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RESEARCH NOTES

Technical Efficiency of Natural Rubber Production in Kerala : A Panel Data Analysis

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INTRODUCTION

The share of area under natural rubber in total cropped area showed a consistent increase in Kerala and it occupied 14.64 per cent of the gross cropped area in 1995-96. Almost 86 per cent of national area and 94 per cent of production was concentrated in the state. The additional land availability for natural rubber cultivation in the state is very limited and once the frontier for extensive cultivation is reached, further increase in production has to come only from improvement in productivity of the crop. In this context, technical efficiencies in production assume paramount importance. This study was taken up with the twin objectives of estimation of technical efficiencies and to identify its determinants in natural rubber production in the estate sector of Kerala.[1] Technical efficiency is somewhat an elusive concept, but it is most frequently associated with the role of management in the production process (Page Jr., 1980). It is reasonable to assume that differences in the efficiency of factor use are attributable to differences in the entrepreneurial talents of the firms. Probing into the reasons for variation in efficiencies will give further impetus to the production of natural rubber by appropriate policy prescriptions. A measure of technical efficiency, which avoided the problems associated with traditional average response function, was first introduced by Farrell (1957). A more satisfactory means of estimating technical efficiency, viz., stochastic frontier model was independently formulated by Aigner *et al.* (1977) and Meeusen and Van den Broeck (1977) which improved the estimation of technical efficiencies by incorporating both statistical noise representing uncontrolled exogenous factors and technical efficiency. Jondrow *et al.* (1982) made it possible to estimate technical efficiencies for each farm. The majority of the application of frontier production function used cross-section data. However, more recently attempts have been made to apply it in the analysis of time-series and panel data (Pitt and Lee, 1981; Battese and Coelli, 1988; Battese and Coelli, 1992).

METHODOLOGY

In this study, the stochastic frontier production function model proposed by Battese and Coelli (1992) with a simple exponential specification of time varying firm effects which incorporated unbalanced panel data was used. The model is defined for N firms over t time periods. It can be represented as,

$$Y_{it} = f(X_{it};\beta)\mathrm{Exp}(V_{it} - U_{it}) \qquad \ldots(1)$$

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and

$$U_{it} = \{Exp[-\eta(t-T)]\} U_i \quad \text{....(2)}$$

$t \varepsilon I(i), i = 1, 2, ..., N.$

where

Y_{it} = production for the i-th firm at the t-th time period,

$f(X_{it}; \beta)$ = a Cobb-Douglas function of a vector X_{it} of inputs associated with the production of the i-th firm in the t-th period of observation and a vector β of unknown parameters,

V_{it} = random errors, which are assumed to be independent and identically distributed $N(0, \sigma_v^2)$,

U_{it} = firm specific error component assumed to be an exponential function of time with non-negative truncation of the $N(\mu, \sigma^2)$ distribution,

η = unknown scaler parameter to be estimated,

I (i) = represents the set of T_i time periods among the T periods involved for which observation for the i-th firm are obtained.

The model is a generalisation of the half normal distribution which has been frequently applied in studies. It is assumed that U_i is a non-negative truncation of the $N(\mu, \sigma_u^2)$. Further U_{it} and V_{it} are assumed to be distributed independently. The technical efficiency of the i-th firm at the t-th time period can be calculated using

$$TE_{it} = Exp\ (-U_{it}) \quad \text{.... (3)}$$

$$E[exp(-U_{it})/E_i] = \frac{1-\phi[\eta_{it}\sigma_i^* - (\mu_i^*/\sigma_i^*)]}{1-\phi(-\mu_i^*/\sigma_i^*)} Exp\left[-\eta_{it}\mu_i^* + \frac{1}{2}\eta_{it}^2\sigma_i^{2*}\right] \quad \text{....(4)}$$

where E_i represents the $(T_i \times 1)$ vector of E_{it}'s associated with the time periods for the i-th firm, and so is η_i *correspondingly.*

$$E_{it} = V_{it} - U_{it}$$

$$\mu_i^* = \frac{\mu\sigma_v^2 - \eta_i' E_i \sigma^2}{\sigma_v^2 + \eta_i'\eta_i\sigma^2} \quad \text{....(5)}$$

$$\sigma_i^{2*} = \frac{\sigma_v^2\sigma^2}{\sigma_v^2 + \eta_i'\eta_i\sigma^2} \quad \text{....(6)}$$

The variance ratio (γ) can be estimated by

$$\gamma = \sigma^2/\sigma_K^2 \quad \text{....(7)}$$

where $\sigma_K^2 = \sigma_v^2 + \sigma^2$

Equation (4) was used to derive the individual technical efficiencies.

The mean technical efficiency of firms at the t-th time period can be derived using,

$$TE_t = E[Exp(-\eta_t U_i)] \quad \text{....(8)}$$

where $\eta_t = Exp[-\eta(t-T)]$, obtained by integration with the density function of U_i is,

$$TE_t = \frac{1-\phi[\eta_t\sigma - (\mu/\sigma)]}{[1-\phi(-\mu/\sigma)]} Exp[-\eta_t\mu + (1/2)\eta^2\sigma^2] \quad ....(9)$$

Specification of the Production Function

Cobb-Douglas production function of the following form was specified for the analysis.

$$\ln Y_{it} = \beta_0 + \beta_1 \ln NT1_{it} + \beta_2 \ln NT2_{it} + \beta_3 \ln NT3_{it} + \beta_4 \ln MD_{it} + \beta_5 \ln FR_{it} + \beta_6 \ln CL1_{it} + \beta_7 \ln CL2_{it} + \beta_8 \ln CL3_{it} + \beta_9 \ln TS1_{it} + \beta_{10} \ln TS2_{it} + E_{it} \quad ....(10)$$

where i = 1,2,....... 35, t = 1,2,3,

Y_{it} = yield of rubber of i-th farm in t-th year in kilograms of dried latex,
$NT1_{it}$ = number of trees in the first age group of i-th farm in t-th year,
$NT2_{it}$ = number of trees in the second age group of i-th farm in the t-th year,
$NT3_{it}$ = number of trees in the third age group of i-th farm in the t-th year,
MD_{it} = man-days used for tapping of i-th farm in t-th year,
FR_{it} = quantity of fertiliser in kg (NPK) of i-th farm in t-th year,
$CL1_{it}$ = area under clones whose average yield is less than 1000 kg/ha/year of i-th farm in t-th year,
$CL2_{it}$ = area under clones whose average yield is between 1001-1250 kg/ha/year of i-th farm in the t-th year,
$CL3_{it}$ = area under clones whose average yield is more than 1251 kg/ha/year of i-th farm in the t-th year,
$TS1_{it}$ = area less than or equal to a tapping intensity of 67 per cent of the i-th farm in t-th year,
$TS2_{it}$ = area with a tapping intensity of more than 67 per cent of the i-th farm in t-th year,
E_{it} = $V_{it} - U_{it}$.
$\beta_1 .... \beta_{10}$ are the parameters to be estimated.

For given levels of other variable inputs, the productivity of trees varies with age, and hence the age distribution of trees as well as the total stock of trees becomes important in determining feasible levels of production (Sepien, 1978; Yee, 1983; Tran *et al.* 1993). The total number of trees in each estate was sub-grouped under three categories. The first category comprised trees of age 8 to 14 years, the second category with 15 to 27 years and the third category with above 27 years. The survey data showed the average immaturity period as 7 years. The first category shows trees with increasing yield over the years, the second category with a more or less stabilised period of yield and the third category with a declining phase in yield.

An average response function and four stochastic frontier production models were estimated by maximum likelihood method under various assumptions to test different hypotheses.

Hypothesis Testing

Model 1. A stochastic frontier production function with time varying farm effects, without any restriction.

Model 2. In this model inefficiency effects have half normal distribution and μ is restricted to be zero.

Model 3. In this model the inefficiency effects were restricted to be time invariant and η is restricted to be zero.

Model 4. Two restrictions were imposed, where $\mu = 0, \eta = 0$.

Model 5. This model is a traditional average response function with three restrictions, $\mu = \gamma = \eta = 0$, in which farms are assumed to be fully technically efficient, and the farm effects, U_{it} are absent.

Sources of Technical Inefficiency

A number of empirical studies have investigated the determinants of technical efficiency variations among firms by regressing the predicted inefficiencies obtained from an estimated stochastic frontier upon a vector of firm specific factors such as farm size, age, education, etc., in a second stage regression (Pitt and Lee, 1981; Kalirajan, 1990). But this method has been criticised about the conflict in distributional assumptions (Battese *et al.*, 1989; Coelli, 1995).

Despite these criticisms, the use of non-parametric statistics will be useful to examine the possible relationship between technical efficiencies and farm specific variables. Accordingly, the non-parametric statistic, viz., Kruskal-Wallis statistic was used to test the significance of firm specific factors in explaining the variations in technical efficiencies.

Kruskal-Wallis test is based on ranks and is used when there are more than two groups to compare. The firm specific technical efficiencies were ranked as though they came from one group. The Kruskal-Wallis statistic (H) was computed using the equation (11):

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{3} \frac{R_i^2}{n_i} - 3(N+1) \qquad \text{....(11)}$$

where N = total sample size, n_i = number of observations in the i-th group, and R_i = sum of ranks of the i-th sample.

Farm size, ratio of supervisors to tappers and the number of training received for the managerial staff were found to vary among the estates and hence were included for the non-parametric test. For each of these three variables, farms were segregated into three sub-groups. The farm size was divided into three groups as less than 200 ha, 200-400 ha and above 400 ha. The supervisor-tapper ratio was divided into three classes as less than 5 per cent, 5-10 per cent and more than 10 per cent. Regarding the number of training received by the managerial staff, it was further divided into a group which received no training, a second group with1-2 training and the third with more than two training received. Now the technical (in)efficiences were ranked over all the three sub-groups together. Then the Kruskal-Wallis test was applied among the sub-groups corresponding to each of the variables.

STUDY AREA AND DATA USED

For any modelling exercise, recorded data on natural rubber production are in fact essential. The varietal, seasonal and regional variations in natural rubber production coupled with the presence of a multiplicity of tapping systems will make it necessary to use recorded data. Such recorded data were available only for the estate sector and hence this study was confined to the estate sector. While interpreting the results, this limitation of the study needs to be considered and the conclusions are relevant only to the estate sector of natural rubber production in Kerala.

The study was restricted to two rubber growing regions of the state. The two regions together covered almost 50 per cent area of the state and constituted the traditional rubber growing tract of the state. The first region consisted of Trivandrum, Quilon and Pathanamthitta districts and the second region consisted of Kottayam, Alleppey, Ernakulam, Idukki and part of Trichur districts (RRII, 1980).

The panel data pertaining to 35 large estates for three years, viz. 1991-92, 1992-93 and 1993-94 were used for the analysis. The first region comprised 49 per cent and the second region with 51 per cent of the sample estates. Data collection was done during the period December 1994 to May 1995.

RESULTS

The Maximum Likelihood estimates of the models are shown in Table 1. While estimating the models, it was considered appropriate, first to test the hypotheses and then select the most suited model for further discussion of the results.

TABLE 1: MAXIMUM LIKELIHOOD ESTIMATES FOR PARAMETERS OF STOCHASTIC FRONTIER PRODUCTION FUNCTIONS

		ML estimates for models				
Variable (1)	Parameter (2)	Model 1 (3)	Model 2 (4)	Model 3 (5)	Model 4 (6)	Model 5 (7)
Constant	β_0	2.3429** (0.7235)	2.4889** (0.7175)	2.2547** (0.6858)	2.3502** (0.6962)	2.0255** (0.6631)
NT_1	β_1	0.0106 (0.0086)	0.0103 (0.0091)	0.0118 (0.0084)	0.0121 (0.0088)	0.0158 (0.0085)
NT_2	β_2	0.0603** (0.0159)	0.0601** (0.0170)	0.0598** (0.0154)	0.0598** (0.0162)	0.0708** (0.0156)
NT_3	β_3	0.0023 (0.0103)	0.0039 (0.0106)	0.0012 (0.0102)	0.0026 (0.0103)	0.0089 (0.0102)
MD	β_4	0.6431** (0.1371)	0.6742** (0.1296)	0.6256** (0.1277)	0.6879** (0.1281)	0.6981** (0.1266)
FR	β_5	0.0316 (0.0170)	0.0329 (0.0168)	0.0303 (0.0170)	0.0300 (0.0170)	0.0321 (0.0186)
CL_1	β_6	0.2041 (0.1315)	0.1767 (0.1317)	0.1926 (0.1298)	0.1678 (0.1302)	0.1355 (0.1232)
CL_2	β_7	0.0740** (0.0222)	0.0746** (0.0239)	0.0716** (0.0220)	0.0726** (0.0230)	0.0897** (0.0213)
CL_3	β_8	0.1009** (0.0311)	0.0977** (0.0315)	0.0969** (0.0313)	0.0953** (0.0307)	0.0972** (0.0305)
TS_1	β_9	0.0234 (0.0157)	0.0225 (0.0168)	0.0235 (0.0156)	0.0243 (0.0166)	0.0388* (0.0161)
TS_2	β_{10}	0.0339* (0.0165)	0.0322 (0.0182)	0.0374* (0.0173)	0.0378* (0.0177)	0.0464* (0.0185)
Total variance	σ_k^2	0.1850* (0.0770)	0.1046** (0.0290)	0.2396** (0.0381)	0.1198** (0.0305)	0.0934** (0.0345)
Variance ratio	γ	0.6576** (0.1562)	0.3998** (0.1245)	0.4626** (0.1682)	0.7362** (0.1831)	0
Distributional parameter	μ	0.6975** (0.2209)	0	0.8399** (0.2915)	0	0
Time varying parameter	η	0.1772 (0.1333)	0.1649 (0.1513)	0	0	0
Log likelihood (LLF)		-15.240	-15.559	-15.783	-16.219	-20.699

Figures in parentheses are standard errors.
** and * Significant at 1 and 5 per cent probability level respectively.

The results of hypotheses test using LR statistic are shown in Table 2. Given the specification of the stochastic frontier with time varying farm effects (model 1), it was evident that the traditional average response function (model 5) was not an adequate representation for the data. The calculated Chi-square statistic was 10.92 indicating significance at 5 per cent probability level. So the null hypothesis, H_0: $\mu = \gamma = \eta = 0$ was rejected. However, all other three hypotheses were not rejected, since the calculated Chi-square statistics were less than the critical values, which means that the following three null hypotheses may not be rejected.

TABLE 2. CHI-SQUARE TESTS OF HYPOTHESES FOR PARAMETERS OF THE FARM EFFECTS

Assumptions (1)	Null hypothesis Ho (2)	χ^2 statistics (3)	$\chi^2 0.95$ value (4)	Decision (5)
Model 1 and Model 5	$\mu = \gamma = \eta = 0$	10.92	7.81	Reject
Model 1 and Model 4	$\mu = \eta = 0$	1.96	5.99	Do not reject
Model 1 and Model 2	$\mu = 0$	0.64	3.84	Do not reject
Model 1 and Model 3	$\eta = 0$	1.67	3.84	Do not reject

H_0:$\mu = \eta = 0$, H_0:$\mu = 0$, and H_0:$\eta = 0$.

The test of hypotheses showed that the half normal distribution of farm effects can be accepted. Based on these test results, model 4 ($\mu = 0, \eta = 0$) was selected for further discussion and estimation of technical efficiencies.

Estimates of Model 4

The Maximum Likelihood estimates of the stochastic frontier production model 4 is shown in Table 1. Apart from harvesting labour (tapping days), the parameter of the number of trees in the stabilised period of yield (second category) was statistically significant. The estimated coefficients with respect to low yielding first category of clones was not significant, while that of categories two and three showed significant positive relationship, at 1 per cent level of significance. A wide range of clones was prevalent in the estate sector. In the forties and fifties, only clonal seedlings were planted followed by budgrafts in the sixties and later. Altogether, 29 clones were present in the various estates surveyed, and most of the clones were imported from Malaysia and Indonesia.

A multiplicity of tapping systems has been employed in the estate sector, depending on the clone, age of the trees, climatic condition, managerial preferences, etc., ranging from once in four days to alternate days. The coefficient of the higher intensity tapping system was significant and that of lower intensity, first category was not significant. The relatively very low share of area under the tapping intensity of less than 67 per cent in the sample estates might have contributed to its insignificance in the function.

The variance ratio was significant at 1 per cent level which indicates that the variation in output of individual estates from its maximum possible frontier output arises mainly from technical inefficiencies rather than random variabilities. The variance ratio showed that about 74 per cent of the difference between observed output and the frontier level of output was caused by differences in firms' technical efficiencies.

Farm Specific Technical Efficiencies

The technical efficiencies derived from model 4 were time invariant. Following the argument that the outer bound farm specific production function may vary for the same farm over time, it is reasonable to expect that the farm specific technical efficiencies may vary over time. However, over a small period of time, the variation may not be statistically significant. The farm specific technical efficiencies showed wide variations and it ranged from 0.546 to 0.957 with a mean technical efficiency of 0.820. In fact, in a large number of farms (63 per cent) technical efficiencies were more than 80 per cent (Table 3). In one farm, technical efficiency was less than 60 per cent.

TABLE 3. FREQUENCY DISTRIBUTION OF FARM SPECIFIC TECHNICAL EFFICIENCIES

Efficiency (per cent) (1)	Per cent of farms (2)
51 - 60	2.86 (1)
61 - 70	2.86 (1)
71 - 80	31.42 (11)
81 - 90	48.57 (17)
91 - 100	14.29 (5)

Figures in parentheses indicate the number of farms.

The regionwise variations in technical efficiencies were not statistically significant. In the first region, the average technical efficiency was 0.789 and in the second it was 0.849. Geographically, these two regions are located contiguously in the state. There was significant variation in efficiencies between public sector and private sector estates. The average technical efficiency of the public sector estates was 0.747 and that of private sector was 0.846. This result was expected and the variation in efficiencies confirm that inherent inefficiencies existed among the public sector estates. The public sector estates constituted 25.71 per cent of the sample estates.

The size of the estates ranged from 30.62 ha to 1,343.71 ha with a sample mean of 410 ha. The average technical efficiencies of different size-groups are shown in Table 4. A direct relation between farm size and technical efficiencies could be observed from the distribution of the efficiencies. This seems to be plausible among a group which comprised capitalistic mode of production. The reason can be attributed to economies with respect to organisation and perhaps superior technical knowledge of larger sized estates. However, in the last category (> 1000 ha), the efficiency was slightly lesser than the efficiencies of immediate lower size-groups. This was due to the cascading effect of a public sector estate whose technical efficiency was 0.757.

TABLE 4. TECHNICAL EFFICIENCIES AND FARM SIZE-GROUPS

Size group (ha) (1)	Per cent of farms (2)	Average technical efficiency (3)
< 200	31.43	0.779
201 - 400	25.71	0.798
401 - 600	22.87	0.856
601 - 800	8.57	0.868
801 - 1000	5.71	0.894
> 1000	5.71	0.812

Determinants of Technical Efficiencies

It is worthwhile to identify the sources of variation in technical efficiencies to draw meaningful policy conclusions. The supervisor-tapper ratio, farm size and the training for managers were identified to vary among the estates. The supervisor-tapper ratio was introduced into the analysis as a measure of the intensity of managerial effort. The non-parametric Kruskal -Wallis statistic was computed and shown in Table 5. All the three variables were found significant at 1 per cent probability level. Apart from farm size, supervisor-tapper ratio and scientific training of managerial staff were found significant factors in explaining the farm specific variability in technical efficiencies. The result suggests the importance of management in achieving the frontier level of output. Such conclusions were drawn in earlier studies on variations in technical efficiencies in some developed countries (Dawson *et al.*, 1991).

TABLE 5. KRUSKAL -WALLIS STATISTIC (K-W) ON SOURCES OF TECHNICAL INEFFICIENCIES

Variable	Average technical efficiency			Calculated K-W (H) statistic
	Group I	Group II	Group III	
(1)	(2)	(3)	(4)	(5)
Supervisor - tapper ratio	0.749 (13)	0.883 (7)	0.858 (15)	77.31**
Farm size	0.803 (9)	0.780 (11)	0.861 (15)	130.11**
Training of managers	0.779 (18)	0.876 (15)	0.781 (2)	94.23**

** Significant at 1 per cent probability level
Figures in parentheses indicate the number of farms.

CONCLUSIONS AND POLICY IMPLICATIONS

The stochastic frontier production with a half normal distribution of farm effects was an adequate representation to measure the technical efficiencies of natural rubber production in the estate sector of Kerala. The unbalanced panel data models were estimated with three years' data. The farm specific technical efficiencies estimated were time invariant and it ranged from 0.546 to 0.957 with a mean technical efficiency of 0.820. Variations in the technical efficiencies of the estates between the two agro-climatic regions were not significant while they are between private and public sector estates.

The supervisor-tapper ratio and scientific training of managerial staff were found significant variables in explaining the variability in technical efficiencies. The management functions such as organisation of the work, motivation, training and supervision of employees, are in fact an integral part of an estate. Further intensification of management effort is needed to achieve the frontier level of output from the rubber estates. As a part of the management, the frequent training of the managerial personnel can also improve the technical efficiencies of natural rubber production in the estate sector of Kerala.

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NOTE

1. Natural rubber is cultivated both in small holdings and in estates. The area under rubber in the estate sector was 42,292 hectares in 1996-97 with a share of 9.28 per cent of total area of rubber in the state.

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