An Analysis of Technical, Allocative, and Scale Inefficiency: The Case of Ecuadorian Dairy Farms

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The economic efficiency of 68 Ecuadorian dairy farms is investigated by estimating technical, allocative, and scale efficiencies for each using stochastic frontier methodology. Empirical results show that technical inefficiency exists for all of these farms—ranging from 11.8% to 12.8%. Large and medium-sized farms are found to be allocatively more efficient than the small farms as a group. Finally, estimates of scale inefficiency show that most of these farms are producing output at a level below the optimum.

Key words: allocative inefficiency, production frontier, scale inefficiency, technical inefficiency.

Considerable literature exists regarding the production efficiency of firms. Much of this research has centered on firms in developing countries (Lau and Yotopoulos; Yotopoulos and Lau; Sidhu; Huang, Tang, and Bagi; Barnum and Squire; Kaiser). Other studies have examined the behavior of groups of U.S. agricultural producers to determine if they acted like profit maximizers (Smith and Martin; Biswas et al.).

More recently, researchers have attempted to quantify the efficiency of individual firms. Most of this research has centered on modeling stochastic production frontiers. The main advantage in using the stochastic production frontier approach over the nonfrontier approach of Lau and Yotopoulos is that the former approach helps to estimate the magnitude of technical, allocative, and scale inefficiency for each production unit. Once such estimates are obtained, one can test the presence of group effects, if any, on the above inefficiencies.

The dairy industry in Ecuador is represented by a wide diversity of farm sizes. Output can vary substantially among farms, and retail prices are administered by the government. However, average farm prices vary widely among 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 (debt load) or its size. Management ability, inventories, asset portfolio, and outside resources may all contribute to a farmer's ability to succeed financially, grow, or be efficient.

This paper examines economic efficiency of Ecuadorian dairy farms by estimating technical, allocative, and scale efficiencies. A direct measure of technical, allocative, and scale efficiency for individual farmers is obtained by estimating the stochastic production function along with the first-order conditions of profit maximization. The following sections present the estimation process and data manipulation, results, and a summary of the study.

Theory and Model Development

Aigner, Lovell, and Schmidt stated that when the output of individual firms is not found

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lying on the production frontier, 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 consists 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 has extended it further in a profit-maximizing framework.

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

$$(1)\qquad y = A\left(\prod_i X_i^{\alpha_i}\right)\exp(v),$$

where y is output, the X_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 which varies across farms. Equation (1) can be related to a stochastic production frontier by designating A as

$$A = \alpha_0\exp(\tau), \qquad \tau \leq 0.$$

τ represents the technical inefficiency of the firm while α_0 is a parameter common to all. By allowing τ to vary across farms, the model captures the idea that all the farms may not be equally technically efficient. The advantages of doing this are: (*a*) the analysis is not based on the notion of a representative farm, and (*b*) an estimate of technical inefficiency, τ, can be obtained for each farm without panel data. This is accomplished by treating τ as a random variable. One can define technical efficiency as $y/y_{\max}$, where $y_{\max}$ is the maximum possible output obtained by putting $\tau = 0$ in (1). Technically efficient firms produce output that lies on the stochastic production frontier with some random fluctuations because of v. Deviations from the frontier can be explained as differences in management that lead to less than optimum output given the level of inputs (Mundlak).

A profit-maximizing farm is said to be economically efficient if it is technically, allocatively, and scale efficient. 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 f_i is the marginal physical product of X_i and w_i is the price of the input x_i). This relationship can be written as

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

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

$$(3)\qquad \frac{\alpha_j}{\alpha_1}\cdot\frac{x_1}{x_j} = \frac{w_j}{w_1}\exp(u_j).$$

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 total cost $= \sum_i w_i x_i$, and p is output price) (Førsund, Lovell, and Schmidt). This could also be written as $\dfrac{\partial c}{\partial y} = p\exp(\xi)$ where ξ is scale inefficiency. Using (1) and (3), this can be rewritten as

$$(4)\qquad \frac{x_1 w_1}{\alpha_1 r y}\left(\alpha_1 + \sum_j \alpha_j\exp(-u_j)\right) = p\exp(\xi),$$

where $r = \sum_i \alpha_i$.

Taking logarithms of (1), (3), and (4) yields

$$(5a)\qquad \ln y = \ln\alpha_0 + \sum_i \alpha_i \ln x_i + \tau + v;$$

$$(5b)\qquad \ln x_1 - \ln x_j = \ln(\alpha_1/\alpha_j) - \ln w_1 + \ln w_j + u_j \qquad j = 2, \ldots, n;$$

$$(5c)\qquad \ln x_1 - \ln y = \ln p - \ln w_1 + \ln\alpha_1 + \ln r - \ln\left(\alpha_1 + \sum_j \alpha_j\exp(-u_j)\right) + \xi.$$

The conditional input demand functions can be obtained by solving the first n equations in (5) (see Schmidt and Lovell) whereas a simultaneous solution of the $(n + 1)$ equations in (5) for $\ln y$ and $\ln x_i$ yields the unconditional input demand and output supply functions.

Method of Estimation

In this section we will be dealing with estimation of (*a*) the production function parameters and (*b*) inefficiency "parameters" τ, u_j, and ξ. Application of the ordinary least squares to (5a) will result in inconsistent estimates of α_i, since x_i and τ are correlated (since technical inefficiency affects input demand). This can be avoided by the maximum likelihood (ML) technique that uses all the equations in (5). Of course, some distributional assumptions are to be made on the error terms.

To estimate the system of equations (5) by the ML method, we need to derive the probability density function (pdf) of the error vector,

$$\left(\tau + v, u', \xi - \ln\left(\alpha_1 + \sum_j \alpha_j \exp(-u_j)\right)\right)',$$

from the pdf of τ, v, and ξ where $u = (u_2, \ldots, u_n)'$. The distributional assumptions on these random errors are:

(i) τ is iid $N(0, \sigma_\tau^2)$ truncated at zero from above,
(ii) u is iid $N(\mu, \Sigma)$,
(iii) ξ is iid $N(0, \sigma_\xi^2)$,
(iv) τ, u, and ξ are independent of each other and also independent of input prices w_i.

Let $z_1 = \tau + v$ and

$$z_2 = \xi - \ln\left(\alpha_1 + \sum_j \alpha_j \exp(-u_j)\right).$$

Then the joint pdf of (z_1, u, z_2), $f(z_1, u, z_2) = f_1(z_1)f_2(u)f_3(z_2 \mid u) = f_1(z_1)f_2(u)f_3(\xi)$, where $f_1(.)$, $f_2(.)$, and $f_3(.)$ are the pdf of z_1, u, and ξ respectively. After some algebraic manipulation, the above joint pdf can be written as:

$$\text{(6a)} \quad f(z_1, u, z_2) = \frac{2\exp(-b/2)\sigma\Phi(-\mu_\tau/\sigma)}{(2\pi)^{n/2}\sigma_v\sigma_\tau\sigma_\xi|\Sigma|^{1/2}} \cdot \exp(-(u - \mu)'\Sigma^{-1}(u - \mu)/2) \cdot \exp\left(-\left(z_2 + \ln\left(\alpha_1 + \sum_j \alpha_j \cdot \exp(-u_j)\right)\right)^2 \Big/ 2\sigma_\xi^2\right),$$

where $\sigma^2 = \dfrac{\sigma_v^2\sigma_\tau^2}{(\sigma_v^2 + \sigma_\tau^2)}$, $b = \dfrac{z_1^2}{(\sigma_v^2 + \sigma_\tau^2)}$, $\mu_\tau = \dfrac{z_1\sigma_v^2}{(\sigma_v^2 + \sigma_\tau^2)}$ and $\Phi(.)$ is the cumulative pdf of a standard normal variable. The log likelihood function for a sample of F farms is then given by:

$$\text{(6b)} \quad L = \sum_{f=1}^{F} \ln f(z_1, u, z_2) + F \ln|J|,$$

where f indexes farm ($f = 1, 2, \ldots, F$). $f(z_1, u, z_2)$ is defined in (6a), and z_1, u, ξ are to be replaced by their observable counterparts from (5b, c). $|J|$ is the determinant of the Jacobian of the transformation from z_1, u, z_2 to $\ln y$, $\ln X_i$. In the present case it is $(1 - r)$. The ML estimates of the parameters can be obtained by maximizing L in (6b).

Now we consider estimation of technical, allocative, and scale inefficiency. Following Kumbhakar, it can be shown that τ given z_1 (the residual of the production function) is normally distributed with mean μ_τ and variance σ^2 truncated at zero. Thus, point estimates of technical inefficiency for each farm can be obtained from the mean of τ, i.e.,

$$\text{(7)} \quad \hat{\tau} = \hat{\mu}_\tau - \hat{\sigma}\frac{\phi(\hat{\mu}_\tau/\hat{\sigma})}{\Phi(-\hat{\mu}_\tau/\hat{\sigma})},$$

where $\hat{\mu}_\tau$, $\hat{\sigma}$ are the estimates of μ_τ and σ, and $\phi(.)$ is the pdf of a standard normal variable.

The presence of technical inefficiency, τ, reduces output given the level of inputs—thereby reducing profit. The loss of potential profit due to technical inefficiency as a percentage of maximum possible profit is:

$$\text{(8)} \quad PT = \frac{\Pi(p, w, v) - \Pi(p, w, v, \tau)}{\Pi(p, w, v)} = 1 - \exp(\tau/(1 - r)),$$

where $\Pi(p, w, v)$ is the maximum possible profit given by

$$\Pi(p, w, v) = py - \sum_i w_i x_i$$

(conditional on $\tau = u_j = \xi = 0$).

$\Pi(p, w, v, \tau)$ is the level of profit without allocative and scale inefficiency, i.e.,

$$\Pi(p, w, v, \tau) = py - \sum_i w_i x_i \quad (\text{given } u_j = \xi = 0).$$

Allocative inefficiency for each firm and for every input (X) can be obtained from

$$\text{(9)} \quad \hat{u}_j = \ln x_1 - \ln x_j - \ln(\hat{\alpha}_1/\hat{\alpha}_j) + \ln w_1 - \ln w_j \qquad j = 2, \ldots, n.$$

Since both positive and negative u_j increase cost, it might be of some interest to estimate the percentage increase in cost due to allocative inefficiency, CA, for each farm. Once u_j is estimated, CA can be estimated from (see Schmidt and Lovell for details):

$$\text{(10)} \quad CA = \exp(E - \ln \hat{r}) - 1,$$

where $E = \sum_{j=2}^{n} \hat{\alpha}_j\hat{u}_j/\hat{r} + \ln(\hat{\alpha}_1 + \sum_{j=2}^{n} \hat{\alpha}_j\exp(-\hat{u}_j))$.

Table 1. Average Ecuadorian Dairy and Farm Characteristics

Category	Size		
	Small	Medium	Large
Number of Observations	19	21	28
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 Production per Cow (liters)	2,384	2,555	3,076
Total Farm Assets (Sucres)	2,142,272	8,611,771	27,418,320

Scale inefficiency for each farm can be estimated from (5c) once allocative inefficiency is estimated. This is given by

$$\hat{\xi} = \ln x_1 - \ln y - \ln p + \ln w_1 - \ln \hat{\alpha}_1 - \ln \hat{r} + \ln\left(\hat{\alpha}_1 + \sum_j \hat{\alpha}_j \exp(-\hat{u}_j)\right). \quad (11)$$

$\hat{\xi}$ can take both positive and negative values. A negative (positive) value of $\hat{\xi}$ indicates that marginal cost $<$ ($>$)p at the observed level of output and hence profit can be increased by expanding (contracting) output. Since a nonzero value of $\hat{\xi}$ implies suboptimal output and profit, it is natural to look at the loss of potential profit due to scale inefficiency, $\hat{\xi}$. Following Kumbhakar, it can be shown that such loss of profit as a percentage (when multiplied by 100) of optimum level of profit is:

$$PS = 1 - \{\exp(\hat{r}\hat{\xi}/(1 - \hat{r})) \cdot [1 - \hat{r}\exp(\hat{\xi})]\}/(1 - \hat{r}). \quad (12)$$

Estimates of PS can be obtained for each farm from (12).

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 hectares 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. While these size categories were established on an arbitrary basis, they represented the interviewer's basic conception of categorical breaks relating not only to size but also input mix. These groups were used only to present the results. Estimation was carried out by pooling all the farms.

Table 1 presents some of the economic characteristics of the farms surveyed. Small farms had under 20 dairy cows, medium-sized farms had 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, while small and medium-sized dairies tended to have owner-operators. Input mixes differed among farms. For example, only 4.5% of small farms used modern milking equipment, while 23% of medium-sized farms used milking equipment. Sixty-eight percent of large farms used milking equipment. This may indicate that access to debt capital is different for different sized farms.

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 price differentials exist among farms. Large farms received the highest price for their milk. This is probably a function of reduced 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 across 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 used in dairy production were considered for the sample. These were labor, capital, and land. Labor represented the time, in labor months, spent in dairy activities on the farm by the operator and hired labor. The wage rate represented actual average payments per month paid to laborers by the farmer.

The opportunity cost of capital used in the dairy buildings consisted of depreciation and interest expenses on the farm (Jorgenson and Griliches; Jorgenson). All capital was depre-

Table 2. ML Estimates for Stochastic Production Frontier

Variable	Parameter Estimates	Asymptotic Standard Error	Asymptotic t-Statistic
Constant	3.863	0.416	9.293
Labor	0.047	0.003	13.579
Capital	0.313	0.023	13.650
Land	0.097	0.007	13.101
Dummies:			
Milking Equipment	0.987	0.248	3.986
Artificial Insemination	0.040	0.022	1.772
Feed Concentrates	0.059	0.029	2.007
σ_v	0.918	0.088	10.455
σ_τ	0.154	0.023	6.753
σ_ξ	1.556	0.162	9.631

ciated on a straight line basis. The market value of capital inputs was estimated by the producer surveyed. Dairy buildings and other structures related to the dairy enterprise were depreciated based on actual farm replacement, but average depreciation was considered to be 3% of its value per year; machinery 10% per year; and milk cows 14% per year. An interest rate of 21% was used to calculate capital interest opportunity costs.

Land used in dairy production was assumed to cost 21% of its value per year. A more appropriate measure for the cost of land would be its rental value. No rental values were obtained in the surveys, however. The opportunity cost of holding land was considered to be the prevailing interest rate available to investors (i.e., 21%). While this figure ignores transaction costs, it does serve as a proxy for the return on assets in an alternative use. Hopper stated that this approach might be an acceptable alternative to using rental rates if rental rates do not reflect all costs of use. Since rental values were not available, the interest rate was the next best alternative.

Milk production was calculated by multiplying annual average production per cow by the total number of cows. Receipts from the sale of dairy livestock 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.

Management plays a key role in any farming operation. However, management strategies especially regarding the use of capital inputs varied widely in the sample. Some of the important differences in management in the sample included (*a*) the use or nonuse of artificial insemination to improve herd genetics, (*b*) the use or nonuse of modern milking equipment, and (*c*) the use or nonuse of feed concentrates in the diet of the farm's dairy herd. While the use of these three management strategies is well accepted in most developed countries, many Ecuadorian dairy farms still do not follow these practices. These three management strategies are included in the production function (1) as dummy variables.

Results

The ML estimates of the parameters are found in table 2. A stochastic production frontier was estimated, and 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 inputted 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 best be accomplished by increasing capital inputs.

Economists who have examined the dairy industry in Ecuador closely believe that output could be increased through better management practices (Wennergren). Management practices do play an important role in production as evidenced by the parameter estimates for the milking equipment, feed concentrates, and artificial insemination dummy variables (table 2). While using milking equipment may increase output, its parameter estimate may also indicate that larger sized operations are more efficient, since a greater proportion of large farms use milking equipment than small farms. Farms utilizing feed concentrates tend to have larger output as would be expected (Feed Concentrates in table 2). The use of feed concentrates in proper proportions has long been recognized as a method of increasing output and subsequently revenues (e.g., Andersen, Miller, and Mickelsen). Cows fed only forage will, in general, produce less than the same cows fed with feed concentrates no matter what their genetic base. The parameter estimate for the artificial insemination dummy variable (table

Table 3. Measures of Different Types of Inefficiency by Farm

Farm ID	τ	*PT*	*CA*	*PS*
1	0.12083	0.23226	0.03999	0.11029
2	0.12288	0.23568	0.02971	0.40906
3	0.13739	0.25956	0.02491	0.66098
4	0.11356	0.21995	0.07525	0.25950
5	0.11963	0.23023	0.03807	0.37521
6	0.11617	0.22438	0.00908	0.06870
7	0.11358	0.21997	0.02656	0.08051
8	0.11822	0.22785	0.08000	0.27045
9	0.12640	0.24155	0.03052	0.62905
10	0.12874	0.24541	0.03377	0.56158
11	0.11726	0.22623	0.04633	0.14065
12	0.11377	0.22030	0.00007	0.43040
13	0.11882	0.22886	0.00914	0.20220
14	0.12750	0.24337	0.02446	0.52741
15	0.12489	0.23904	0.05217	0.30574
16	0.14209	0.26713	0.01681	0.61063
17	0.12962	0.24687	0.03689	0.15735
18	0.12842	0.24489	0.04774	0.53675
19	0.11913	0.22939	0.02191	0.28103
20	0.15059	0.28063	0.00655	0.79166
21	0.13619	0.25761	0.12991	0.50438
22	0.13684	0.25866	0.00148	0.70358
23	0.12680	0.24220	0.01602	0.41851
24	0.11641	0.22480	0.07830	0.33443
25	0.11536	0.22301	0.07954	0.08845
26	0.11769	0.22696	0.01624	0.13035
27	0.13356	0.25333	0.08898	0.78806
28	0.12021	0.23120	0.11066	0.03958
29	0.11814	0.22772	0.15553	0.06943
30	0.12249	0.23503	0.13572	0.15736
31	0.12486	0.23899	0.12977	0.42715
32	0.12885	0.24560	0.24819	0.28360
33	0.12667	0.24199	0.24440	0.18405
34	0.11198	0.21725	0.09345	0.00920
35	0.12534	0.23979	0.13196	0.37540
36	0.14114	0.26562	0.15030	0.75656
37	0.11455	0.22164	0.04508	0.25439
38	0.11468	0.22185	0.16814	0.04721
39	0.11375	0.22027	0.07476	0.14752
40	0.12702	0.24258	0.03945	0.46450
41	0.12738	0.24317	0.08708	0.67535
42	0.10957	0.21310	0.09969	0.01091
43	0.11408	0.22082	0.08328	0.20948
44	0.11551	0.22326	0.08856	0.25203
45	0.10798	0.21036	0.06755	0.05527
46	0.11013	0.21406	0.04615	0.03223
47	0.11671	0.22530	0.06303	0.06254
48	0.13150	0.24996	0.01615	0.55699
49	0.12011	0.23103	0.05854	0.23143
50	0.11734	0.22637	0.05895	0.20124
51	0.13975	0.26338	0.03710	0.79948
52	0.13048	0.24829	0.02523	0.70586
53	0.12838	0.24482	0.03977	0.44808
54	0.11198	0.21724	0.05475	0.00026
55	0.11853	0.22837	0.06482	0.30370
56	0.12648	0.24168	0.03620	0.45785
57	0.13173	0.25034	0.07812	0.75566
58	0.11510	0.22256	0.04516	0.00000
59	0.13426	0.25448	0.08854	0.74893
60	0.10232	0.20052	0.07875	0.00843
61	0.11397	0.22064	0.05892	0.01453
62	0.11661	0.22513	0.12158	0.16330
63	0.10683	0.20838	0.12316	0.11044
64	0.12142	0.23324	0.06143	0.07636
65	0.11176	0.21687	0.06736	0.12378
66	0.11240	0.21797	0.05279	0.15841
67	0.11762	0.22683	0.04656	0.11002
68	0.11883	0.22889	0.00327	0.05217

2), while significantly different than zero, is smaller than the feed concentrate parameter estimates. Logically, better genetics (artificial insemination) will help increase potential production, but dairy cows must also be fed to meet that potential. Ecuadorian dairy farmers using feed concentrates are likely obtaining output levels per cow closer to genetic potential than farmers not using feed concentrates (Wennergren).

Table 3 gives the individual measures of inefficiency for all farms in the sample. Table 4 gives summary descriptive statistics for each of the inefficiency measures. The absolute value of technical inefficiency, τ, is reported in tables 3 and 4.

Large farms were found to be the most technically efficient group (*PT* in table 4). However, the average losses for all three groups were quite similar. For example, the profit loss due to technical inefficiency for large farms (*PT* in table 4) was less than 2% lower in absolute terms than the loss to small farms. This indicates that all farm sizes have difficulty obtaining an optimum input mix, although large farms are somewhat more technically efficient than the other sizes. This could be explained if insufficient credit is extended to the farmers to buy capital items or if additional labor is not readily available. The former is the more likely case. This could also reflect an educational problem associated with the agricultural producers. For example, even dairy farmers with tractors were observed cutting native forage with hand labor. This may reflect the relative costs of labor to purchasing some haying equipment. However, a more likely explanation may be an educational need to teach farmers the value and use of capital inputs. Basic farm management training possibly could correct this problem if no institutional barriers

Table 4. Measures of Inefficiency by Size of Dairy Farm

Measure		Size	
	Small	Medium	Large
PT^a			
$\bar{x}^b$	0.244	0.234	0.227
σ^c	0.016	0.015	0.012
t^d	3.981**	1.978**	
CA^e			
$\bar{x}^b$	0.084	0.063	0.056
σ^c	0.075	0.046	0.028
t^d	1.688*	0.574	
PS^f			
$\bar{x}^b$	0.341	0.348	0.255
σ^c	0.260	0.257	0.228
t^d	1.198*	1.344	
τ^g			
$\bar{x}^b$	0.128	0.122	0.118
σ^c	0.010	0.009	0.007
t^d	3.982**	1.978**	

[a] *PT* = Loss in profit due to technical inefficiency (multiply by 100 for percentage).
[b] Mean.
[c] Standard Deviation.
[d] *t* statistic for testing difference between means of the distribution and the large form distribution (e.g., H_o: $\bar{x}$ small = $\bar{x}$ large).
[e] *CA* = Increase in cost due to allocative inefficiency (multiply by 100 for percentage).
[f] *PS* = Change in profit due to scale inefficiency (multiply by 100 for percentage).
[g] τ = Technical inefficiency (multiply by 100 for percentage).
Double asterisk denotes statistical difference in means at .05 level.
Single asterisk denotes statistical difference in means at .10 level.

to efficiency (e.g., credit restrictions) are present.

Medium-sized farms were statistically as allocatively efficient as large farms. This indicates that medium-sized farms minimize costs relatively well but still do not use an optimum input mix relative to the large farms.

Hopper found that farms in India with relatively few capital inputs were still quite allocatively efficient. This was based on the relative scarcity of inputs and also agricultural practices established through cultural practices established by trial and error over a long period. Medium-sized farms in the sample are obviously quite allocatively efficient. Consequently, these farms could be effective at minimizing costs but still be unable to obtain an efficient input mix.

Small farms, although having a statistically high mean loss due to allocative inefficiency (*CA* in table 4), have a large standard deviation. This indicates a wide range of very allocatively efficient farms to very allocatively inefficient farms.

Estimates of scale inefficiency show that for most of the farms price of milk is greater than marginal costs (i.e., $\xi < 0$). This means that actual output is less than the optimal level of output. The loss of profits due to such inefficiency for three different farm sizes are reported in table 4. This loss is referred to as *PS* [see equation (12)]. Since the loss of percentage profit for each group is substantial and these farms are surviving, one can argue that the government-regulated price must be reflected back to the farm level with a price above the average variable costs for most farms.

Another study showed that a group of dairy farms in Utah was more technically efficient than this group of Ecuadorian farms. However, the Ecuadorian farms in the medium- and large-sized categories were about as allocatively efficient as farms with under 50 dairy cows in the Utah study (Kumbhakar, Biswas, and Bailey). Assuming that the Utah farms are relatively allocatively efficient, this would indicate that the medium and large Ecuadorian dairy farms are allocating resources well.

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. Large and medium-sized farms are quite efficient at minimizing costs. All sizes of farms examined appear to be about equally technically inefficient. This may reflect some inaccessibility to credit to obtain capital inputs and/or simply an educational problem associated with the producers. 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. Increasing output will reduce scale inefficiency. The largest supply response would occur if more capital is utilized. Also, producers may need to be educated in the value and use of some capital inputs.

Farm management education may increase efficiency, if it teaches farmers to use capital inputs efficiently. This would have the effect of both increasing output (if more capital is used) and decreasing technical inefficiency.

Current government price controls in Ecuador appear to be maintained above average variable costs as well as marginal costs for many producers. This shows that actual output produced is less than the profit-maximizing level of output. Policies should be designed to encourage efficiency as well as production. Otherwise, production expansion will be difficult from an economic viewpoint. Increasing efficiency will lower average total costs and may encourage increased capital investment in the dairy industry.

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