Madras Agric. J. 91 (4-6) : 286-291 April-June 2004
https://doi.org/10.29321/MAJ.10.A00108

Measurement of technical efficiency in the stochastic frontier production function model : An application to the tea industry in the Nilgiris district

N. MAHESH AND A. MALAISAMY
CARDS, Tamil Nadu Agricultural University, Coimbatore - 641 003, Tamil Nadu

Abstract: The study was conducted in the Nilgiris district of Tamil Nadu during this year 1998-99 to estimate technical efficiency in the stochastic frontier production function model. It was found that the co-efficient of labour, FYM and fertilizers, plant protection chemicals and variety for both tea farmers and corporate sector remained significant. It was also identified that about 15.00 per cent of the total farmers who operated the estates belonged to the most efficient category (91-99 per cent) and 65.00 per cent in the least efficient group (64-80 per cent) with a mean technical efficiency of 76.52 per cent. Whereas in the case of corporate units, about 70.00 per cent belonged to the most efficient category (91-99 per cent) and 11.67 per cent in (64-80 per cent the least efficient group with a mean technical efficiency of 86.68 per cent. Therefore, in short run it is possible to increase tea yield on an average by 23.48 per cent in the case of farmers and 13.32 per cent in the case of corporate units by adopting better management practices used by the best performers.

Key words : Tea farmers, Corporate sector units, Stochastic frontier, Maximum likelihood estimates and Technical efficiency.

Introduction

Tea industry is one of the traditional plantation based industries and India holds a prime position in production, consumption and export of tea. India is a major tea producing country in the world with about 29.76 per cent of global tea output during the year 1998-99. The two main tea-growing areas in India are the North East India comprising the states of Assam, West-Bengal and Tripura and South India comprising the states of Tamil Nadu, Kerala and Karnataka. Small quantities of tea are also produced in Bihar, Uttar Pradesh, Himachal Pradesh and Sikkim. Extension of tea cultivation is being attempted in Meghalaya, Manipur, Arunachal Pradesh, Nagaland and Mizoram. Out of the total production, about 53 per cent was accounted by Assam followed by West-Bengal, Tamil Nadu and Kerala. These together accounted for 98 per cent of tea production in the country during the year 1998-99.

The production of tea in Tamil Nadu increased from 74.02 million kg to 125.09 million kg from 1980-81 to 1998-99. The dramatic increase in production took place in 1980s due to better adoption of management practices coupled with the expansion of area under tea. The difference in growth pattern between early 80s and late 90s adequately reflects the task before the tea industry in Tamil Nadu namely sustained and accelerated augmentation of production and productivity. There is a good potential for increasing output by the way of adoption of advanced management practices and technological improve ments. A comparison of the highest yields level with the respective district's average reveals that sufficient scope exists to raise the yield of low yielding plantations. The analysis of the yield difference at national level indicates the possibility of raising production by around 500 million kg, if each district were to raise

Table 1. Estimated parameters of MLE for farmers and corporate sector units

Variables	Symbol	Coefficient of	
		Farmers	Corporate sector units
Constant term	$\beta 0$	2.0132** (2.9672)	3.4572**
Total labour (Mandays ha^{-1})	X_1	1.5607** (3.0170)	1.8741** (3.1238)
Value of FYM and fertilizers (Rs ha^{-1})	X_2	0.9841** (2.7812)	0.3897** (2.6072)
Value of capital service (Rs ha^{-1})	X_3	0.2817 (1.3025)	0.4836 (1.2295)
Value of plant protection chemicals (Rs ha^{-1})	X_4	-0.6812** (3.2157)	0.7132** (2.9545)
Dummy for variety	D_1	0.2018** (3.1124)	0.4662** (3.2965)
Dummy for plucking	D_2	0.0478 (0.0979)	-0.0679 (0.0812)
Dummy for irrigation	D_3	0.0321 (0.0668)	0.0571 (0.0774)
λ		892.7 (72510.4)	997.8 (87471.2)
Υ		0.99	0.99
N		60	60

Note : The figures in parentheses are 't' value
** indicates significance at 1 per cent level

Table 2. Frequency distribution of technical efficiency

Efficiency level	Tea farmers	Corporate units
Low (64-80)	39 (65.00)	7 (11.67)
Medium (81-90)	12 (20.00)	11 (18.33)
High (91-99)	9 (15.00)	42 (70.00)
Mean	76.52	86.68
Total estates	60.00 (100.00)	60.00 (100.00)

Note : Figures in parentheses indicate percentage to total

its average yield to the level of its highest yielding plantations. This necessitates an analysis of production efficiency of the tea gardens to help in formulating policy measures to remove the production constraints in the Nilgiris district of Tamil Nadu.

Materials and Methods

Among tea producing districts in Tamil Nadu, the Nilgiris district accounted for about 72.67 per cent of total area under cultivation. Hence, this district was purposively selected for the present study based on the area of concentration. The tea growers were classified into two groups namely, estates owned by farmers and estates owned by corporate firms listed in the Tea Board records. From this list, the 60 corporate sector units and 60 tea farmers were selected randomly. The primary data pertain to the agricultural year 1998-99 were collected by personal interview method using a pre-tested comprehensive interview schedule.

Production frontier

Frontier production function represents a maximum possible output for any given set of inputs making use of best technology available thus sets a limit or frontier on the observed values of dependent variable. In the sense that no observed value of output is expected to lie above this frontier. Any deviation of a farm from the frontier indicates the extent of farm's inability to produce maximum output from its given set of inputs and hence represents the degree of technical inefficiency.

A production process may be inefficient in two ways, only one of which can be detected by an estimated production frontier. It can be technically inefficient, in the sense that it fails to produce maximum output from a given input bundle. The other type of inefficiency could be allocative inefficiency in the sense that input becomes inefficient, eventhough the technology is efficient. Allocative inefficiency results in utilization of inputs in the wrong proportion with given input prices.

The technical efficiency in production was estimated by using the stochastic frontier production function. The stochastic frontier production function was independently proposed by Aigner *et al.* (1977) and Meeusen and Van den Broeck (1977). The estimation of stochastic frontier production function made it possible to find out whether the deviation in technical efficiency from the frontier output is due to firm specific factors or due to external random factors. The stochastic frontier model can be represented as

$$Yi = f(Xi,\beta) \exp(v_i - u_i)$$

where,

Y_i = production of i^{th} farm

X_i = is a suitable function of the vector X of inputs for the i^{th} farm

B = is the vector of unknown parameters

V_i = is the symmetric component of the error term

u_i = is the non-negative random variable which is under the control of the farm.

Given the density function of u_i and v_i, the frontier production function can be estimated by Maximum Likelihood Technique.

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

$$E(U_i/\varepsilon_i) = \sigma_u\sigma_v/\sigma \, [\, \phi(\varepsilon_i\lambda/\sigma) / \{1 - \varepsilon_i\lambda\varphi\ (\varepsilon_i\lambda/\sigma\} - \varepsilon_i\lambda/\sigma]$$

ε = $U_i + V_i$, the composed error term

i = 1,2,...n,

ϕ = represent the standard normal density function and φ represents the cumulative density function, and

λ = is the ratio of standard errors, σ_u/σ_v

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

$$TE_i = \text{Exp}\ (-u_i)$$
$$i = 1,2,3,\ldots,n, 0 \leq TEi \leq 1$$

The various ratio λ explaining the total variations in output from the frontier level of output attributed to technical efficiencies can be computed as :

$$\lambda = \sigma^2_u/\sigma^2$$

Model specification

The stochastic frontier production function of the Cobb-Douglas type was specified for this study. Due to its advantages over the other functional forms, it is widely used in the frontier production studies.

The model used was :

$$Yi = \beta_0 + \beta_1 \log X_1 + \beta_2 \log X_2 + \beta_3 \log X_3 + \beta_4 \log X_4 + \beta_5 \log D_1 + \beta_6 \log D_2 + \beta_7 \log D_3 + v_i - u_i$$

where,

Y_i = Total green tea leaf yield (kg ha^{-1})

X_1 = Total labour (mandays ha^{-1})

X_2 = Value of fertilizer and farmyard manure (Rs ha^{-1})

X_3 = Value of capital services (Rs ha^{-1})

X_4 = Value of plant protection chemicals (Rs ha^{-1})

D_1, D_2 and D_3 = Dummy variable

D_1 = 0, if old variety

D_1 = 1, otherwise,

D_2 = 0 if handpicking

D_2 = 1, if otherwise

D_3 = 0, if traditional irrigation system

D_3 = 1, if otherwise

β_0 = Constant term

u_i = Specific technical efficiency related factors

v_i = Random variable and

i = 1,2,3 ....n,

From the residual, the farm specific technical efficiencies were estimated.

Results and Discussion

Frontier production function

The maxium likelihood estimates of the frontier production function estimates are presented in Table 1. From the table, it is clear that in the case of tea farmers, the estimates of λ (892.7) was significantly different from zero indicating a good fit and the correctness of the distributional assumption specified. The variance ratio (γ) showed that 99 per cent of the differences between the observed and the maximum production frontier output were due to differences in farmer's level of technical by adopting different management practices and not related to random variability. These factors are under the control of the farm and the influence of which can be reduced to enhance technical efficiency of the estate owners.

With an upward shift in the constant term, the co-efficient of labour, FYM and fertilizers, plant protection chemicals and variety remained significant in the stochastic production function. It implies that the estate owners could use more of labour and FYM and fertilizer and also adoption of new or improved varieties. It also indicated that reduction in use of inferior plant protection chemicals would increase the green leaf yield further.

In the case of corporate units, the estimates of λ (997.8) were also significantly different from zero indicating a good fit and the correctness of distributional assumptions specified. The variance factor showed that 99 per cent of the differences between the observed and the maximum production level was due to different management practices adopted and not related to random variability.

With positive shift in the intercept term, the co-efficient of labour, FYM and fertilizers, plant protection chemicals and variety remained significant in the stochastic production function. It implies that the corporate units could use more of labour, fertilizer and FYM, and plant protection chemicals and also adopt the improved variety.

Farm specific technical efficiencies

The farm specific technical efficiencies were estimated and the frequency distribution is presented in Table 2. From the table, it is clear that about 15.00 per cent of the total farmers who operated the estates belonged to the most efficient category (91-99 per cent) and 65.00 per cent in the least efficient group (64-80 per cent) with a mean technical efficiency of 76.52 per cent. It was found that the most efficient farm employed 405 mandays of labour, and used Rs.10425.50 worth of FYM and fertilizer, Rs.4975.25 worth of plant protection chemicals and produced 12235.45 kgs of green tea leaf per ha. Whereas in the case of corporate units, about 70.00 per cent belonged to the most efficient category (91-99 per cent) and 11.67 per cent in (64-80 per cent) the least efficient group with a mean technical efficiency of 86.68 per cent. It was also found that, the most efficient corporate sector employed 412 mandays of labour and used Rs.11925.75 worth of FYM and fertilizer, Rs.5845.75 worth of plant protection chemicals and produced 14625.35 kgs of green tea leaf per ha. It was also observed that the farm specific technical efficiency varied between 0.64 to 0.99 in both groups of tea growers.

Therefore, in the short run it is possible to increase tea yield on an average by 23.4 per cent in the case of farmers and 13.3 per cent in the case of corporate units by adopting better management practices used by the best performers. Even though, homogeneity and full utilization of resources are assumed, the non-availability of quality inputs and lack of technical management may be the main reason for the low efficiency in production of tea in the case of farmers, whereas in the case of corporate units, higher financial support, timely operations and high technical management may favour the higher efficiency in tea production (Hazarika and Subramanian, 1999).

Conclusions

The present study showed that even under the existing management practices and technological potentials, there exists a good scope for improving the productivity with proper allocation of existing resources. Hence, proper extension strategy needs to be taken to educate the estate owners about the rational use of inputs. Any increase in tea production in this district should come from productivity led growth rather than area led growth. Hence, the existence of obsolete tea bushes is one of the factors that inhibited the growth of the industry. The high percentage of vacancy and old age bushes weakened the productivity of the plantations, so the estate owners should be educated on the need for understanding infilling, replanting and replacement planting.

Unlike manufactured industries, tea industry is labour intensive, extra efforts are required for maintaining better relationship between the workers and the management which in turn improves working relationship, workers productivity and also their welfare. The continuing development of the managerial and technical skills of the existing managers should be given more attention. To achieve this, the greater interface with the industry and various tea research stations is needed on human resource management.

References

Aigner, D.J., Lovell, C. and Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, **6**: 21-37.

Battese, G.E. and Coelli, T.J. (1988). Prediction of firm-level technical efficiencies with a generalized frontier production function and panel data. *Journal of Econometrics*, **38**: 387-399.

Hazarika, C. and Subramanian, S.R. (1999). Estimation of technical efficiency in the stochastic frontier production function model. An application to the tea industry in Assam. *Indian Journal of Agricultural Economics*, **54**: 201-211.

Jondrow, J., Lovell, C.A.K., Materov, I.S. and Schmidt, P. (1982). On the estimation of technicale inefficiencies in the stochastic frontier production function model. *Journal of Econometrics*, **19**: 233-238.

Meeusen, N. and Van Den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composted error. *International Economic Review*, **18**: 435-444.

Schmidt, P. and Lovell, C.A.K. (1979). Estimating technical and allocative efficiency relative to stochastic production and cost-frontiers. *Journal of Econometrics*, **9**: 343-366.

(Received: April 2002; Revised: May 2004)