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TECHNICAL EFFICIENCY MEASURES FOR NEW ENGLAND DAIRY FARMS BASED ON A DETERMINISTIC STATISTICAL PRODUCTION FRONTIER

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ABSTRACT

The purpose of this paper is to measure and explain the technical efficiency (TE) of a sample of New England Dairy Farms. A simple corrected OLS procedure is used to estimate a Cobb-Douglas production frontier which provides the basis for measuring farm level TE. The average level of TE for the sample is around 70 percent with a low of 48.7 percent and a high of 100 percent. Efforts to explain the variation in TE as a function of socioeconomic variables yielded extremely poor results.

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The current and projected oversupply of dairy products suggests that further and perhaps more drastic policies than those recently implemented (e.g., The Dairy Termination Program) will be legislated in the near future. Although the exact nature of the policies to be adopted are unknown at the present it is clear that they will force additional dairy farmers out of production. It appears safe to argue that the relative efficiency of existing producers is an important variable in determining those that are more vulnerable and hence more likely to be forced out of production. If this is the case, empirical measures of efficiency can be helpful in anticipating the impact that future policies might have on the structure of the dairy production sector and also in designing programs geared to enhance the chances of survival for dairy farm operators. Therefore, the purpose of this paper is to measure the technical efficiency in dairy production based on a sample of New England dairy farms. Once efficiency is measured attempts are made to explain the variation in efficiency across farms using socioeconomic variables. Identifying specific variables that affect efficiency can provide useful information to farmers, educators and policy makers on how to improve performance.

It should be noted that several methodologies designed to measure technical efficiency, based on the frontier production function concept initially developed by Farrell, have been presented in the literature. Recent reviews of these methods

(Forsund, Lovell and Schmidt; Schmidt 1985-86) make it clear that agreement has not been reached on the most desirable approach. Moreover, concern has been expressed as to whether the measurement of technical efficiency is even possible (Pasour). These unsettled issues and their possible implications are recognized here but their resolution is well beyond the scope of this study.

The remainder of this paper is divided into four sections. The first section presents a very brief discussion on alternative methods found in the literature for measuring efficiency. The second section contains a discussion of the data and the empirical frontier production model employed. Next is the presentation and discussion of the results followed by some concluding remarks in the fourth and final section.

MODELS FOR MEASURING TECHNICAL EFFICIENCY

As already stated, several frontier function models have been presented in the literature since Farrell's initial paper. These models include deterministic nonparametric frontiers (Farrell), deterministic and probabilistic parametric frontiers (Aigner and Chu; Timmer), deterministic statistical frontiers (Afriat; Richmond; Schmidt 1976; Greene), and stochastic or composed error frontiers (Aigner, Lovell and Schmidt; Meeusen and Broeck).

In general, the deterministic frontiers have the advantage of providing unambiguous individual firm efficiency measures but the resulting parameter estimates are sensitive to extreme observations. By contrast, the stochastic frontier model solves the extreme observation problem but a satisfactory measure of individual firm efficiency is yet to be found. Chiao has recently argued that the measure proposed by Jondrow et al. is inadequate since it yields "another deterministic frontier approach with a particular technical efficiency distribution" (p. 74). Studies conducted by Olson, Schmidt and Waldman and by Broeck et al. have evaluated the various frontier procedures but these authors were not able to recommend one model over another.

In sum, if the objective is to measure individual farm efficiency then the best model seems to be the deterministic statistical frontier. Recent support for the use of this model can be found in the work by Gomes, and by Taylor, Drummond and Gomes.

DATA AND EMPIRICAL MODEL

A survey was mailed early in 1985 to a random sample amounting to 50 percent of the New England Dairy Herd Improvement Association (DHIA) membership for 1984 in order to obtain socioeconomic information for these farm operators. After careful screening of the returned survey questionnaires, 537 farms could be used in the analysis. The data collected with the survey document was combined with input-output data from DHIA records for the calendar year 1984. Table 1 presents a summary of the descriptive statistics of the variables used in the analysis.

In order to obtain individual farm efficiency measures the following Cobb-Douglas production function model was formulated:

$$(1) \quad \ln Y = \ln \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \gamma_1 D_1 + \gamma_2 D_2 + \gamma_3 D_3 + \gamma_4 D_4 + \gamma_5 D_5 + \gamma_6 D_6 + e$$

Table 1. Descriptive Statistics for a Sample of New England Dairy Farms - 1984

Variables	Unit (Annual)	Mean	Standard Deviation	Min. Value	Max. Value
Continuous Variables					
Milk Output (y)	cwt.	10342.00	7234.00	2243.60	69601.80
Cows (X_1)	Hd.	65.00	40.30	20.20	340.00
Conc. Feed (X_2)	Ton	177.30	142.70	27.30	1397.10
Forage Equiv. (X_3)	Ton	232.70	165.60	40.10	1308.70
Labor (X_4)	Worker Equiv.	2.02	0.93	0.81	10.00
Binary Variables					
Register Herds (D_1)	%	39.10			
Holstein Herds (D_2)	%	81.80			
Maine (D_3)	%	18.10			
New Hampshire[1/]	%	9.50			
Vermont	%	50.80			
Massachusetts (D_4)	%	11.90			
Connecticut	%	9.70			
Technology A (D_5)	%	30.00			
Technology B (D_6)	%	5.40			

1/ New Hampshire, Vermont and Connecticut are not included as separate variables in the model.

where:

Y = annual milk production per farm measured in hundred weight adjusted to a 3.5 percent butterfat basis;

X_1 = average annual number of dairy cows per farm;

X_2 = annual consumption of purchased dairy concentrate in tons per farm;

X_3 = annual consumption of forage equivalent feed in tons per farm;

X_4 = annual labor used per farm including hired, operator and family labor, measured in full time man-equivalents;

D_1 = binary variable equal to one for registered herds and zero otherwise;

D_2 = binary variable equal to one for holstein herds and zero otherwise;

D_3 = binary variable equal to one for farms located in Maine and zero otherwise;

D_4 = binary variable equal to one for farms located in Massachusetts and zero otherwise;

D_5 = binary variable equal to one for farms with technology A and zero otherwise. Farms with technology A are those that have a stanchion barn and a pipeline milk system;

D_6 = binary variable equal to one for farms with technology B and zero otherwise. Farms with technology B are those that have a stanchion barn and a bucket and carry milking system;

β_i, γ_j = parameters to be estimated; and

e = normally distributed error term.

The model shown in equation (1) was first estimated using ordinary least squares (OLS). The justification for using single-equation models to estimate production functions has been presented by several authors including Hoch (1959), who assumes that firms maximize profits with respect to 'anticipated output;'

and by Zellner, Kmenta and Dreze who assume that " . . . entrepreneurs maximize the mathematical expectation of profit ..." (p. 787).

In order to obtain the statistical deterministic frontier the OLS model was adjusted using a Corrected Ordinary Least Squares (COLS) procedure discussed by Greene. This COLS procedure is simply to correct the intercept obtained in the OLS model until no residual is positive and one is equal to zero. This procedure amounts to a neutral upward shift of the function estimated using OLS where the shifter is equal to the largest positive OLS residual. According to Greene, the COLS method provides consistent estimates for all parameters; however, the intercept estimates is not necessarily efficient. Finally, the technical efficiency of the ith firm is equal to Y_i/Y_{fi} where Y_i is the observed output and Y_{fi} is the output predicted by the production frontier (after taking antilogs).

RESULTS

Results obtained from the OLS estimation of the C-D production function for New England dairy farmers are presented on Table 2. Also shown on that table is the statistical production frontier. Given the procedure used, the only difference between the two models is the intercept term which is higher for the COLS model. Four continuous variables and six binary variables are included in the models. All variables are significant at least at the five percent level except for labor which is significant at a level below 10 percent. The function coefficient is 1.04 indicating slightly increasing returns to scale.

Table 2. Ordinary (OLS) and Corrected Ordinary (COLS) Least Square Estimates of a Cobb-Douglas Milk Production Function for a Sample of New England Dairy Farms - 1984.

	MODEL	
Variable	OLS	COLS[1]
Intercept	4.507** (.06)[2]	4.866**
Cows	0.719** (.03)	0.719**
Concentrate Feed	0.254** (.02)	0.254**
Forage Equiv.	0.049* (.02)	0.049*
Labor	0.021 (0.1)	0.021
Registered Herds	0.063** (.02)	0.063**
Holstein Herds	0.142** (.02)	0.142**
Maine	-0.057** (.01)	-0.057**
Massachusetts	-0.057** (.02)	-0.057**
Technology A	0.027* (.01)	0.027*
Technology B	-0.050* (.02)	-0.050*
R^2	0.96	
F Statistic	1225	
Function Coefficient	1.04	1.04

[1] Standard errors and other statistics are the same as in the OLS model.

[2] Figures in parenthesis are standard error of regression coefficients.

** Significant at 1% level.

* Significant at 5% level.

As indicated earlier, the production frontier is the basis for estimating individual farm technical efficiency. A summary of the resulting efficiency ratings is presented in Table 3. The data show a mean efficiency of 70.3 percent with a minimum of 48.7 percent and a maximum of 100 percent. The majority of the farms (just under 80 percent) have an efficiency level between 60 and 80 percent. These figures reveal that considerable efficiency improvements are possible for the farms in the sample.

Information on what factors determine the variation in technical efficiency across firms can be useful to policy makers as well as firm managers. Several authors have attempted, with varying degrees of success, to explain this variation in efficiency based on variables commonly associated with performance such as firm size, operator education and various other socioeconomic variables (e.g., Kalirajan; Grisley and Mascarenhas; Chiao; Pitt and Lee; Moock; Page; Shapiro and Mueller).

Following previous work on explaining efficiency, various models were formulated in this study in order to explain technical efficiency variation across New England dairy farms. The variables included initially were farm size, and operator age, experience, extension contacts and education. A variety of functional forms and of variable combinations were tried.

The most reasonable model found is the following:

$$\text{(2)} \quad \underset{\text{Index}}{\text{Efficiency}} = 66.9 + \underset{(1.50)}{0.224}\ (\text{Edoper}) + \underset{(1.60)}{0.081}\ (\text{Exmeet})$$

$$R^2 = .01$$

Table 3. Summary of Technical Efficiency Ratings and Related Statistics for a Sample of New England Dairy Farms - 1984

Relative Efficiency (E)	No. of Farms	Percent of Total
90 ≤ E < 100	12	2.23
80 ≤ E < 90	49	9.12
70 ≤ E < 80	199	37.06
60 ≤ E < 70	225	41.90
50 ≤ E < 60	48	8.94
E < 50	4	0.75
Total	537	100.00

Maximum Efficiency	100.0 %
Minimum Efficiency	48.7 "
Mean Efficiency	70.3 "
Standard Deviation	8.2 "

where:

Edoper = operator's education measured by the total number of years of schooling; and

Exmeet = extension contacts equal to the number of extension meetings attended by the operator during 1982, 1983, and 1984.

As revealed by equation (2) the attempt to explain efficiency was not very successful. The implied elasticity of technical efficiency with respect to operator eduation and extension, computed at the corresponding means, are .04 and .006 respectivebly. (The sample mean for operator education is 12.98 years and for extension contacts is 5.73 meetings).

CONCLUDING REMARKS

The results of this study suggest that on average, if all farms in the sample were to operate on the production frontier, output could increase around 30 percent without any changes in input use. These estimates are similar to results reported by Grisley and Mascarenhas and by Bravo-Ureta. Attempts to explain the variation in technical efficiency proved to be unsatisfactory which suggest two things: 1) the methodology employed provides inadequate measures of firm efficiency; and/or 2) the factors that explain efficiency are extremely difficult to capture with data on socioeconomic characteristics of farm operators. Additional work is clearly needed in order to better understand the forces that explain variation in technical performance.

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