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Abstract

The relative technical allocative, and scale inefficiencies of small, medium, and large-sized dairy farms in Ecuador was investigated. Large farms were found to be the most technically efficient group. However, medium-sized farms were discovered to be the most allocatively efficient group of farms. Capital inputs were found to have the largest output elasticity. Government retail milk pricing ceilings in Ecuador reflect a farm level milk price which is likely above average costs for many producers. However, marginal costs exceed the farm level price indicating that increasing efficiency of the farms would be an essential part of any government designed to increase milk production.

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An Analysis of Inefficiency on Dairy Farms in Ecuador Using Stochastic Production and Profit Frontiers

Considerable literature exists regarding the production efficiency of firms. Much of this research has centered on firms in developing countries (Lau and Yotopoulos; Yotopoulous and Lau; Barnum and Squire; and Kaiser). Other studies have examined the behavior of groups of U.S. agricultural producers to determine if they acted like profit maximiziers (Smith and Martin; Biswas, et. al). These studies generally dealt with the efficiency of groups of firms with no direct measure of efficiency for single firms.

More recently researchers have attempted to quantify the efficiency of individual firms. Most of this research has centered on modeling stochastic production frontiers. Estimation of stochastic frontiers, may help to explain the behavior of agricultural producers. Farmers are, in general, price takers who will use similar inputs in varying amounts and in different proportions to obtain similar output levels. This, coupled with the impacts of government intervention, raises questions regarding the relative production efficiency of farmers. If some farmers or groups of farmers are more efficient than other farmers then explaining why differences in efficiency between the farms exist is important.

The dairy industry in Ecuador is represented by a wide diversity of farm sizes. Output can vary substantially between farms and retail prices are administered by the government. However, prices vary widely between farm sizes since milk is purchased by a variety of handlers who pay different prices.

Stigler states that the optimum size of a firm really "depends upon the resources that the firm uses" (page 162). If this is true, questions about why a farm succeeds, fails, grows, or exits the industry cannot be answered by only its relative financial position or its size. Management ability, inventories, asset portfolio, and outside resources may all contribute to a farmer's ability to succeed.

This paper examines the relative technical, allocative, and scale efficiencies of dairy farmers in Ecuador. A direct measure of technical, allocative, and scale efficiency for individual farmers is obtained by estimating the stochastic production and profit frontiers for a random sample of dairy farms. The following sections present the estimation process and data manipulation, results, and a summary of the study.

Theory and Model Development

Aigner, et al., stated that when the output of individual firms is not found lying on the production frontier, that this deviation could consist of a systematic as well as a random component. The random component consists of occurrences beyond the firm's control (weather, disease, etc.) while the systematic component consisted of technical inefficiencies associated with differences in management abilities. Schmidt and Lovell extended this idea to include allocative as well as technical inefficiency in the estimation of cost functions. Kumbhakar estimated allocative and technical inefficiency as they related to profit frontiers.

Following Kumbhakar we begin with a Cobb-Douglas production function:

$$(1) \quad y = A(\underset{i}{\pi} X_i^{ai}) \exp(v)$$

where y is output, the ${}_i$'s are the inputs (e.g., i=land, labor, capital), v is a random error term representing random shocks not in the control of the firm. A is a technical efficiency parameter represented by the intercept. Equation (1) can be related to a stochastic production frontier by designating A as

$$A = \alpha_o \exp(T) \qquad T \leq o$$

T represents the technical inefficiency of the firm while α_o represents an industry technical inefficiency. T is distributed as the non-positive portion of a normal distribution with mean zero. Technically efficient firms produce output that lies on the stochastic production frontier with some random fluctuations. Inefficient firms produce at a point below the stochastic production frontier. This deviation is not merely random, but can be explained as differences in management that lead to less than optimum output to maximize profit (Mundlak).

Allocative inefficiency occurs if the ratio of the marginal physical products of two inputs does not equal the ratio of their prices (e.g., $f_j/f_i \neq w_j/w_i$, where i and j are inputs, f is the marginal physical product, and w is the price of the input). This relationship could be written as

$$(2) \quad \frac{f_j}{f_1} = \frac{w_j}{w_1} e^{u_j} \qquad j = 2, \ldots n$$

where u_j is a representation of allocative inefficiency. If $u_j = 0$, no allocative inefficiency exists and the equilibrium conditions are met. Equation (2) can be rewritten using (1) as follows:

$$(3) \quad \frac{\alpha j}{\alpha i} \cdot \frac{x_1}{x_j} = \frac{w_j}{w_1} \cdot \quad e^{u_j}$$

Similarly, scale inefficiency can be described as a firm not achieving output levels where marginal cost equals output price (e.g., $\partial c / \partial y = P$, where C is the cost function, y is output, and P is output price) (Forsund, Kumbhakar). This could also be written as

$$\frac{\partial c}{\partial y} = P\xi \qquad \text{where } \xi \text{ is scale inefficiency.}$$

or

$$(4)\quad Pe^{\xi} = \frac{w_1 x_1}{Y \cdot \alpha_1} \left(1 + \sum_j e^{u}{}_j\right) \text{ (see Kumbhakar)}$$

Placing (1), (3), and (4) in logarithmic form yields

$$(5)\quad \ln y = \ln \alpha_0 + \quad \alpha_i \ln x_i + T + v$$

$$\ln x_1 - \ln x_j - \ln w_j + \ln w_1 + \ln(\alpha_j/\alpha_i) = u_j$$

$$\ln x_1 - \ln y - \ln w_1 - \ln \alpha_1 + \ln(1 + \sum_j e^{-uj}) = \xi$$

Equation (5) represents a system of (n+1) equations to solve for the output supply and input demand functions. Solving (5) for the (n+1) unknowns yields the production function and conditional demand functions (see Schmidt and Lovell): Ordinary least squares estimates (OLS) are inconsutent since the χ's and T's are correlated. The following section presents the full information maximum likelihood (FIML) model used to complete this study.

<u>The Maximum Likelihood Estimator</u>

The error vector in (5) is the following:

$$\begin{bmatrix} T + v \\ u_2 \\ \cdot \\ \cdot \\ u_n \\ \xi - \ln(1 + \sum_j e^{-u}{}_j) \end{bmatrix}$$

Let $Z_1 = T + v$

$Z_2 = u$

$Z_3 = \xi - \ln(1 + \sum_j e^{-u}{}_j)$

From this, the joint probability distribution function (pdf) of (Z_1, Z_2, Z_3) can be found from the pdf's of , v, u, and . The distributional assumptions are the following:

(i) v iid $N(o, \sigma_v^2)$

(ii) T a half normal distribution or T $N(o, \sigma_T^2)$, T 0

(iii) u multivariate normal (μ, Σ) , iid over all firms

(iv) ξ iid $N(o, \sigma_\xi^2)$

and (v) v, T , u, and ξ are independent among themselves.

The log likelihood function for a single observation can be written as follows (see Kumbhakar):

$$(6) \quad L_c = \text{const.} - \frac{b}{2} + \log\sigma + \log o(-\mu_T / \sigma) - \log\sigma_v - \log\sigma_T - \log\sigma_\xi - \frac{1}{2\sigma_\xi^2}\left(Z_3 - \ln\left(1 + \sum_j e^{Z_{2j}}\right)\right)^2 + \log|J|$$

where Z_1, Z_2, and Z_3 are replaced by their deterministic parts from (5). $|J|$ is the determinant for the Jacobian matrix $\frac{\partial(Z_1, Z_2, Z_3)}{\partial(\ln y, \ln x_i, \ldots \ln x_n)}$.

In this case $|J|$ is $(1-r)$ where $r = \sum_{i=1}^{n} \alpha_i$. The maximum likelihood estimates (ML) of $\ln \alpha_0$, $\alpha_1, \ldots \alpha_n$, σ_v, σ_T^2, and σ_T^2 can be obtained by maximizing (6).

Following Kumbhakar, it can be shown that the conditional distribution of given Z_1 (the residual of the production function) is truncated normal with mean and variance ^{2}. Then technical inefficiency is estimated by the mean or mode of the error term, i.e.,

$$(7) \quad \hat{T} m = \mu_T - \sigma\frac{\phi(T/\sigma)}{\phi(-T/\sigma)}$$

Allocative inefficiency for each input (relative to input 1) can be estimated from

$$(8) \quad \hat{u}_j = \ln x_1 - \ln x_j - \ln w_j + \ln w_1 + \ln(w_j/w_1) \text{ for each firm,}$$

$j_{22}, \ldots n$.

Scale inefficiency can be estimated from the last equation in (5), i.e.,

(9) $\hat{\ } = \ln x_1 - \ln y - \ln w_1 - \ln {}_1 + \ln (1 + e^{-uj})$ where uj is obtained from (8).

The loss of potential profit due to technical inefficiency alone is

(10) $TT_T (p, w, T, v) = TT(p, w, v) - TT(p, w, T, v)$

where (p, w, T, v) is the profit function with technical inefficiency and $PT = 1 - \frac{TT_T(\cdot)}{TT^*}$ where PT is the percentage reduction in potential profit due to technical inefficiency and TT^* represents potential profit for the firm if no technical inefficiency existed. Similarly, the foregone profit (or percentage increase in cost) due to allocative inefficiency in producing a given level of output, y_0, is

(11) $$\frac{C (w, y_0, v, u)}{C^* (w, y_0, v)} = (e^{E-\ln r} - 1)$$

where C (·) is the actual cost of producing y_0 with the presence of allocative inefficiency and C* (·) is the minimum cost of producing the given level of output, y_0.

Finally, the loss of potential profit due only to scale inefficiency, , is

$$TTs = (p, w, v, \xi) = TT(p, w, v) - TT(p, w, v, \xi)$$

(12 $= \frac{II^{*}_{-}}{1-r} \exp(r\,\xi/1-r)[1 - re^{\xi}]$

The following section describes data gathering and data preparation for estimation of equation (6).

Data and Procedures

The data for this study were obtained from a random sample of dairy farmers in Ecuador. Face-to-face interviews were conducted with the sample which consisted of 68 observations. Questions regarding a wide range of farm characteristics were asked including numbers of acres and cows, input costs, asset values, milk prices, capital structure, etc. The observations were separated by size based on number of cows milked during 1986.

Table 1 presents some of the economic characteristics of the farms surveyed. Small farms had under 20 dairy cows, medium-sized farms between 21 and 60 dairy cows, and large farms had over 60 dairy cows. Large farms tended to be operated by absentee land owners with hired managers. Large farms had higher production levels per cow and used less labor, on average. Smaller farms tended to milk the cows by hand while large farms used modern milking equipment.

The government of Ecuador establishes maximum retail prices for milk. However, prices at the farm level vary by farm. Milk prices are not based on component pricing. Thus, no quality differential exists between farms. Large farms received the highest price for their milk. This is probably a function of assembly cost for processors. Some small producers had prices similar to large farmers. However, these prices were received for unprocessed milk sold on the street. Assets varied greatly between farm sizes. Smaller farms tended to be near subsistence level and depended heavily on labor inputs while large farms were quite capital intensive.

Three inputs were considered for the dairy farms in the estimation of (6) -- labor, capital, and land. Labor represented the time, in labor hours, spent in activities on the farm by the operator and hired labor. The wage rate represented acutal payments to labor by the farmer.

The opportunity cost of capital consisted of depreciation and interest expenses on the farm (Jorgensen). All capital was depreciated on a

Table 1. **Average Farm and Farm Family Characteristics.**

Category (Avg. Values)	Size Small (under $100,000 sales)	 Medium ($100,000-$250,000 sales)	 Large (over $250,000 sales)
Number of Cows	10.9	40.1	125.5
Milk Price (Sucres/liter)	21.5	22.5	24.3
Total Hectares	13.1	45.7	122.0
Average Annual Milk Prod. per Cow (liters)	2384	2555	3076
Total Farm Assets (Sucres)	2,142,272	8,611,771	27,418,320

Table 2. **FIML Estimates for Capital, Land, and Labor.**

Parameter	Estimate	Standard Error	T-Statistic
Constant	7.284	0.621	11.73
Labor	0.005	0.571	8.963
Capital	0.151	0.018	8.489
Land	0.131	0.026	5.047
σ_V	0.920		
σ_T	1.100		
σ_Z	7.108		

Table 3. **Measures of Inefficiency by Size of Dairy Farm-Ecuador 1986.**

Measure	Size Small	 Medium	 Large
PT[a]	81.9%	69.4%	54.8%
CA[b]	26.1%	5.9%	7.9%
PS[c]	91.9%	87.9%	91.0%

[a] PT = Loss in profit due to technical inefficiency.

[b] CA = Increase in cost due to allocative inefficiency.

[c] Change in profit due to scale inefficiency.

straight line basis. Buildings and other structures were depreciated based on actual farm replacement but average depreciation was considered 3% per year, machinery at 10% per year, and milk cows at 14% per year. An interest rate of 21% was used to calculate capital interest opportunity costs. Land costs were determined to be an approximate opportunity cost of owned property (21% of agricultural value). The farm's output was measured in liters of milk produced. Milk production was calculated by multiplying annual average production per cow by the total number of cows. Receipts from the sale of livestock and crops were divided by the price of milk and then added to output. Total output was adjusted downward for costs other than land, labor, and capital that were not included in the estimation

Results

The FIML estimates of (6) are found in Table 2. A stochastic production and profit frontier were estimated and direct measures of efficiency for individual farms were calculated. As expected, all three inputs have a positive and significant impact on output. However, capital has the largest coefficient (elasticity). This indicates that the largest impacts on output, on average, would be experienced if additional capital was inputed on the farms. Labor has the smallest output elasticity. This result would be expected given the small amount of capital used on many of the farms. Significant increases in production will likely be best accomplished by increasing capital inputs.

While larger farms utilize inputs in a more technically fashion than the other size categories (PT in Table 3) they appear to allocate those input less efficiently than medium-sized farmers. The additional costs of production associated with allocative inefficiency (CA in Table 3) show that medium-sized farms are the most allocatively efficient group with costs averaging only 5.9% above the cost-minimizing amount. Some of the larger farms may over invest in capital items. For example, some large farmers had center pivot irrigation systems that are generally regarded as unnecessary given annual average precipitation.

Small and medium sized farmers may have difficulty obtaining credit to expand their capital bases. Income from the dairy operation is, on average, also more critical for the medium and small-sized farms. Consequently, these farms have more incentive to minimize the cost of available inputs. Perhaps medium-sized farmers are more educated than small farmers or have better managers. However, data concerning education levels were not available.

Government price controls reflected back to the farm level prices as derived demand appear to generate farm level prices above average cost since few dairy farmers are existing the industry. However, marginal costs for increasing production are well above the farm level price (PS in Table 3). Thus, the most economic benefit will likely accure if these operators use inputs more efficiently before they attempt any large scale expansion.

Another study found that U.S. dairy farms were more technically efficient than this group of Ecuador farms. However, the Ecuador farms in the medium to large sized categories were actually found to be more allocatively efficient than the U.S. farms (Author publication). This may reflect more accessible credit in the United States. The U.S. farms may rely on adding inputs to achieve efficiency while the Ecuador farms rely on minimizing costs.

Conclusions

These results show that a considerable amount of inefficiency (technical, allocative, and scale) exists in the dairy industry in Ecuador. Small farms were found to be much less efficient than large and medium-sized farms. Medium-sized farmers are the most efficient group at minimizing costs. This likely refelcts the reliance on farm income of the operator and also difficulty in obtaining credit. On average, the greatest supply response would be expected if capital inputs are increased based on the output elasticity.

Government policies relating to dairy production should be fashioned to a specific goal. For example, one policy goal might be to increase overall production while another might be to reduce inefficiency. Current government price controls appear to be maintained above average costs for many producers. However, marginal costs exceed those price levels. Policies should be designed to encourage efficiency as well as production. Otherwise, production expansion will be difficult from an economic view point. Ceiling for these dairy farmers if asset fixity exists. Policy makers may wish to consider programs that account for relative efficiency of farmers as well as production levels.

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