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Technical Efficiency of Dairy Farms in Tamil Nadu

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SUMMARY

The study 'Technical Efficiency of Dairy Farms in Tamil Nadu' was carried out to evaluate dairy farm households in terms of efficiency of milk production using stochastic frontier production methods. The data for the study comprised of fixed investments on dairy farms, quantity and price of feeds and fodders fed to individual animals, labour utilization pattern, veterinary and miscellaneous expenses, quantity of milk produced and price realized, etc. collected from 160 sample households across flush and lean seasons for the year 2002-03. The coefficients for the value of green fodder and concentrate were found to be statistically significant with a relatively higher magnitude implying their greater and significant role in crossbred cow milk production. The technical efficiency of crossbred cow farms ranged from 72.30 to 97.90 per cent with an average of 82.10 per cent. The study indicated that there existed a scope to increase milk production of an average farm by 16.32 per cent for crossbred cows and 14.04 per cent for buffaloes without incurring any extra expenditure on these farms.

Key words: Technical efficiency, Stochastic frontier production function.

1. INTRODUCTION

Livestock sector plays a critical role in the welfare of India's rural population. It contributes 5.4 percent of total GDP and 27 percent to the GDP from agriculture and allied sectors (Economic Survey, 2005-06). This sector is emerging as an important growth leverage of the Indian economy with an annual milk production of 97.1 million tons in 2005-06 (Economic Survey, 2006-07) by involving more than 30 million small producers, each raising one or two cows or buffaloes. It accounts for more than 65 percent of the total value of livestock output. Though, India is all set to be the world's top milk producer, but the per capita milk availability remains low at 241 grams per day (Economic Survey, 2005-06), which is lower than the minimum recommended requirement of 250 grams per day as recommended by ICMR. The average productivity of cow is also very low, which is 917 kg per milch animal per year against the world average, which is 2038 kg/milch animal/year (FAO 2000). Therefore, there is a need to overcome these challenges through development of suitable policies and strategies for dairy development both in the short and long run keeping in view the limitations and constraints under the existing conditions in India.

It is a known fact that dairying in India is practised as a subsidiary occupation and is a regular source of earning to the farmers. Although it has made rapid strides, yet there is a need to improve the production and productivity so as to avoid malnutrition as well as achieve the substantial competitive advantage through liberalization. It is, therefore, necessary to undertake research efforts in ensuring better ways to estimate the efficiency of dairy farms in a manner that will enable to improve upon productivity of milch animals in a sustainable manner. This will not only ensure poverty reduction but also food security to the millions of rural poor in India.

Technical efficiency is a comprehensive measure of productivity and states as to how much gain in milk output could be realized without changing the level of input (efficiency component) when a least efficient farmer begins to follow the production practices of the most efficient one. It is considered to be one of the important factors of the productivity growth. Estimation of the extent of inefficiency can also help in deciding how to raise dairy farm productivity, whether by improving the farm efficiency or by developing new technologies itself (Ali and Chaudhry 1990). Thus, the dairy farm households were evaluated in terms of efficiency of milk production using stochastic frontier production methods.

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2. SAMPLING FRAMEWORK AND DATA COLLECTION

The state of Tamil Nadu has been purposively selected for the present study considering both the growth and importance of dairying in the state. In order to serve as a model for any research work, it is necessary to be representative study of the region. Tamil Nadu is an important state in terms of milk production and utilization. It has emerged as the ninth largest milk producer state of the country with a milk production of 4.75 million tons accounting for 5.40 per cent to the total milk production in the country and the second largest milk producer in the southern region (CSO 2004). In the southern states, Tamil Nadu performed highest number of Artificial Inseminations (A.I.), which were more than 2682 thousand in the year 2000 (CSO 2004).

In order to achieve the objectives of the present study, a multi-stage stratified random sampling technique was adopted to select the sample households. Considering the variations in agro-climatic features, cropping pattern, dairy and other livestock enterprises, socio-economic characteristics and milk production, the two districts of Tamil Nadu, namely, Erode and Trichy were purposively selected for the study. Two blocks were selected randomly from each of the two districts. In order to select sample households, a complete enumeration of all households in the selected villages was carried out. A sample of 20 households from each village were randomly selected on the basis of probability proportional to the number of the households in each category subject to a minimum of five households from each category. The data for the investigation consisted of both primary data for two seasons, namely, flush (August to February) and lean (March to July) for the year 2002-03 through a well structured, pre-tested proforma by personal interview method and secondary data obtained from published sources. The primary data pertaining to milk production and quantity and price of feeds and fodders fed to individual animals, labour utilization pattern, miscellaneous expenses, quantity of milk produced and price realized were collected.

3. METHODOLOGY

Stochastic Frontier Production Function Approach

The herd's productivity in the form of milk yield per day per animal has been widely used as a synonym of efficiency of dairy animals. This measure of efficiency does not take into account the effect of all the factors of production. Under Indian conditions, a number of studies have attempted to measure some or all of the inputs and outputs of dairy farming but failed to combine these into a satisfactory measure of efficiency. Till now, the policy analysis have been hypothesizing that the problem was in the adoption of technology and that all dairy farms were efficient on the basis of assumptions of functional analysis of ordinary least-squares regression i.e. efficiency was generally believed to be directly correlated with average productivity of animal in dairying.

In order to provide a satisfactory measure of efficiency, Farrell (1957) gave the concept of production frontier, which defines the maximization of physical production with a given level of resources. But his deterministic framework did not include the statistical noise and other distributional assumptions. Aigner *et al.* (1977) and Meeusen and Broeck (1977) independently proposed 'composed error' model i.e. the error term is composed of two independent elements ($\in = v + u$) and its distributional assumptions were popularly known as stochastic frontier production function approach. The objective of the present investigation was to estimate the efficiency of the farm household with respect to milk production for both crossbred cow and buffalo farms.

A large number of studies are available on the use of stochastic frontiers for the measurement of technical efficiency in production (Battese and Corra 1977, Dawson and Lingard 1989, Kalirajan 1990, Battese 1992, Hazarika and Subramanian 1999, Saha 2003, Manoharan 2004).

The stochastic frontier production function is defined as

$$Y_i = f(X_{ki}; \beta_i)\exp(\in_i) \qquad (4.1)$$

$$i = 1, \ldots, n; \; k = 1, \ldots, k$$

where

Y_i = Output of the i^{th} farm

X_{ki} = Vector of k inputs of the i^{th} farm

β = Vector of parameters and

$\in_i$ = Farm specific error term

This stochastic frontier is also called a "composed error" model because the error term is composed of two independent elements as

$$\in_i = u_i + v_i \qquad i = 1, \ldots, n \qquad (4.2)$$

The symmetric component, v_i represents statistical "white noise" and permits random variation in output due to factors outside the control of the farm such as weather and diseases. It is assumed to be independently and identically distributed (i.i.d) as $N(0, \sigma_v^2)$. A one-sided component ($u_i \leq 0$) reflects technical efficiency relative to the stochastic frontier, $f(X_i; \beta)e^{vi}$ thus $u_i = 0$ for any farm's output lying on the frontier and is strictly negative for any output lying below the frontier, representing the amount by which the frontier exceeds the actual output on farm 'i'. Assume that it is identically and independently distributed as $N(0, \sigma_u^2)$; that is the distribution of u is half normal.

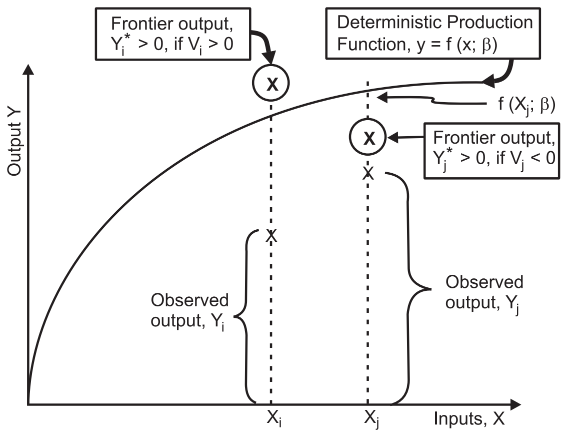

Fig. 4.1. Stochastic Frontier Production

The basic structure of the stochastic frontier model (4.2) is depicted in Fig. 4.1 in which the productive activities of two firms, represented by 'i' and 'j', are considered. Firm 'i' uses inputs with values given by (the vector) x_i and obtains the output, Y_i, but the frontier output, Y_i^*, exceeds the value on the deterministic production function, $f(x_i; \beta)$, because its productive activity is associated with 'favourable' conditions for which the random error, V_i, is positive. However, firm 'j' uses inputs with values given by (the vector) x_j and obtains the output, Y_j, which has corresponding frontier output, Y_j^*, which is less than the value on the deterministic production function, $f(x_j; \beta)$, because its productive activity is associated with 'unfavourable' conditions for which the random error, V_j, is negative. In both cases, the observed production values are less than the corresponding frontier values, but the (unobservable) frontier production values would lie around the deterministic production function associated with the firms involved. It is possible that both the observed and frontier values, Y_i and $Y_i^* = f(x_i, \beta) \exp(V_i)$, lie above the corresponding vlaue of the deterministic production function, f(xi, iβ), if $V_i > U_i$. This case is not depicted in Fig 4.1.

Further, following Aigner *et al.* (1977) define λ as the ratio of standard errors in stochastic to symmetric disturbances

$$\lambda = \sigma_u / \sigma_V \qquad (4.3)$$

Battese and Corra (1977) on the other hand define γ as the total variation in output from the frontier, which is attributable to technical (in) efficiency that is

$$\gamma = \sigma_u^2 / \sigma^2 \qquad (4.4)$$

So that $0 \leq \gamma \leq 1$. An estimate of γ can be obtained from estimates of σ^2 and λ.

Jondrow *et al*. (1982) have demonstrated that individual farm specific technical efficiencies can be estimated from the error terms. It is possible because $\in_i = v_i + u_i$ can be estimated and it obviously contains information on u_i. One can evaluate by considering the conditional distribution of u_i given $\in_i$. This distribution contains whatever information $\in_i$ yields about u_i. For commonly used cases of half-normal and exponential u_i, these expressions are easily evaluated. In case of half-normal model, the expected value of u_i, conditional on $\in_i$, that is

$$E[u_i \mid \in_i] = \frac{\sigma_u \sigma_V}{\sigma}\left(\frac{f(\in_i, \lambda \mid \sigma}{1 - F(\in_i, \lambda \mid \sigma)} - \frac{\in_i \lambda}{\sigma}\right) \qquad (4.5)$$

where $i = 1, 2, ..., n$

f (.) = Standard normal density function, and

F (.) = Standard normal distribution function

The primary advantage of a stochastic frontier production function is that it enables one to estimate u_i and, therefore, also to estimate farm specific technical efficiencies. The measure of technical efficiency is equivalent to the ratio of the production of the i^{th} farm to the corresponding production value, if the farm effect u_i were zero.

Following Battese and Coelli (1988), when output is measured in logarithms, the farm specific technical efficiency can be estimated as

$$TE_i = \text{Exp}(-u_i) \qquad (4.6)$$

$$i = 1, 2, \ldots, n; \; 0 \leq TE_i \leq 1$$

The ML estimator for the technical efficiency of the i^{th} farm was obtained by substituting the ML estimators for the relevant parameters in the above equation using the software FRONTIER 4.1 (Coelli 1995).

Model Specification

A limited number of studies are available for measuring technical efficiency by using stochastic production frontier method. The Cobb-Douglas (C-D) production frontier was used by Manoharan *et al*. (2004) and both C-D as well as translog frontier function were used by Saha (2003) and Mbaga *et al*. (2003) in dairy farm studies.

In the present study, the Cobb-Douglas functional form was estimated with the specification

$$\text{Log } Y_{ki} = \alpha + \sum_{i=1}^{6} B_{il} \log X_{ikl} + \epsilon_{ikl} \quad (4.7)$$

$$\epsilon_{ikl} = u_{ikl} + v_{iki} ; u \leq 0$$

where

i = Independent input variables used in the model (1, 2, ., 6)

k = Number of dairy farms in the study area (1, 2, …, 135 for crossbred cows; 1, 2, …, 59 for buffaloes)

l = Number of milch animal species used in the study (1, 2) namely crossbred cow and buffalo

The description of various variables in the equation (4.7) is stated as

Y_{kl} = Total milk produced on k^{th} farm per l^{th} milch animal species per annum (litres)

X_{1kl} = Total value of green fodder used on k^{th} farm per l^{th} milch animal species per annum (Rs.)

X_{2kl} = Total value of dry fodder used on k^{th} farm per l^{th} milch animal species per annum (Rs.)

X_{3kl} = Total value of concentrate feed used on k^{th} farm per l^{th} milch animal species per annum (Rs.)

X_{4kl} = Total wages paid by k^{th} farm per l^{th} milch animal species per annum (Rs.)

X_{5kl} = Total veterinary cost and services, and miscellaneous cost incurred on k^{th} farm per l^{th} milch species per annum (Rs.)

X_{6kl} = Total value of interest and depreciation on k^{th} farm per l^{th} milch species per annum (Rs.)

β_{il} = Parameters of regression coefficients of the i^{th} variable for the l^{th} species

4. RESULTS AND DISCUSSION

Measurement of Efficiency for Crossbred Cow Milk Production

The present analysis provides insights into the sustainable methods of productivity improvement through change in inputs or technological change, which requires additional resources. The results of the study have policy implications because the study not only provides empirical measures of technical efficiency indices, but also intensifies the potential of improvement in milk production across various dairy farms based on efficiencies. The stochastic frontier production approach was used to estimate the farm specific technical efficiency and the results thereon are presented in the ensuing paragraphs.

Frontier Functional Analysis for Milk Production

Based on the model discussed in the methodology, ordinary least squares (OLS) and maximum likelihood estimation (MLE) techniques were employed to estimate the parameters of the Cobb-Douglas production function using Frontier version 4.1 software package. The results of the same for crossbred cows and buffaloes have been presented in Table 4.1.

a) Crossbred cow farms

A perusal of the table showed that the coefficient of multiple determination (R^2) was 0.8805 indicating that 88.05 per cent of the variation in milk production was explained by the explanatory variables included in the model. The OLS function provided the estimates of the average production function while the MLE model provided estimates of the stochastic production frontier. The MLE function results provided in the Table 4.1 showed that the influence of all the explanatory variables on milk production was positive and statistically significant. The value of the estimate of log likelihood ratio (137.95) was significantly different from zero, which followed chi-square distribution indicating goodness of fit of the model. The green fodder and concentrate were the dominant factors in determining the milk output. The estimated value of elasticities for these variables indicated that one per cent increase in the value of green fodder, concentrate and human labour would raise the milk output by 0.1919, 0.1056 and 0.1001 per cent, respectively. The coefficients of remaining variables like dry fodder, veterinary and miscellaneous expenses and fixed expenses were also found to be statistically significant but very low in magnitudes which were 0.0778, 0.0678 and 0.0855, respectively. It indicates that ten per cent increase in these variables would increase the milk production by less than one percent only. The variance parameters σ^2 and γ were positive and significant at one percent level showing that the farm specific variability contributed more to the variation in the milk yield among the crossbred sample households which implied that the total variation in milk production from the frontier was attributable to technical inefficiency. A value of 0.8102 for γ suggested that about 81 per cent of the differences in farmers milk production level were related to farm specific technical efficiency and the remaining differences were due to random error. These factors being under the control of the farm, their influence can be reduced to enhance technical efficiency of the sample farms. Relatively higher value of the constant term in MLE and comparable value of slopes in the present study supported the Hick's neutral technical change. The coefficients for value of green fodder and human labour obtained by both the OLS and MLE methods were statistically significant at one percent level indicating increasing role of green fodder and human labour in determining the efficiency of crossbred cow milk production.

b) Buffalo farms

A perusal of Table 4.1 revealed that the variables dry fodder and concentrate were statistically significant and the remaining variables were non significant. A one per cent increase in value of concentrate and dry fodder would increase the milk output by 0.2062 and 0.1203 per cent, respectively, indicating their importance in milk production. The estimates of log-likelihood function (60.02), which followed chi-square distribution, indicated the goodness of fit of this model. The variance parameters σ^2 and γ were positive and statistically significant at one per cent level showing that the farm specific variability contributed more to the variation in yield among the sample farms. The value of gamma was 0.85 implying that 85 per cent of the differences in the milk output of farms were due to farm specific technical efficiency and remaining milk output loss was due to random errors. The relatively higher value of the constant term in MLE technique than OLS technique supported the implicit assumption of Hick's neutral technical change. Though the coefficient of concentrate was statistically significant in both OLS and MLE models yet the magnitude of coefficient was higher in case of MLE than OLS which implied increasing role of concentrate in determining the efficiency of milk production of buffalo farms in the study area. Similar findings were observed by Saha (2003) in a study on buffalo milk production in Haryana.

Estimation of Farm Specific Technical Efficiencies and Potential for Increasing Milk Production

The farm specific technical efficiencies were estimated and the frequency distribution of the crossbred cow and buffalo farms according to technical efficiency intervals are presented in Table 4.2.

a) Crossbred cow farms

The estimates of technical efficiency of farms ranged from 72 to 98 per cent with an average of 82.05 per cent, indicating that on an average, the sample crossbred dairy farms in the selected study area of Tamil Nadu state tend to realize only 82 per cent of the technical abilities. It means that approximately 18 per cent of technical potentialities were not realized. The farm number CB-41 was found to be the most efficient farm with a production 2746.95 litres of milk per annum and the least efficient farm (CB-17) had a production of 2046.42 litres per annum. Approximately 31 per cent of the total sample farms realized more than 90 per cent of its output and remaining 70 per cent of the farms lost their output by more than 10 per cent (i.e., TE < 90 per cent) under the existing technology.

Productivity enhancement in crossbred cows is one of the most important goals of Indian dairying. Based on the technical efficiency of the most efficient farm, the average potential to increase milk production of the crossbred cow farms was determined using the following formula.

Potential for increasing milk production per milch animal

$$= \left[1 - \frac{\text{Mean TE}}{\text{Maximum TE}}\right] \times 100$$

The average potential for increasing milk production through technical efficiency improvement in case of crossbred cow dairy farms was 16.32 per cent, which implied that if the average farmer in the sample was to achieve the technical efficiency level of its most efficient counterpart, then the average farmer would be able to increase his milk output by 16.32 per cent. A similar calculation for the least technically efficient farmer revealed an increase in milk output by {[1 – (72.30 / 98.00)] = 26.22}, i.e., 26.22 per cent.

b) Buffalo farms

Table 4.2 further revealed that the estimated technical efficiency of buffalo farms ranged from 69 to 99 per cent with a mean technical efficiency of 85.10 per cent indicating that on an average, the sample dairy farms in the study area tend to realize approximately 85 per cent of the technical potentialities. This implied that approximately 15 per cent of technical abilities were not realized. Only 22 per cent of farms achieved more than 90 per cent of their output potential and remaining 78 per cent of the farms lost more than 10 per cent of their output under the existing resources and technology. Further, it was observed that the most efficient farm produced 1319.04 litres of milk per annum per buffalo with the existing resources. On the other hand, the least efficient farm produced 923.32 litres per annum per buffalo.

Based on the technical efficiency of the most efficient buffalo farm, the average potential to increase milk production was determined by the formula as {[1 – (85.1 / 99)] × 100 = 14.04}, i.e., 14.04 per cent. This suggested that if the average farmer in the sample was to achieve a technical efficiency level of its most efficient counterpart, then the average farm can increase its milk output by 14.04 per cent. Likewise, the least efficient farm would be able to increase the milk production by 30.70 per cent by following the practices of most efficient farm in the sample.

5. SUMMARY AND CONCLUSIONS

It can thus be concluded from the results that the coefficients for value of green fodder and concentrate were statistically significant with a relatively higher magnitude as compared to the coefficients of other inputs which implied that these inputs would have greater and significant impact on crossbred cow milk production. This result was in conformity with the findings of Ganesh Kumar (1997) and Kumaravel (1998) who conducted study of milk production in Tamil Nadu and Chand (1998) in Rajasthan. It was further concluded that the technical efficiency of the crossbred cow farms ranged between 72.30 and 97.90 per cent with an overall average of 82.05 per cent. It indicated that there exists a scope to increase milk production of an average farm by 16.32 per cent without incurring any extra expenditure on these farms. The results observed in the present study were in conformity with the findings of Battesse and Coelli (1998), Kumbharkar *et al.* (1989), Bravo-Ureta and Rieger (1990), Srivastava (1995), Chand (1998), Mbaga *et al.* (2003), Saha (2003) and Manoharan (2004) who observed the technical efficiency to vary between 57 to 100 per cent in crossbred cow dairy farms.

It was further concluded that concentrate and dry fodder were the major determinants to enhance the milk production which was in conformity with the findings of Rai and Gangwar (1976) and Saxena *et al*. (1998) while conducting a study on buffalo milk production in Haryana. The result of technical efficiency indicated that there existed a scope to increase milk production of average farm by about 14 per cent using the existing resources without incurring any extra expenditure on the buffalo farms. Srivastava (1995) and Saha (2003) observed the technical efficiency to vary between 57 and 100 per cent respectively in Delhi and Haryana buffalo farms, which was similar to the finding of the present study.

6. POLICY IMPLICATIONS

There is a scope to improve the milk production of crossbred cows and buffaloes across dairy farms using the existing resources as shown by technical efficiency estimates. This suggested that the milk producers should be educated periodically with regard to appropriate feeding practices, maintaining optimal herd size, balanced feeding, artificial insemination and new technologies in dairying in order to achieve the maximum milk production thereby realizing more profit.

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Table 4.1. Estimates of OLS and MLE parameters of stochastic Cobb-Douglas production frontier for crossbred cow and buffalo milk production

Variables	CB Cows				Buffaloes			
	OLS Estimates		ML Estimates		OLS Estimates		ML Estimates	
	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
Constant term	-0.3379*	0.1666	-0.1344	0.1742	-0.4121	0.3342	-0.1002	0.2598
Value of green fodder	0.1403**	0.0301	0.1919**	0.0363	0.0767	0.0807	0.1095	0.1867
Value of dry fodder	0.0949**	0.0234	0.0778**	0.0185	0.1564*	0.0696	0.1203*	0.0555
Value of concentrates	0.2458**	0.1092	0.1056*	0.0380	0.2014**	0.0539	0.2062**	0.0387
Wage rate	0.0998**	0.0334	0.1001**	0.0273	0.1009*	0.0506	0.0807	0.0669
Veterinary and Miscellaneous cost	0.0811**	0.0244	0.0678**	0.0210	0.0956	0.0743	0.0681	0.0425
Fixed expenses	0.0912**	0.0256	0.0855**	0.0283	-0.0265	0.0454	-0.0316	0.0280
Variance parameters σ^2	0.0081	-	0.0159**	-	0.0105	-	0.0289**	0.0004
γ	-	-	0.8102**	-	-	-	0.8500**	0.0110
Log-likelihood function	136.51	-	137.95	-	54.37	-	60.02	-
Coefficient of multiple determination	0.8805	-	-	-	0.8665	-	-	-
No. of observations	135	-	135	-	59	-	59	-

* Significant ($P < 0.05$)

** Significant ($P < 0.01$)

Table 4.2. Frequency distribution and descriptive statistics of technical efficiency of crossbred cows and buffalo farms in the study area

Efficiency Level (Percent)	CB Cows		Buffaloes	
	Frequency of Farms	Per cent	Frequency of Farms	Per cent
95 – 99	30	22.22	10	16.95
90 – 94	13	9.63	3	5.09
85 – 89	63	46.67	22	37.28
80 – 84	28	20.74	10	16.95
75 – 79	0	0.00	8	13.56
70 – 74	1	0.74	4	6.78
< 70	0	0.00	2	3.39
No. of observations	135	100.00	59	100.00
Mean	0.8205		0.8510	
S.D.	0.0472		0.0839	
Maximum	0.9790		0.9900	
Minimum	0.7230		0.6860	