cost function was estimated along with input cost share equations for each milking technology by Iterative Seemingly Unrelated Regression. Any pair of inputs among feed, hired Labor, and cows had some degree of substitutability except for a pair of feed and hired labor evaluated by the Allen elasticity, and that of hired labor and feed evaluated by the Morishima elasticity. Additionally, economies of scale were found to exist over the entire range of output levels of the samples. The cost of stanchion technology was lower than that of parlor technology over the sample range of output levels of stanchion technology, but because parlor using farms were larger and costs continually decline, parlor using farms eventually experience lower costs than farms milking with stanchions.

Introduction

The New York dairy sector in recent years has followed the U.S. industry trend towards fewer and larger farms. The number of operations with milk cows in New York decreased from 11,000 in 1993 to 7,200 in 2002. At the same time, milk production per operation increased from 1,038 thousand pounds in 1993 to 1,697 thousand pounds in 2002. More significantly is that operations with fewer than 100 cows declined from 9,100 to 5,400, while operations with over 200 cows increased from 400 to 600 during the same ten years, displaying a trend of decreasing numbers of small farms and increasing numbers of larger farms. (New York Agricultural Statistics Service, 2003).

There are two different types of milking technologies prevalent in New York, often referred to as “stanchion” and “parlor”. Stanchion barns are generally conventional stall housing for dairy cows, where cows are milked in stalls or stanchions. On the other hand, parlor milking is a milking system where cows enter a raised milking platform and leave after they are milked.

Generally, farms which parlor milk use free stall housing. It is inferred by economic intuition that dairy farms that milk by stanchion technology have small herd sizes because the technology is labor intensive, and dairy farms with large herd size use parlor technology which is more capital intensive. It is therefore presumed that the cost of production favors stanchion milking technology for small herd sizes and parlor milking technology for large herd sizes. Tauer (1998) shows this presumption to be true for New York dairy farms in 1995 by estimating cost curves separately for stanchion and parlor technologies.

Given the situation of the New York dairy sector, dairy farmers are facing decisions of whether or not to expand their herd sizes, and whether or not to switch their milking technology from stanchion to parlor if they expand their production scale. According to economic principles, only producers who achieve low cost production by pursuing economies of scale and management efficiency through the appropriate use of production technologies can survive over time in a competitive industry such as the dairy sector. Therefore, it is very important and useful to understand the structural characteristics of production cost and underlying production technology in the dairy industry.

This paper identifies the structural cost characteristics of the two basic types of milking systems used in New York, by estimating cost functions for these technologies. Cost functions are estimated separately for stanchion and parlor technologies using panel data because these different technologies are expected to result in different production costs. This approach allows us to examine the structural characteristics of the underlying production technology, such as input shares of total cost, input demand elasticity, elasticity of substitution between inputs, and economies of scale, separately for stanchion and parlor technology. In addition, farm size where it is cost optimal for a farmer to switch from stanchion to parlor milking at various input prices can be determined from these estimated cost functions.

Literature Review

Various studies have empirically estimated cost curves and functions using econometric analysis across a range of agricultural production industries including dairy. Previous studies of dairy production in England and Wales estimated long-run average cost curve equations, and reported that the average cost curves derived from these equations were U-shaped (Dawson and Hubbard, 1987; Mukhtar and Dawson, 1990; Hubbard, 1993) or L-shaped (Burton, Ozanne and Collinson, 1993).

Previous milk production cost studies using translog methodology in their econometric analyses, include Hoque and Adelaja (1984), who estimated a cost function using pooled time series-cross section data from five northeastern States to study structural changes in the dairy industry. The Allen elasticity of substitution, price elasticity of input demand, elasticity of scale, and rate of technical progress were calculated using the parameter estimates of the cost function, and showed that there was substitution between energy and non-energy inputs, and indicated the competitiveness of the dairy industry by the estimated elasticity of scale.

Grisley and Gitu (1984) also estimated a translog cost function using cross-section data of Pennsylvania State dairy farms in order to examine production structure of that industry. The substitutability between feed and hired labor was shown to be inelastic by the Allen elasticity of substitution, and price elasticities of input demand were also inelastic.

Moschini (1988) studied the cost structure of Ontario dairy farms by estimating a multiproduct hybrid-translog cost function using a panel data set at the farm level. All inputs were found to be net substitutes, by estimating price elasticities of compensated input demand instead of the Allen elasticities of substitution. Substitutability between feed and intermediate inputs and between feed and capital were found to be strong. The existence of scale economies was reported for a wide range of output level.

These studies implicitly assumed that all farmers used the same technology since they estimated only one cost curve equation and cost function for all producers.

Translog Cost Function Model

We assume the dairy farms have identical slope coefficients but different intercept terms in order to take into consideration the specific features of each dairy farm, such as management ability. Dummy variables for the intercept of each farm are introduced to capture this individual-specific effect. This fixed effect model rather than a random effect model is chosen because individual-specific effects such as management ability which is unobservable are presumed to be correlated with the output.

Dairy farms use four inputs: purchased feed (F), hired labor (L), dairy cows (C), and other inputs (O). The other category includes inputs used to produce crop for feed such as fertilizer, seed, fuel, tractor, rent, taxes, inputs for care and maintenance of the dairy herd such as veterinary, medicine, bedding, and operator and family labor.

All farmers are assumed to face the same prices of these inputs in a given year because individual farm input prices are not available. This is not unreasonable because the sample farmers are within the same state, and these input markets are competitive. It is also assumed that the single output is milk, and output level is exogenously determined.

Under these assumptions, the translog cost function, which is a second-order approximation of an unknown cost function, is specified as:

$$\ln C_{kt} = m + \sum_{l} a_l D_{kl} + \sum_{i} a_i \ln P_{it} + \frac{1}{2}\sum_{i}\sum_{j} g_{ij} \ln P_{it} \ln P_{jt} + a_Q \ln Q_{kt} + \frac{1}{2} g_{QQ} (\ln Q_{kt})^2 + \sum_{i} g_{iQ} \ln P_{it} \ln Q_{kt} \quad (1)$$

where C is total cost, Q is the quantity of milk sold, and P are input prices. The identifiers are i,j = F, L, C, O for the four inputs, k,l = for each dairy farm, and t = year from 1993 to 2002. The D variables are individual-specific effect dummy variables = 1 if k=l and = 0 otherwise. The m coefficient is a constant term and a_l, a_Q, a_i, a_l, g_{ij}, g_{QQ}. and. g_{iQ} are coefficient parameters to be estimated.

The cost function must be homogeneous of degree one in input prices specified by:

$$\sum_{i} a_i = 1, \quad \sum_{i} g_{ij} = \sum_{j} g_{ij} = 0, \quad \sum_{i} g_{iQ} = 0 \quad (2)$$

Cost share equations are derived through Shephard's lemma from the total cost function (1) as:

$$S_{ikt} = \frac{P_{it} X_{ikt}}{C_{kt}} = \frac{\partial C_{kt}}{\partial P_{it}} \cdot \frac{P_{it}}{C_{kt}} = \frac{\partial \ln C_{kt}}{\partial \ln P_{it}} = a_i + \sum_{j} g_{ij} \ln P_{jt} + g_{iQ} \ln Q_{kt} \quad (3)$$

where S is cost share, X is cost minimizing input demand, and the other notations are the same as in equation (1). If independent variables (the input prices and the quantity of output) are normalized by their mean values before estimation, the coefficient a_i in the equation (3) can be interpreted as the cost share of an input i to be estimated at the means of the independent variables. On the other hand, the other coefficients, g_{ij} and g_{iQ}, can be interpreted as the measures for the change of the cost share of an input i when the values of the dependent variables are away from their means. It is clear from equations (3) that the value of the cost share can be also interpreted as the elasticity of total cost with respect to the price of the input i.

A traditional measure for substitutability between inputs is the Allen elasticity of substitution. This can be calculated as:

$$\sigma_{ijkt} = \frac{g_{ij} + S_{ikt}S_{jkt}}{S_{ikt}S_{jkt}}, \quad i, j = F, L, C, O \text{ and } i \neq j$$

$$\sigma_{iikt} = \frac{g_{ii} + S_{ikt}^2 - S_{ikt}}{S_{ikt}^2}, \quad i = F, L, C, O \qquad (4)$$

Another well-known measure of elasticity of substitution is the Morishima elasticity of substitution, which can be calculated as:

$$\sigma_{ijkt}^{M} = S_{jkt}(\sigma_{ijkt} - \sigma_{jjkt}) = e_{ijkt} - e_{jjkt} \qquad (5)$$

where $i, j = F, L, C, O\,(i \neq j)$ and e is the price elasticity of input demand defined below.

A pair of inputs is classified as substitutes if the elasticity of substitution is positive and as complements if it is negative. The Allen elasticity measures how one input adjusts to a two input price ratio change. The Morishima elasticity measures relative input adjustment to an input price change. The Allen elasticity is symmetric, while the Morishima elasticity is not.

The price elasticity of input demand (ε) can be calculated as:

$$e_{ijkt} = \frac{g_{ij} + S_{ikt}S_{jkt}}{S_{ikt}}, \qquad i, j = F, L, C, O \text{ and } i \neq j$$

$$e_{iikt} = \frac{g_{ii} + S_{ikt}^2 - S_{ikt}}{S_{ikt}} \quad , \qquad i = F, L, C, O \tag{6}$$

When these elasticities are calculated at the sample means, the parameter estimates and fitted shares should replace the $g's$ and $S's$ in the equations (4), (5), and (6).

The measure of scale economies, that is, the elasticity of total cost with respect to output (Q) can be calculated from the estimated cost function as:

$$e_{cQkt} = \frac{\partial \ln C_{kt}}{\partial \ln Q_{kt}} = a_Q + g_{QQ} \ln Q_{kt} + \sum_i g_{iQ} \ln P_{it} \tag{7}$$

The cost elasticity less than one shows economies of scale and a value greater than one implies scale diseconomies. As is in the case of the cost share equations, the coefficient a_Q can be interpreted as the elasticity of total cost with respect to output at the sample means of the input prices and the output. The other coefficients, g_{QQ} and g_{iQ}, can be interpreted as the measures for the change of the cost elasticity when the values of the dependent variables change from their means.

In addition, the cost function (1) can be reduced to an average cost curve where the only independent variable is Q by fixing all the input price variables at specific values as:

$$\begin{aligned} & \ln C_{kt} = c_1 + (c_2 + a_Q) \ln Q_{kt} + \frac{1}{2} g_{QQ} (\ln Q_{kt})^2 \\ \Leftrightarrow \quad & C_{kt} = \exp\{c_1 + (c_2 + a_Q) \ln Q_{kt} + \frac{1}{2} g_{QQ} (\ln Q_{kt})^2\} \equiv C(Q_{kt}) \\ \Rightarrow \quad & AC_{kt} = \frac{C_{kt}}{Q_{kt}} = \frac{C(Q_{kt})}{Q_{kt}} \end{aligned} \tag{8}$$

where c_1 and c_2 are constants.

Econometric Estimation

Although all the parameters of the cost function (1) can be obtained by estimating only the cost function, more efficient parameter estimates can be obtained by estimating the cost function jointly with the share equations as a system of equations. In order to specify a stochastic framework for this system to be estimated, it is necessary to add random error terms to the cost function and the share equations. The error terms are assumed to be normally distributed with mean zero. It is also assumed that the error terms are correlated for one dairy farm in the same year (contemporaneously correlated), but they are uncorrelated for one farm at different years and are also uncorrelated for different dairy farms at any years. Under the above specification of error terms, the cost function (1) and the share equations (3) can be estimated jointly by the Seemingly Unrelated Regression (SUR) method. SUR method provides asymptotically efficient estimators for this equation system of (1) and (3).

Since the shares always sum to unity, and the coefficients meet conditions of homogeneous of degree one in input prices (2), the sum of the error terms across the cost share equations must be zero at each observation. Thus, the estimated residual variance-covariance matrix for this estimation becomes singular. The common technique to solve this singularity problem is to arbitrarily drop one of the share equations from this equation system. According to Christensen and Greene (1976), maximum-likelihood estimates of an equation system are invariant whichever equation is dropped from the system, and the iterative SUR results in maximum-likelihood estimates.

Therefore, in this study the system of equation (1) and (3) with the share equation of the other input dropped is estimated by iterative SUR after imposing the constraint of homogeneity of degree one in input prices. At the same time, the constraint of coefficient equalities across the equations, which represent the coefficient relationships between the cost function and the share equations, is also imposed.

With the constraint of homogeneous of degree one of input prices (2), the parameters relating to the price of the “other input” variable can be eliminated from the equation system in the estimation. The eliminated parameters can be obtained from the remaining parameters to be directly estimated by using the homogeneity constraint. Variances of these eliminated parameters can be also calculated as a linear combination of the variances and covariances of the estimated remaining parameters. In addition, standard errors, z-values, and P-values of these eliminated parameters can be similarly calculated.

Thus, the final formulas for the equation system of the translog cost function and the share equations are as follows:

$$\ln(C_{kt}/P_{ot}) = m + \sum_{l} a_l D_{kl} + \sum_{i} a_i \ln(P_{it}/P_{ot}) + \frac{1}{2}\sum_{i}\sum_{j} g_{ij} \ln(P_{it}/P_{ot}) \ln(P_{jt}/P_{ot})$$

$$+ a_Q \ln Q_{kt} + \frac{1}{2} g_{QQ} (\ln Q_{kt})^2 + \sum_{i} g_{iQ} \ln(P_{it}/P_{ot}) \ln Q_{kt}$$

$$S_{ikt} = a_i + \sum_{j} g_{ij} \ln(P_{jt}/P_{ot}) + g_{iQ} \ln Q_{kt}$$

$$i, j = F, L, C \qquad (9)$$

where notations are the same as the equation (1).

Prior to the estimations, the data of the independent variables are normalized to one at their geometric means before taking their logarithms.

After the estimation, properties of the cost function such as monotonicity and concavity in input prices are verified. Monotonicity requires that first-order derivatives of a cost function with respect to input prices are non-negative, and concavity requires that the matrix of second-order derivatives (Hessian matrix) of a cost function is negative semi-definite. According to Hayashi, for the case of translog cost function, the conditions for monotonicity and concavity are as follows: The right hand sides of the coast share equations in (9) are non-negative for monotonicity. The matrix of g_{ij} is negative semi-definite for concavity. In particular, the diagonal elements of the matrix , g_{ff}, g_{ll}, and g_{cc} have to be non-positive.

Data

The data for all the variables except for input prices used in this study originate from farms that participated in the New York Dairy Farm Business Summary (NYDFBS) for the years 1993 though 2002. The NYDFBS extension program is primarily meant to help dairy farmers improve accounting and financial analysis techniques, develop managerial skills and solve business and financial management problems. These farm data are also used in dairy economics research. Participation in this program is voluntary, so that these farms are not drawn randomly from a population of New York dairy farms. Thus, the sample farms in this study do not necessarily represent the population of New York dairy farms.

Table 1 presents the values of average herd size (an average number of dairy cows on each farm during a year) and milk quantity per cow (pounds) respectively for New York state and the of farms in this program. The average farm in this program is larger and more productive as measured by output per cow than the average New York dairy farm. Therefore, the farms participating in this program may be regarded as being representative of better-managed and commercially viable New York dairy farms.

The data of input prices except for the interest and the proxy for “the other inputs” paid by dairy farmers were obtained from New York Agricultural Statistics, New York Crop and Livestock Report (NYASS), and Agricultural Prices of the USDA. The data of the interest and the proxy indices were derived from USDA-NASS Agricultural Statistics. The NYDFBS extension program did not collect data of the input prices at the dairy farm level (the farm gate prices) and therefore individual farm input prices are not available.

The total cost of producing milk includes the operating cost, the depreciation cost, and the imputed cost of producing milk. The operating cost is calculated by subtracting the total accrual non-milk receipts (cull cows, calves, and excess feed sold) from the total operating expenses (including the cost of expansion livestock to offset any related inventory increase included in accrual receipts). This calculation assumes that the cost of producing non-milk products is equal to their value. Although the translog cost function can accommodate multiple outputs, this approach and approximation to estimating the cost of non-milk products can be justified because the sales of non-milk products are small compared to the milk sales (less than 10%) of each farm in the NYDFBS final report (Knoblauch, Putnam, and Karszes), and that small percentage represents mostly by products from milk production, such as calves and cull dairy cows. The depreciation cost comprises of machinery and building depreciation. The imputed cost consists of the opportunity cost of the equity capital and the operator’s labor and management, and the value of unpaid family labor. The quantity of milk is defined as pounds of milk sold (accrual) by farms in each year.

The four cost shares of inputs are for purchased feed, hired labor, cow, and other inputs. The respective variables are calculated by dividing each input cost by the total cost. The cost of feed is the accrual expenses for purchased feed, and the cost of labor represents the accrual expenses for hired labor. The cost of cow represents the expenditures of keeping and expanding herd size, and it comprises the accrual expenses of replacement and expansion of dairy cows, breeding dairy cows, cattle lease and rent, and custom boarding. The cost share of other inputs is derived by subtracting the sum of these three cost shares from unity.

Table 1 Herd Size and Quantity of Milk in NY and NYDFBS

Year	Herd Size (No. of Cows)		Milk per Cow (Pounds)	
	NY Average	NYDFBS Average	NY Average	NYDFBS Average
1993	66	130	15,702	18,858
1994	67	151	15,877	20,091
1995	70	160	16,501	20,269
1996	76	167	16,396	20,113
1997	78	190	16,495	20,651
1998	81	210	16,762	20,900
1999	85	224	17,235	21,439
2000	87	246	17,378	21,516
2001	93	277	17,530	21,762
2002	95	297	18,019	22,312

Source: New York State Department of Agriculture and Markets, and New York Agricultural Statistics Service, 2003. New York State Agricultural Statistics: Annual Bulletin 2002-2003, and Knoblanch, W.K., Putnam, L.D., and Karszes, J., 2003. Dairy Farm Management: Business Summary New York State 2002, Department of Applied Economics and Management, Cornell University Agricultural Experiment Station

There are four input price variables for purchased feed, hired labor, cow, and other inputs. The price of purchased feed represents the Northeast region average price of mixed dairy feed with 16% protein ($/ton). The price of hired labor is wage rate for all hired farm workers ($/hour), and it is based on the value of New York and New England combined. The price of cow is defined as the New York average price of dairy cows for replacements

($/head), while the price of other inputs is a price index for all commodities and is regarded in this study as a proxy for the other inputs.

The input price variables shown in Table 2 are indexed by the values of the year 1993 as the index base (= 1.0). The prices of each input for each farm have the same value for each year because individual input price data at the farm level could not be obtained.

Table 3 Input Price Indices

Year	PFEED	PLAB	PCOW	PO
1993	1	1	1	1
1994	1.0585	1.0296	1	1.0192
1995	1.0234	1.0237	0.9182	1.0385
1996	1.3216	1.0636	0.9364	1.1058
1997	1.2632	1.1287	0.8909	1.1442
1998	1.1637	1.1287	0.9545	1.0865
1999	1.0234	1.2012	1.1364	1.0673
2000	1.0175	1.2929	1.1364	1.1154
2001	1.0292	1.2899	1.4545	1.1538
2002	1.0409	1.3698	1.2727	1.1442

The NYDFBS classifies the milking system types of the farms into seven groups: (1.Bucket and Carry; 2.Dumping Station; 3.Pipeline; 4.Herringbone; 5.Parallel; 6. Rotary; 7.Other), and farms were regarded as stanchion technology farms if their milking systems were type 1, 2 or 3, parlor technology otherwise.

Figure 1 shows the mean value of the total cost per hundredweight each year for stanchion and parlor technology respectively. The cost movements over the 10 years of both technologies were similar.

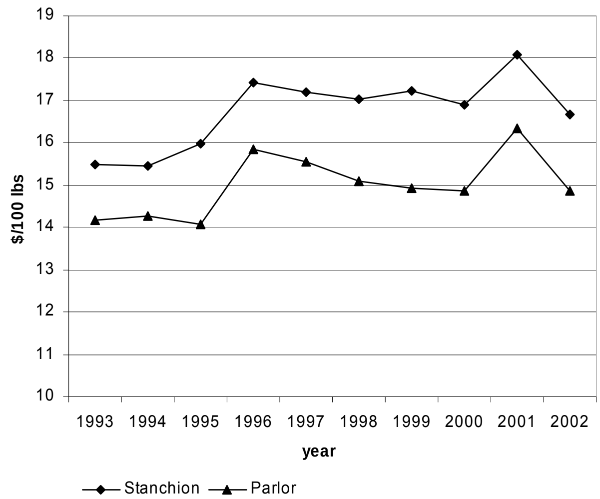

Figure1.Total Cost per Hundredweight for Stanchion and Parlor

The trends in quantity of milk at their mean values for stanchion and parlor technology respectively are shown in Figure 2. The trend of parlor technology increased more than twice during the ten years, while that of stanchion technology changed slightly.

As was stated previously, participation of the dairy farms in NYDFBS extension program is voluntary. Over the ten-year period some dairy farms participated every year, others participated some but not other years, while some began or discontinued participation sometime during the ten-year period. In addition, a few farms participating in this program changed their milking technology from stanchion to parlor. Consequently, the cross-sectional data used for the cost curve approach have different composition of farms each year, and a different number of observations each year, and thus the panel data sets used for the cost function approach are unbalanced. Table 3 presents the composition of the unbalanced panel data sets for stanchion and parlor technology by sorting the farms according to their frequency (the number of years) of participation in the program.

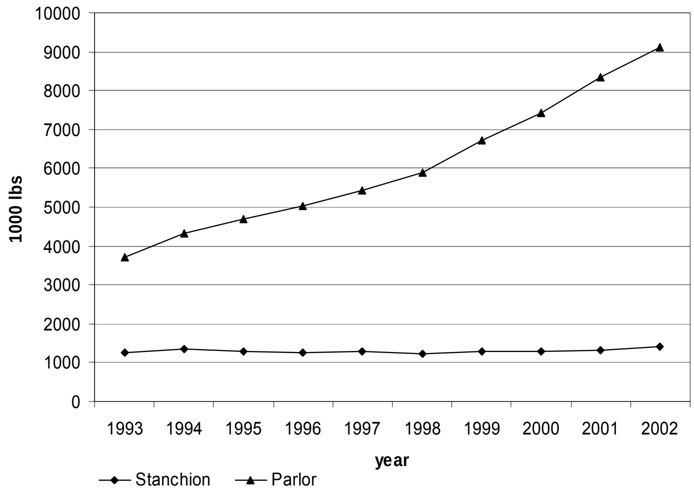

Figure 2 Trends in Quantity of Milk at Mean Values for Stanchion and Parlor Technology

Table 3 Composition of Panel Data

Frequency	Stanchion		Parlor	
	Farms	Observations	Farms	Observations
10	13	130	39	390
9	19	171	19	171
8	12	96	23	184
7	21	147	19	133
6	15	90	24	144
5	27	135	42	210
4	29	116	26	104
3	46	138	39	117
2	64	128	53	106
1	148	148	103	103
Total	394	1299	387	1662

NOTE: Frequency is the number of years of farm's participating in the NYDFBS extension program

Results of Estimating the Cost function and Its Share Equation System

The estimation results of the translog cost function model and the share equations (9) with constraints on coefficient equalities across equations consistent with economic theory for both stanchion and parlor technology are presented in Table 4. All the directly estimated coefficients except for g_{CC}, g_{QQ}, and g_{CQ} for stanchion technology, and g_{CC} and g_{FL} for parlor technology are significantly different from zero at the 1 percent probability level. The six coefficients of the translog cost function relating to the price of "other input" which were deleted in the estimation equations are calculated directly from the estimated parameters by using the homogeneity constraint in input prices (2). In addition, standard errors, z-values, and P-values of these excluded parameters are also calculated by the procedure described earlier. The estimated coefficients on the farm dummy variables (393 parameters for stanchion and 386 parameters for parlor technology) are not reported in this table to save space.

R^2 values for the stanchion technology are 0.93 for the cost function, 0.05 for the feed share equation, 0.17 for the labor equation, and -0.01 for the cow share equation, while R^2 values for the parlor technology are 0.99 for the cost function, 0.06 for the feed share equation, 0.39 for the labor equation, and 0.02 for the cow share equation. The R^2 value for the cost function of each technology is high indicating a very good fit of the cost function.

Cost Function Properties and Tests for Underlying Technology

The conditions for monotonicity of the estimated cost functions in prices evaluated at the sample geometric means of independent variables are satisfied for both stanchion and parlor technology because all the estimated values of the parameters a_F, a_L, a_C, and a_O are positive. However, since the values of the parameters g_{FF}, g_{CC} and g_{OO} are positive, the conditions for the concavity of the estimated cost functions in prices are violated. This violation could be corrected by imposing negative constraints on the estimation, but this requires specialized code, with results that are forced on the system estimation.

Table 5 Results of the SUR Estimates

Parameter	Stanchion: Obs. 1299				Parlor: Obs. 1661			
	Estimate	Std. Err.	z	P>z	Estimate	Std. Err.	Z	P>z
a_F	0.251931	0.00210	120.2	0.000	0.28099	0.00158	177.75	0.000
a_L	0.062687	0.00151	41.43	0.000	0.12291	0.00127	97.13	0.000
a_C	0.034481	0.00125	27.48	0.000	0.05536	0.00145	38.06	0.000
a_O	0.650901	0.00276	235.5	0.000	0.54074	0.00221	244.33	0.000
g_{FF}	0.093547	0.02722	3.44	0.001	0.14455	0.02455	5.89	0.000
g_{LL}	-0.08845	0.03035	-2.91	0.004	-0.07206	0.02586	-2.79	0.005
g_{CC}	0.014407	0.01618	0.89	0.373	0.01407	0.01638	0.86	0.390
g_{OO}	0.085399	0.08963	0.95	0.342	0.27594	0.08280	3.33	0.001
g_{FL}	-0.07256	0.02224	-3.26	0.001	-0.00949	0.01979	-0.48	0.632
g_{FC}	0.063634	0.01676	3.80	0.000	0.04732	0.01559	3.04	0.002
g_{FO}	-0.08846	0.04554	-1.94	0.052	-0.18238	0.04254	-4.29	0.000
g_{LC}	0.041874	0.01608	2.60	0.009	0.05687	0.01479	3.85	0.000
g_{LO}	0.119137	0.04396	2.71	0.007	0.02469	0.03852	0.64	0.522
g_{CO}	-0.11992	0.02800	-4.28	0.000	-0.11825	0.02600	-4.55	0.000
a_Q	0.745715	0.02191	34.03	0.000	0.84757	0.01061	79.86	0.000
g_Q	0.06927	0.04295	1.61	0.107	0.06681	0.01398	4.78	0.000
g_{FQ}	0.02772	0.00420	6.61	0.000	0.01658	0.00190	8.72	0.000
g_{LQ}	0.049017	0.00303	16.17	0.000	0.04835	0.00154	31.44	0.000
g_{CQ}	0.000371	0.00251	0.15	0.883	0.00882	0.00175	5.05	0.000
g_{Oq}	-0.07711	0.00555	-13.87	0.000	-0.07375	0.00268	-27.48	0.000
m	12.20537	0.03164	385.8	0.000	13.28	0.02356	563.71	0.000

Coefficients of dummy variables are omitted

NOTE: The parameters a_O, g_{FO}, g_{LO}, g_{CO}, g_{OO}, and g_{OQ} are calculated from the homogeneity of degree one in input prices. The standard errors, z-values, and P-values are also calculated from linear combinations of the variances and covariances of the remaining parameters.

Input Cost Shares (Cost Elasticities with respect to Input Prices)

Table 6 reports the input shares and various elasticities evaluated at the sample means. In both cases of stanchion and parlor technology, the feed share accounts for more than 25% of the total costs, and it is the highest share value of all inputs other than the composite variable of other inputs. The hired labor share of parlor technology (12.3%) is about twice as high as the stanchion technology (6.3%), reflecting the fact that dairy farms with parlor technology hire more workers than those with stanchion technology. According to the parameters (g_{FQ}, g_{LQ}, and g_{CQ}) which are all significantly different from zero, the feed share, the labor share, and cow share increase with the quantity of milk, increasing in both stanchion and parlor technology. Among them, the change of the hired labor share is most sensitive, implying that dairy farms become more hired labor intensive as the production increases. The estimated coefficients also infer that farms using parlor technology tend to expend more on dairy cows than those with stanchion technology as the output level increases, because the parameter g_{CQ} of parlor technology is much higher than that of stanchion technology.

Input Demand Elasticities

The evaluated elasticities of input demand with respect to prices of inputs are reported in Table 6. These elasticities are based upon cost minimization behavior and limited price data variability, and thus must be interpreted cautiously. Own elasticities of input demand for feed, hired labor, and cow all have negative signs as expected. (The elasticity of other input for the parlor is positive, but it is relatively small at 0.05). Thus, other than for the "other input" an increase in the price of an input results in a decrease in the demand quantity of that input. Much of the “other input” consists of quasi-fixed inputs, which are modeled to change with prices, but which may not have changed much to prices over this 10 year period, especially family labor and capital. The elasticity of hired labor is most elastic, -2.35 for stanchion technology, and –1.46 for parlor technology, implying that use of hired labor is price sensitive but less so in the parlor farms than the stanchion farms. This result is logical since many of the larger parlor farms are very dependent upon hired labor. The input demand elasticities for feed and cows are lower than hired labor and similar for both stanchion and parlor technology. For instance, the demand elasticity for cows is -0.548 in the stanchion technology and is -0.691 in the parlor technology.

Elasticities of Substitution

Table 6 also reports the Allen elasticities of substitution. The signs of own price elasticities are the same as those of the input demand elasticities. There is substitution between feed and cows, and hired labor and cows in both technologies. Feed and hired labor are complements in stanchion technology (-3.59), while they are substitutes in parlor technology which is inelastic (0.725).

Table 6 also presents the Morishima elasticities of substitution. The Morishima value of 2.123 on feed associated with a change in hired labor price in the stanchion barn case indicates that an increase in hired labor price leads to an increase in feed usage. To illustrate the differences in the Allen and Morishima elasticity measures, check the values of the two feed elasticities;

Table 6 Elasticities Computed from the Tranlog Cost Functions

	Stanchion				Parlor			
	Feed	Hired Labor	Cow	Other	Feed	Hired Labor	Cow	Other
Input Cost Shares	0.252	0.063	0.034	0.651	0.281	0.123	0.055	0.541
Input Demand Elasticities								
Feed	-0.38	-0.225	0.287	0.315	-0.205	0.089	0.224	-0.108
Hired Labor	-0.91	-2.348	0.702	2.551	0.2038	-1.46	0.518	0.742
Cow	2.097	1.277	-0.548	-2.83	1.1358	1.15	-0.691	-1.595
Other	0.122	0.246	-0.15	-0.22	-0.056	0.169	-0.163	0.051
Allen elasticities of substitution								
Feed	-1.5	-3.594	8.325	0.484	-0.728	0.725	4.042	-0.2
Hired Labor		-37.46	20.37	3.92		-11.9	9.358	1.371
Cow			-15.88	-4.34			-12.47	-2.95
Other				-0.33				0.094
Morishima elasticities of substitution								
Feed		2.123	0.835	0.533		1.553	0.914	-0.159
Hired Labor	-0.53		1.25	2.769	0.4084		1.209	0.691
Cow	2.474	3.625		-2.61	1.3404	2.614		-1.646
Other	0.499	2.594	0.398		0.1483	1.632	0.527	

-3.594 (Allen) and 2.123 (Morishima) associated with a change in labor price in the stanchion case. According to the Allen elasticity, as labor price rises, feed usage declines; they are classified as complements. On the other hand, the Morishima elasticity shows that as hired labor price rises, feed usage increases. A property of the Morishima elasticities is asymmetry. For instance, in stanchion technology, there is substitutability between feed and hired labor with respect to a change in hired labor price (2.123), but slight complementary relationship is observed between feed and hired labor with respect to a change in feed price (-0.53).

Economies of Scale

The cost elasticities for the stanchion and parlor technologies are 0.746 and 0.848 respectively, and they are significantly below one at the 1 percent probability level (Table 5). This demonstrates that there are economies of scale in milk production at the mean production level, and the economy of scale in stanchion technology at its mean production level is greater than that of parlor technology at its mean production level.

The coefficients of quadratic output term of cost functions (g_{QQ}) are about 0.069 and 0.067 respectively for stanchion and parlor technology. Only the coefficient of parlor technology is statistically significant. Therefore, the degree of scale economies decrease as milk output increases in the parlor technology, and the same is expected with stanchion technology.

In addition, the parameters of the interaction terms of output level and prices of feed, hired labor, and cow (g_{FQ}, g_{LQ} and g_{CQ}) are positive, though they are very small. Thus, an increase in these input prices would also result in a decline of scale economies in the milk production.

The cost elasticities with respect to various output levels can also be calculated from the equation (8). The values of the cost elasticity at the largest output of the sample range and at the geometric means of input prices are about 0.836 for stanchion technology (at Q= 4189 thousand lbs) and about 1.002 (at Q= 42000 thousand lbs) for parlor technology. Therefore, the economies of scale of stanchion technology are not exhausted within the sample range of output, while those of parlor technology are just exhausted. This implies that given current technology, the largest parlor farms may have exhausted all economies of scale (at about 2,000 cows), although there are a limited number of observations at these large herd sizes, questioning the validity of this result.

Average Cost Curves

Average cost curves that represent the scale of economies analyzed in the previous section can be derived from equation (9) by using the estimated parameters of the translog cost functions. The average cost curves in Figure 3 are plotted over the sample output ranges respectively for stanchion and parlor technology evaluated at the input prices for year 2002. The average cost of parlor technology becomes lower than that of stanchion technology with the output level beyond about 16462 thousand lbs, and the optimal average cost is about 12.80 ($ per hundredweight) which is achieved at the output level of about 37501 thousand lbs. (see Figure 3). These average cost curves shift upwards in all cases with the increase of input prices, with the effects of feed price change the largest of the three inputs. The average cost

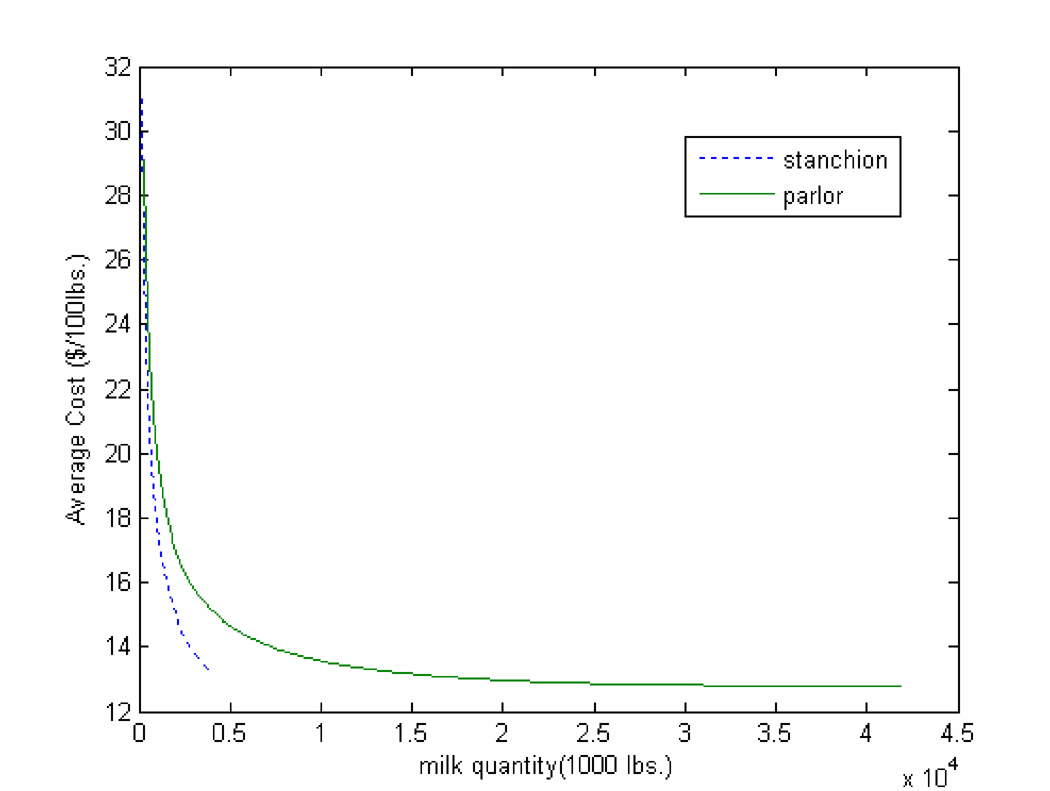

Figure 3. Average Cost Curves for Stanchion and Parlor Technology Derived from the Translog Cost Function

curve of stanchion technology is lower than that of parlor technology, and these two curves do not cross within the sample range of milk production. Thus, a cost advantage switching point from stanchion to parlor technology does not exist within the range of the data. The lowest average cost of stanchion technology is about 13.10 ($ per hundredweight) at the largest output level of the sample for this technology (about 4189 thousand pounds). These results clearly show that smaller farms should stay with stanchion technology.

Summary and Conclusions

This study analyzed empirically the structural characteristics of production cost on New York dairy farms. Cost functions were estimated for two milking technologies: stanchion and parlor, using the farm level data from the years 1993 through 2002.

A translog cost function specified as a fixed effects model was estimated with input cost share equations for each milking technology by the Seemingly Unrelated Regression method using a panel data set. This approach provided measures of input cost shares (cost elasticities with respect to input prices), input demand elasticities, and elasticities of substitution between inputs, all calculated from the parameters of the estimated cost functions. The feed share accounts for more than 25% of the total cost in both two technologies, and the hired labor share of parlor technology is about twice as high as that of stanchion technology. The elasticities of hired labor input demand are elastic, while those of the other three inputs are inelastic.

The substitutability between inputs was evaluated by the Allen and the Morishima elasticities of substitution. Any pair of inputs among feed, hired labor, and cows has some substitutability except for a pair of feed and hired labor evaluated by the Allen elasticity and that of hired labor and feed evaluated by the Morishima elasticity. Additionally, a measure of scale economies in terms of the elasticities of total cost with respect to output was also calculated. Economies of scale were found to exist over the range of output levels of the samples, and scale economies of stanchion technology were not exhausted, while those of parlor technology are just exhausted at the farm with the largest production scale within the sample range. Average cost curves derived from the estimated cost function show that the cost of stanchion technology is lower than that of parlor technology within the entire sample range of output of stanchion technology. It may be that stanchion costs eventually exceed the cost of parlor milking but that is not observed with the farm sizes found in the data.

The existence of scale economies in producing milk was verified for most dairy farms. This suggests that dairy farms can pursue lower unit cost of production milk by expanding their herd sizes Therefore, the trend towards larger units in New York dairy industry is expected to continue in the foreseeable future.

REFERENCES

Aguero, J.M., and Gould, B.W., 2004. “Structural Changes in U.S. Cheese Manufacturing: A Translog Cost Analysis of a Panel of Cheese Plants”, Paper Presented at the 2004 Annual Meeting American Agricultural Economics Association

Ball, V.E., and Chambers, R.G., 1982. “An Economic Analysis of Technology in the Meat Products Industry”, American Journal of Agricultural Economics, 64, 699-709

Berndt, E.R., 1991. The Practice of Econometrics: Classic and Contemporary, Addison-Wesley, 469-476

Burton, M.P., Ozanne, A. and Collinson, C., 1993. “Long-Run Average Cost Curves in the England and Wales Dairy Industry - Comment”, Journal of Agricultural Economics, 44, 502-506

Christensen, L.R., and Greene W.H., 1976. “Economies of Scale in U.S. Electric Power Generation”, Journal of Political Economy, 84, 655-676

Dawson, P.J., and Hubbard, L.J., 1987. “Management and Size Economics in the England and Wales Dairy Sector”, Journal of Agricultural Economics, 38, 27-37

Grisley, W., and Gitu, K.W., 1984. “The Production Structure of Pennsylvania Dairy Farms”, Northeastern Journal of Agricultural and Resource Economics, 13, 245-253

Gujarati, D.N., 2003. Basic Econometrics, Forth Edition, MacGraw-Hill, 636-652

Hayashi, H., 2000. Econometrics, Princeton University Press, 298-306

Hoque, A., and Adelaja, A., 1984. “Factor Demand and Returns to Scale in

Milk Production: Effects of Prices, Substitution and Technology", Northeastern journal of agricultural and resource economics, 13, 238-244

Hubbard, L. J., 1993. "Long-Run Average Cost Curves in the England and Wales Dairy Sector", Journal of Agricultural Economics, 44, 144-148

Hubbard, L.J., 1993. "Long-Run Average Cost Curves in the England and Wales Dairy Industry - Reply", Journal of Agricultural Economics, 44, 507-508

Knoblanch, W.A., Putnam, L.D., and Karszes, J., 2003. Dairy Farm Management: Business Summary New York State 2002, Department of Applied Economics and Management, Cornell University Agricultural Experiment Station

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

Martinez-Budria, E., Jara-Diaz, S., and Ramos Real, F.J., 2003. "Adapting Productivity Theory to the Quadratic Cost Function. An Application to the Spanish Electric Sector", Journal of Productivity Analysis, 20, 213-229

Moschini, G., 1988. "The Cost Structure of Ontario Dairy Farms: A Microeconometric Analysis", Canadian Journal of Agricultural Economics, 36, 187-206

Mukhtar, S. M., and Dawson, P.J., 1990. "Herd Size and Unit Costs of Production in the England and Wales Dairy sector", Journal of Agricultural Economics, 41, 9-20

New York State Department of Agriculture and Markets, and New York

Agricultural Statistics Service, 2002. Dairy Farm Transition Survey

New York State Department of Agriculture and Markets, and New York Agricultural Statistics Service, 2003. New York State Agricultural Statistics: Annual Bulletin 2002-2003

Schumacher, S.K., and Marsh, T.L., 2003. "Economies of Scale in the Floriculture Industry", Journal of Agricultural and Applied Economics, 35, 497-507

Stefenides, Z., and Tauer, L.W., 1999. "The Empirical Impact of Bovine Somatotropin on a Group of New York Dairy Farms", American Journal of Agricultural Economics, 81, 95-102

Tauer, L.W., 1998. "Cost of Production for Stanchion versus Parlor Milking in New York", Journal of Dairy Science, 81, 567-569

United States Department of Agriculture, 2003. Agricultural Statistics

United States Department of Agriculture, 2004. Agricultural Statistics

Verbeek, M., 2004. A Guide to Modern Econometrics, Second Edition, Wiley, 341-360

OTHER A.E.M. WORKING PAPERS

WP No	Title	Fee (if applicable)	Author(s)
2008-10	Are Higher 529 College Savings Plan Fees Linked to Greater State Tax Incentives?		Bogan, V.
2008-09	Microfinance Institutions: Does Capital Structure Matter?		Bogan, V.
2008-08	Estimation of Treatment Effects of recombinant Bovine Somatotropin using Matching Samples*		Tauer, L.
2008-07	Attacking Poverty: What is the Value Added of a Human Rights Approach?		Kanbur, R.
2008-06	Conceptualizing Economic Marginalization		Kanbur, R.
2008-05	Poverty Effects of the Minimum Wage: The Role of Household Employment Composition		Kanbur, R.
2008-04	Poverty Dynamics: Measurement and Understanding from an Interdisciplinary Perspective		Addison, T., Hulme, D. and R. Kanbur
2008-03	Globalization, Growth and Distribution: Framing the Questions		Kanbur, R.
2008-02	Revenue-Recycling and the Efficiency and Spatial Distributional Impacts of Development Taxes		Bento, A., Franco, S. and D. Kaffine
2008-01	The Impact of Ethanol Plants on Cropland Values in the Great Plains		Henderson, J. and B. Gloy
2007-21	The Economics of U.S. Ethanol Import Tariffs with a Consumption Mandate and Tax Credit		deGorter, H. and D.R. Just
2007-20	The Economics of a Biofuel Consumption Mandate and Excise-Tax Exemption: An Empirical Example of U.S. Ethanol Policy		deGorter, H. and D.R. Just
2007-19	Distributional and Efficiency Impacts of Increased U.S. Gasoline Taxes		Bento, A., Goulder, L., Jacobsen, M. and R. von Haefen
2007-18	Measuring the Welfare Effects of Slum Improvement Programs: The Case of Mumbai		Takeuchi, A., Cropper M. and A. Bento

Paper copies are being replaced by electronic Portable Document Files (PDFs). To request PDFs of AEM publications, write to (be sure to include your e-mail address): Publications, Department of Applied Economics and Management, Warren Hall, Cornell University, Ithaca, NY 14853-7801. If a fee is indicated, please include a check or money order made payable to Cornell University for the amount of your purchase. Visit our Web site *(http://aem.cornell.edu/research/wp.htm)* for a more complete list of recent bulletins.