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Technical Efficiency of New York Dairy Farms

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The technical efficiencies of New York dairy farms were estimated using a frontier production function. The average farm was 69 percent efficient. Individual farm efficiency was regressed on variables not considered inputs to explain why a farm was not on the frontier. Favorable location in the state and larger size (cows) as proxies for technology lead to greater efficiency. Participation in the Dairy Herd Improvement Cooperative and use of mail-in computerized records as proxies for management result in a reduction in efficiency. However, only 9 percent of variation in farm efficiency could be explained.

Introduction

The efficiency of a dairy farm will be paramount for survival with the changes that may occur in that industry in the years ahead. Those changes include an increased pace of technological change, both biological and nonbiological, as well as alterations in the marketing of milk, possibly including a movement to a free market. In such a dynamic and competitive environment only the more efficient farmers will generate profits and survive.

Efficiency in the firm includes technical efficiency, allocative (price) efficiency, and scale (size) efficiency. In this paper we measure technical efficiency by estimating a frontier production function for a group of New York dairy farmers using their 1984 farm records. Their individual technical efficiency is then computed. The failure of individual firms to be on the frontier production function is then explained by characteristics of the farm or the farm managers.

Measuring Technical Efficiency

The seminal paper on measuring efficiency was written by Farrell in 1957. Following a period of gestation, the last decade saw an

enormous number of articles published discussing the measurement of efficiencies by different techniques. A recent survey of studies estimating frontier functions was made by Forsund, Lovell, and Schmidt, and recent advances in defining and measuring efficiencies can be found in Fare, Grosskopf, and Lovell.

Frontier functions have been estimated for farmers in developing and developed countries (Shapiro; Bagi). In developed countries many of these functions have been estimated for dairy farms (Bravo-Ureta; Grisley and Mascarenhas; Russell and Young). As discussed by Forsund et al., an estimated production function can be used to determine technical efficiency. Combined allocative and technical efficiency can be derived from the cost curve, while allocative, technical, and scale efficiency can be obtained from the profit function.

Forsund et al. discuss the various procedures available to estimate deterministic and probabilistic frontier production functions. In this study a deterministic production function was estimated by corrected ordinary least squares (COLS) for a Cobb-Douglas form (log-linear).¹

COLS techniques require first estimating a function by OLS. The error term is assumed to satisfy all of the usual conditions except normality. Thus best linear unbiased estimates of

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¹ An alternate estimation technique is maximum likelihood estimation. Olson et al. show using Monte Carlo results that the COLS estimator is more (MSE) efficient than the maximum likelihood estimator for sample sizes 200 and below. Even for sample sizes of 800 and COLS is still superior for estimating β .

the parameters are obtained. Next a specific distribution is assumed for the error term. If the parameters of that distribution can be derived from its central moments, then these parameters can be consistently estimated from the moments of the OLS residuals, and used to shift the estimated OLS constant term. Greene has shown that shifting the estimated constant term upward by the amount of the largest residual assumes the error term is uniformly distributed. Using the largest residual does, however, make the results especially sensitive to data "outliers."

This COLS procedure assumes that the production frontier is deterministic and all variation in output is attributed to firm inefficiencies. This may be considered an unrealistic assumption given the biological nature of agricultural production. In fact, the typical assumption is that this biological stochastic process creates an error term that is normally distributed and independent of input variables. To correct for this limitation of frontier functions Aigner et al., proposed a stochastic frontier model with an error term composed of two parts. A symmetric component captures the stochastic nature of production, while a one-sided component captures the effects of inefficiency. Unfortunately, with that procedure there is no way to separate an individual observation (residual) into inefficient and random components.² The best that can be done is to derive an estimate of mean inefficiency for the sample (Forsund et al.). Since individual measures of inefficiency are desired that procedure is not useable here.

Data

Individual farm records from the 1984 New York Dairy Farm Summary were the data source (Smith, Knoblauch and Putnam). These data consist of income and balance sheet items as well as production information and farm characteristics. The dependent or output variable is the value of production from the dairy farm. It consists of the sum of the value of milk, livestock, and crops sold minus the cost of milk marketing, plus government payments received, machinery work, miscellaneous income, and the net change in live-

stock and feed inventory with livestock valued at beginning year prices.

Seven input categories were defined and are listed in Table 1. Hired labor input was the expenditure on hired labor, part of which may have been paid family labor. Operator and family labor consisted of the estimated value of operators' labor and management plus the value of unpaid family labor imputed at \$500 per month. The operators provided the estimate of the value of their own labor and management and thus may be a biased estimate. However, an estimate of the value of management was deemed a useful addition, even if that variable was estimated by the farmers themselves. Farmer self-estimation also occurs with inventory adjustments while accuracy of record keeping would also be reflected in the measurement of other variables. The third variable was purchased feed. Feed inventory adjustment was included in the output variable rather than the feed purchased input variable, because feed was both grown and purchased, and thus feed inventory change (output) was due to the productivity of all seven inputs.

Machinery and crop expenses consisted of machinery service, which was computed as 5 percent (interest) on the beginning inventory value of machinery, minus the net change in machinery inventory, adjusting for machinery sales and purchases, as a measure of economic depreciation. As Yotopoulos has shown this is not an entirely accurate measure but the information to make the necessary corrections was not available by farm. To machinery service was added fuel (minus fuel tax refund), machine services hired, machine repair, fertilizer, seed, and crop chemical expenses.

Livestock expenses were breeding expenses, veterinary expenses and other livestock expenses, as well as 5 percent interest on beginning livestock. Added to livestock expense was livestock purchased for replacement purposes which was considered a proxy for animal depreciation which was not collected. (Farmers separate livestock purchases into those for replacement and those for expansion).

Real estate input consisted of real estate service, which was computed as 5 percent of beginning inventory (interest) plus building tax depreciation, building repair, real estate taxes and any real estate rent paid. Tax depreciation on buildings was assumed to be a reasonable proxy for economic depreciation on

² Recently, however, Jondrow et al. have devised a procedure that permits individual measures of efficiency.

buildings. Miscellaneous expenses input consisted of farm auto expenses, insurance, electricity, telephone, and other expenses.

Individual expense and inventory items used to arrive at these variables are those items used and reported in the New York Dairy Farm Business Summary (Smith, Knoblauch and Putnam). Five percent interest on inventory to compute machinery, livestock, and real estate inputs was chosen since 5 percent is the estimate of the real rate of interest used in the Business Summary program to impute the opportunity cost of equity capital. Inflation cost of money is assumed to be recovered by asset appreciation. The \$500 a month for unpaid family labor used here is also the value used in the Farm Business Summary. A summary of the variables is listed in Table 1.

The number of farms in the summary program for 1984 was 545. Sixty-six dairy farms that participated in the dairy diversion program that year were eliminated from the data set. Other farms that purchased most of their feed or replacement livestock or who had significant portions of their gross returns from non-milk sales were also eliminated. It was felt that all these farms operated under technologies different enough to be excluded. To measure technical efficiency the same basic production techniques must be used by all the farmers in the data set or separate production functions should be estimated. If the error term is the same these different functions may be estimated using dummy variables. Ten farms were removed who purchased more than \$924 of feed per cow, which was two times the standard deviation plus the mean of feed purchases for the sample. Twenty-one farms were removed whose total purchases of

livestock were more than \$167 per cow, again two standard deviations greater than the mean. This not only eliminated farms which were purchasing most of their replacements but also those involved in major expansion. Eighteen farms were eliminated whose total gross receipts were more than 1.3 of milk sales. Again this was two standard deviations above the mean and indicated substantial non-dairy income. These eliminations resulted in a final data set of 432 observations.

Results

The Cobb-Douglas production function estimated in log form using ordinary least squares is presented in Table 2. All coefficients are of the expected signs. The function has an output elasticity of 1.076 and thus exhibits slight increasing returns to scale.³ The marginal value products of the seven inputs evaluated at their geometric means are reported in Table 3. Since all inputs are measured in dollars one would expect under expected profit maximization that marginal value products should be equal to 1. However, since prices are not known with certainty (nor output and possibly input), marginal products computed from observed data may be significantly different from those expected by the farmer in his input decisions. It is interesting that the marginal products for labor (family and hired), as well as for real estate are less than \$1. Of all the inputs listed labor and real estate are probably the least flexible. Since 1984 was a relatively unprofitable year compared to previous years, farmers may not yet have adjusted their use of

³ The $F_{1,424}$ test value was 15.95 under the null hypothesis that output elasticity was equal to 1.

Table 1. Summary Statistics on Output and Inputs, 432 New York Dairy Farms, 1984

Variable	Mean	Standard Deviation	Minimum	Maximum*
Gross Receipts	\$186,099	\$167,149	\$29,505	\$1,800,000
Hired Labor	18,074	27,409	1**	300,000
Family Labor	23,092	10,670	1,500	80,000
Feed Purchases	45,126	41,959	5,583	500,000
Machinery and				
Crop Expenses	45,556	41,372	4,626	300,000
Livestock Expenses	20,291	17,615	2,162	200,000
Real Estate Expenses	28,301	22,731	1,683	200,000
Miscellaneous Expenses	10,161	6,734	1,904	50,000
Cows (number)	85	65	20	700

* Approximates to prevent disclosure. Maximums and minimums are not all from the same farm.

** Not set at 0 to allow use of logs in statistical estimation.

Table 2. Estimated Cobb-Douglas Dairy Farm Production Function, 432 New York Dairy Farms, 1984

Variable	Estimated Coefficient	Standard Error	t-Ratio*
Intercept	1.099	0.191	5.75
Hired Labor	0.014	0.003	4.69
Family Labor	0.098	0.020	4.82
Feed	0.288	0.017	16.70
Machinery Expenses	0.232	0.019	12.08
Livestock Expenses	0.211	0.024	8.61
Real Estate Expenses	0.122	0.019	6.36
Miscellaneous Expenses	0.111	0.023	4.92
$\bar{R}^2 = 0.94$			
F-ratio = 1024.15			
N = 432			

* All significant at the .01 level.

labor and real estate to the extent of the other variable inputs. The ability to attract good hired labor is important to these farmers and that labor may be considered almost as fixed as family labor.

The next step was to obtain the frontier function by shifting the intercept of the production function until no residual was positive and at least one was zero.⁴ When this was done the new intercept became 1.477. The estimated elasticities are not altered. The measure of technical efficiency, the ratio of actual to potential output, was then calculated for each observation. Potential output was calculated by substituting the actual input quantities into the frontier function (i.e., the corrected ordinary least squares equation).

The average ratio of technical efficiency of the group was 0.693, with a minimum of .316 (Table 4). This implies that on average the dairy farmers only obtained 69 percent of potential output from their use of a given set of inputs. This compares to an average of 72 percent for English dairy farms (Russell and Young), and an average cost efficiency of 70 percent for small Pennsylvania dairy farms (<60 cows) and 80 percent for large Pennsylvania dairy farms (Grisley and Mascarenhas), and 82 percent for New England dairy farms (Bravo-Ureta).

The question then arises as to why a farmer was not on the frontier. Or, in other words, to explain the difference between the actual output of a farmer and the frontier output, or

Table 3. Marginal Products of Inputs used in Dairy Production Evaluated at Geometric Means, 432 New York Dairy Farms, 1984

Input	Marginal Product
Hired Labor	\$0.526
Family Labor	0.682
Feed	1.200
Machinery Expenses	1.015
Livestock Expenses	1.955
Real Estate Expenses	0.806
Miscellaneous Expenses	1.929

alternatively, the measure of efficiency. Stigler has expressed the view that all perceived technical inefficiency is allocative inefficiency which in itself is perceived because of the failure of the observer to measure all relevant inputs, or to correctly perceive what is being optimized, or to account for all the constraints on the optimization process, etc. Timmer and others argue that management ability can explain differences in efficiency. As Shapiro states, "technical efficiency refers to the manner in which the inputs are used," and the role of management is to make those decisions. Others argue that farmers may simply waste inputs, or the sheeps in the meadow, the cows in the corn, syndrome. Hall and Winsten also state that differences in measured technical efficiency may simply be due to environmental variables, such as the climate. After reviewing many of these types of arguments, Forsund et al. conclude that the discussion is mainly philosophical.

In this study we have attempted to include all relevant inputs in the production function, even a measurement of management. The differences in soil and climate qualities should be reflected in the real estate input which was based on market values. Management input was estimated by each farmer in dollars. Obviously measurement error exists in all studies including this one, although we were able to explain most variation in output (94 percent).

Explaining Technical Efficiency

With a few exceptions (Page; Timmer; Grisley and Mascarenhas) most previous articles measuring technical efficiency reported technical efficiency without attempting to explain technical efficiency differences between observations. As stated earlier this may be appropriate since any explanation variable

⁴ As mentioned earlier, this approach is sensitive to data outliers. In order to deal with this problem, two extreme outliers were deleted before the intercept was shifted.

Table 4. Technical Efficiency of 430 New York Dairy Farms, 1984

Variable	Mean	Standard Deviation	Minimum Value	Maximum Value
Actual Output	\$186,099	\$167,149	\$29,505	\$1,800,000
Potential Output	266,777	220,728	56,752	2,355,048
Technical Efficiency Ratio	.693	.103	.316	1.00

should be included in estimating the frontier production function. In this study we attempted to include all relevant inputs, including a measure of management.

Yet, there may be constraints on a farm that are manifested by the type of inputs used within an input category. An example might be the necessity to use urea as a nitrogen fertilizer when anhydrous ammonia would be more productive, but not available, although total expenditure on fertilizer was identical. If those differences are considered important then they should be differentiated inputs in the production function. However, either those differences are not available from the data source (farm records) or *a priori* are not expected to be important. Even if constraints on input usage do not exist, different levels of managerial skills may explain optimal timing and use of specific inputs.

Another explanation of technical efficiency is that farmers are actually operating with different technologies. Since capital is aggregated into a dollar value, differences in technologies are not apparent. Yet, if the market is efficient then the value of inefficient or obsolete technologies should be lower so that their value of marginal product should be equal to that of more productive technology.

In order to test these ideas, technical efficiency of the sample farms was regressed on a number of dummy explanatory variables. Differences in technology were measured by type of barn and location within the state, since soils and crop growing conditions are variable across the state. Also included were cow numbers which may be a proxy for different technologies used.

Proxy variables for management input were also used. These included the commonly used age and education variables. For non sole proprietorships the age and education of the first listed manager were used. Also included was the type of record keeping system and participation in dairy production evaluation programs. A distinction was also made whether there was one manager per farm (sole

proprietor) or more. Sample farms that continuously participated in the New York Dairy Farm Business Summary program for each of the previous ten years were also identified. Finally, since credit constraints may have restricted the optimal selection of sub-inputs, the debt/asset ratio of each farm was used as a proxy for credit constraints. These variables are summarized in Table 5.

The technical efficiency was regressed on these 15 independent variables using OLS with a linear equation.⁵ The estimated equation explained 9 percent of the variability of technical efficiency and 5 of the 15 explanatory variables were statistically different from zero.

The use of a mail-in record keeping system decreases the efficiency of a farm by almost three percentage points. Since the purpose of these programs is to reduce the clerical time a farmer spends entering record data and to provide him a detailed analysis of the business, this result is unexpected. However, many farmers still only keep records for tax purposes and many enroll in the mail-in systems in order to reduce their work load in keeping records. Often they do not keep current in their mailings and any analysis other than a final analysis is not particularly useful. It could also be that mail-in systems simply result in more expenses actually being recorded rather than lost in a pile of paper decreasing perceived but not actual efficiency. It might also be argued that farmers who use an account book acquire greater cognizance of the business performance as they enter numbers. That does not appear to be the case since the estimated coefficient on the account book dummy is statistically not different from zero.

The negative coefficient on participation in DHIC (Dairy Herd Improvement Cooperative) is especially surprising since the purpose

⁵ Since the technical efficiency falls between one and zero a logit model was also estimated. Since the statistical results were similar to the linear model, the linear model only is reported here. The derivatives of the linear model are constant which expedites reporting and analysis of results.

Table 5. Variables used to Explain Technical Efficiency of 430 New York Dairy Farms, 1984

Variable	Average Value or Number of Observations	Estimated Coefficient (t-value)
Stanchion Barn (dummy)	275	-.0084 (-0.70)
Account Book (dummy)	178	-.0070 (-.49)
Mail-in Records (dummy)	172	-.0274 (-1.86)*
On-Farm Computer Records (dummy)	10	-.0299 (-.86)
Dairy Herd Improvement Cooperative (dummy)	318	-.0294 (-1.89)*
Owner Sample for Dairy Production (dummy)	61	-.0028 (-.15)
Sole Proprietor (dummy)	308	.0126 (1.14)
Southwest New York (dummy)	66	.0000 (.00)
Northwest New York (dummy)	49	.0339 (1.89)*
Central New York (dummy)	49	.0409 (2.40)*
Northern New York (dummy)	79	.0152 (.99)
Catskill Area (dummy)	87	.0018 (.8017)
Participation in Record Program for 10 Years (dummy)	66	-.0032 (-.23)
Age (First Manager)	44.25	.0002 (.3669)
Education (First Manager)	13.05	.0001 (.07)
Cows	85.20	.0003 (3.30)*
Debt/Asset	.37	.0306 (1.3772)
Intercept		.6632 (13.65)*
F = 2.43		
R ² = .09		
N = 430		

* Significant at the .10 level.

of that organization is to specifically improve the performance of dairy farms. However, the emphasis of DHIC is on output per cow, which is not a complete measure of technical efficiency of all inputs. Although the organization does compute milk/feed and other output/input ratios, the peer recognition is primarily on production per cow. Maximizing production per cow may overuse feed and other variable inputs from an economic standpoint. Likewise, participation in the farm

business summary for 10 years does not lead to greater technical efficiency.

Location in the northwest or central regions of New York will increase a farmer's technical efficiency by three and four percentage points respectively. These regions have the most productive soils and best weather in the state. Apparently these productivities are not fully reflected in the value of the farm capital input services used in the production function.

Finally, greater cow numbers will increase technical efficiency. An addition of 100 cows will increase efficiency by three percentage points. Larger farms apparently are able to utilize technologies that are more technically efficient. Surprisingly, however, the use of a stanchion barn is not technically inefficient.

Summary and Conclusions

This paper measures the technical efficiency of New York dairy farms using a frontier production function. The data used were 1984 individual farm observations obtained from a business summary program. The frontier function was estimated for seven inputs using corrected ordinary least squares.

The average farm was 69 percent efficient, indicating that substantial improvements in technical efficiency are possible. Efficiency indices were regressed on variables not considered input factors in order to explain why a farm was not on the frontier production function. Only 9 percent of variation in efficiency could be explained. Besides location in the more fertile crop growing regions of the state, additional cows lead to greater efficiency. Participation in the Dairy Herd Improvement Cooperative (DHIC) and use of mail-in computerized records resulted in a reduction in efficiency. The former has an emphasis on production rather than efficiency and the latter may induce farmers to delay timely record analysis.

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