Analysis of the technical efficiency of state rubber farms in Vietnam

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ABSTRACT

This study entails an analysis of the technical efficiency of natural rubber production by state farms in Vietnam. A time-varying stochastic frontier production function model for unbalanced data is estimated for 33 farms. Individual farm technical efficiencies are reported and discussed. One of the main results concerns the bimodal distribution of technical efficiency indices. A few farms operate near the production frontier while the bulk operate well away from the frontier. Some implications are drawn from the results as a guide to future policy research work in the rubber industry in light of recent moves by the Vietnamese government towards economic reform.

RESEARCH PROBLEM

In recent years, the Vietnamese government has undertaken considerable economic reforms, and is considering yet further reforms. The agricultural sector is seen as a potentially leading sector in these reforms because of its important contributions to both employment and output. Existing organisation structures in agriculture are largely based on socialist tenets of public ownership of the means of production and reliance for technical aid on the former USSR and East European countries. Their potential to contribute to a reformed agricultural sector is coming under increasing scrutiny.

The rubber industry comprises predominantly state farms at present, although private owners are being encouraged to increase their area of

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plantings under current reform plans. The state-owned rubber companies have been the beneficiary of funds and technical assistance from Eastern Europe since Vietnamese reunification.

The problem is whether the farms operated by these state-owned companies operate at a level of technical efficiency sufficient to justify their future survival as an organisational form in the rubber industry. Given the importance of the rubber industry to the agricultural sector and the economy as a whole, this is a critical issue. If their level of technical efficiency is low, it would suggest that agricultural policy makers might need to consider whether greater technical efficiency can be achieved by restructuring the industry or increasing the amount of rubber production under private ownership, either as plantations or smallholdings.

It is difficult to provide an unequivocal answer to this issue without a comparison of both technical and allocative efficiency of farms in the Vietnamese rubber industry with those in rubber industries elsewhere in the world. However, a study of the technical efficiency of state rubber farms in Vietnam should at least give an idea of how many such farms are operating near the frontier of technically efficient production under prevailing conditions in Vietnam. Further, it should also be possible to compare the attributes of those firms operating near the frontier with those of farms operating far from this frontier.

GOALS AND HYPOTHESES

The general research goal in this study is to measure and compare the technical efficiency of state rubber farms in Vietnam. The comparison of technical efficiency takes three forms:
(a) between four selected state-owned rubber companies (Dong-Nai, Dong-Phu, Dau-Tieng and Tay-Ninh);
(b) specifically, between Dong-Nai Rubber Company, which follows the French management style and has nine red soil farms (considered more productive) and six grey soil farms, and the other three companies, which are in grey soil region and apply an indigenous management style more in the traditional state farm mode; and
(c) between farms owned by these selected rubber companies in the red and grey soil regions.
Thirty-four farms owned by these four rubber companies are considered.
  Five hypotheses are tested:
(1) There is no difference in technical efficiency between farms within and between the rubber companies under investigation.
(2) There is no difference in mean technical efficiency between farms from the different companies.

(3) There is no difference in mean technical efficiency between farms in red and grey soil regions.

(4) There is no difference in mean technical efficiency between farms of Dong-Nai Rubber Company and other companies.

In addition, a fifth hypothesis is tested, to determine whether a stochastic frontier production is preferred to ordinary least squares (OLS) estimation.

BACKGROUND TO THE RUBBER INDUSTRY IN VIETNAM

The agricultural sector produces nearly half of the gross domestic product of Vietnam and employs around two-thirds of its labour force. Natural rubber has been the major cash crop, and has been continuously exported over the past 30 years. Vietnam currently ranks ninth in the world production of natural rubber and seventh in area of land under rubber cultivation.

Natural rubber can be extracted from numerous trees or plants. However, thus far, only *Hevea brasiliensis* has been used for commercial production anywhere in the world. *Hevea brasiliensis* is a tree from which rubber may be obtained by tapping (i.e., the controlled wounding of the bark of the trunk).

Organisational structure

The natural rubber sector has three components:
(a) state farms belonging to rubber companies which are under the control of the Vietnam Rubber Corporation (VNRC);
(b) state farms under the control of local rubber companies; and
(c) smallholdings (private ownership).

The smallholdings constitute a small proportion of the total rubber area, with a total planted area of 10 000 ha in 1989 (Thiet, 1991). According to the economic reform policies and the Vietnam Rubber Project for the year 2000 (VNRC, 1991), private owners will be encouraged to increase this area of plantings by 90 000 ha, and occupy 20% of the total potential rubber area.

VNRC owns 87.5% of the total rubber area. It comprises 18 state-owned rubber companies of which fourteen have been created since 1985, and are still in the establishment stage with no area of old trees. Eleven are local rubber companies (at the province or district level) created since 1987 and hence also still in the establishment stage.

These companies are located in six provinces: Dong-Nai (1), Song-Be (6), Tay-Ninh (2), Dak-Lak (2), Gialai-Kontum (6), and Thua-Thien (1). Each

company has a number of farms according to its land size. The largest is the Dong-Nai Rubber Company, which has fifteen farms, while the Tay-Ninh Rubber Company has only three farms. Besides owning farms which are responsible for planting rubber trees and collecting latex, these companies also own one or two factories which process latex into dried rubber.

The company pays salaries and wages to managers and workers and calculates total revenue, total costs and profit of the company as a whole. Meanwhile, the farms only calculate their costs incurred in collecting latex and planting, and try to save input costs while producing maximum output. The company has a strong degree of control over its farms. It gives awards to them and provides technical advice on tree planting and latex collection. The farms are permitted to modify these instructions marginally to suit their local conditions.

There are also some other industrial rubber firms, located in the city, which produce rubber products such as gloves and sandals. These firms are either privately owned, run by local government or under VNRC ownership.

Institutions within VNRC serve all rubber companies in the development of their production. They include a specialised bank for rubber, a rubber import-export company (Rubximco) and a rubber research institute (RRIV). Only a small proportion (10%) of rubber production is now consumed domestically.

Production

Rubber latex is a milk liquid that comes out of the rubber tree. It is unstable and must be processed soon after collection. In the field, a quantity of ammonia liquor is added to the tanks containing latex to prevent coagulation. These tanks are then driven to the factory by trucks or tractors. A sample of latex in each tank is taken out to weigh, and it is then put into a small span under fire. This latex becomes a piece of dried rubber which is weighed again. A conversion factor is drawn from this job. All latex collected from the field is converted into dried rubber which is recorded as the standard output of the farm. This is the dependent variable used in our analysis.

Overall, the quantity of dried rubber output has increased steadily. However, yield per hectare has not followed a consistent trend. It decreased continuously from 1986 to 1990, then increased slightly in 1990. The decrease is most probably due to the large areas of new trees coming into production during this period. The yield in new tapping areas is low because trees coming to tap are very young; it should increase as trees become more mature. Tapping areas also should continue to increase.

MODEL FORMULATION

Survey description

A survey was conducted by the senior author during August and September 1991 in three provinces: Dong-Nai, Song-Be, and Tay-Ninh. Of the 34 farms surveyed, fifteen belonged to Dong-Nai Rubber Company, four to Dong-Phu Rubber Company, eleven to Dau-Tieng Rubber Company, and three to Tay-Ninh Rubber Company. All are located in three neighbouring provinces in the south-east region. They are big companies which produced 60% of total rubber production in 1990. Farms of other companies are smaller and mostly in the establishment stage. With little output, they were considered unsuitable for estimating technical efficiency.

Details of the survey method and individual company and farm characteristics are provided by Tran (1992, pp. 40–45). A brief coverage of some pertinent attributes of the companies and their farms follows.

Dong-Nai Rubber Company farms are located 70 km east of Hochiminh City. Its farm sizes are generally larger than those of other companies. This company was created and developed by a French company whose owner left Vietnam in 1975. After the nationalisation of this plantation, all its previous managers, staff members and workers were retained. Hence, the French management style has been continuously applied. During the war, this company suffered less damage than others.

This company is considered the leading rubber producer in Vietnam. It has a high proportion of skilled labourers and experienced managers and tapping labourers, and has utilised computerised accounting and record keeping since the early 1970s. Also, it is the major producer of rubber for export, supplying almost one-half of total exports in 1990 (Dong-Nai Rubber Company, 1991). Indeed, in the past, farms from other companies have usually sent their staff members and workers to Dong-Nai Rubber Company to learn technology and production management.

Dong-Phu Rubber Company (five farms) and Dau-Tieng Rubber Company (eleven farms) are in Song-Be province which is located 70 km north-west of Hochiminh City. They were established after 1975 with new staff and new workers. Within their areas, there are three farms with old trees which were abandoned due to lack of security before 1975. Tay-Ninh Rubber Company comprises three farms located in the Tay-Ninh province which is 70 km south-west of Hochiminh City.

All farms of these three companies are in the grey soil region. Because they are new companies, with new farms created after the reunification of Vietnam, the state farm model has been adopted by the managers, most of whom have come from the north. This model is characterised by a lack of

experience of staff members in rubber production. Moreover, staff are accustomed to obeying completely orders from above. Therefore, they generally lack flexibility in business management. Another feature is a cumbersome organisational structure with a high proportion of administrative staff members (indirect labour) compared with the total labour of the farm and/or the company. This proportion is more than 10% compared with about 3–4% in Dong-Nai Rubber Company.

Selection of variables

In estimating a rubber production function for the 34 farms, panel data were collected for five consecutive years from 1986 to 1990. Data were obtained on rubber latex produced in each farm every year (converted to tonnes of dried rubber). Inputs in the production function tested for inclusion were area of rubber trees, by number and age; labour, measured as number of tapping days; chemical fertilizers (urea and potassium); stimulants; and transportation (measured as litres of gasoline used in latex collection).

Stochastic frontier production functions

The stochastic frontier production function was independently proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977). This function differs from the traditional (average) production function in that its disturbance term has two components: one to account for technical inefficiency and the other to permit random events to affect production.

This model was viewed as a significant improvement over two alternative models existing at that time. The first of these alternatives was the traditional function, which is estimated using least squares and thus only considers the influence of random errors. Second, deterministic functions, such as that proposed by Aigner and Chu (1968), use mathematical programming to construct production frontiers. They permit technical inefficiency to affect production but take no account of random effects. The stochastic frontier allows consideration of both sources of variability in its disturbance.

Many authors have altered and generalised the original specification of the stochastic frontier production function. Schmidt (1986), Bauer (1990) and Battese (1992) provide thorough reviews of this literature, with Battese (1992) making particular reference to the applications of stochastic frontiers in agricultural economics.

In this paper, we use the stochastic frontier production function proposed by Battese and Coelli (1992), who followed a model developed by Aigner et al. (1977). This model is defined for panel data (which need not be complete) and has an error term which is assumed to be the sum of a normal random variable and a truncated normal random variable. The truncated normal random variable, which is assumed to reflect technical inefficiency, is permitted to have a non-zero mode and be an exponential function of time. It is defined as follows:

$$Y_{it} = \mathrm{f}(X_{it}; \beta) \exp(V_{it} - U_{it}) \qquad \begin{matrix} i = 1, \ldots, N \\ t = 1, \ldots, T \end{matrix} \qquad (1)$$

where Y_{it} is the production of the ith firm in the tth time period; $\mathrm{f}(\cdot)$ is a suitable function (in this study, the Cobb–Douglas function); X_{it} is the $k \times 1$ vector of input quantities of the ith firm in the tth time period; and β is a vector of unknown parameters. The V_i are assumed to account for random factors such as luck, weather and measurement error, while the U_i are due to technical inefficiency. A logarithmic transformation provides a function which is linear in parameters with a normal error term which immediately lends itself to OLS estimation.

For a Cobb–Douglas function, the equation can be written in logarithmic form as:

$$\ln Y_{it} = \beta_0 + \beta_1 \ln X_{1it} + \ldots + \beta_n \ln X_{nit} + E_{it} \qquad \begin{matrix} i = 1, 2, \ldots, N \\ t = 1, 2, \ldots, T \\ T = 5 \\ N = 34 \end{matrix} \qquad (2)$$

where

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

The only difference between this frontier production function and the traditional OLS production function is the presence of the term U_t. The V_{it}'s are random variables not under the control of the farm and are assumed to be independent and identically distributed as normal random variables with mean zero and variance s_v^2. The U_i's are random variables which are under the control of the ith farm. They are assumed to be independent and identically distributed non-negative random variables which are obtained by the truncation at zero of the $\mathrm{N}(m, s^2)$ distribution. For the time-varying model, $U_{it} = U_i \exp[-h(t - T)]$, where h is an unknown parameter.

Maximum likelihood estimates of the parameters of this stochastic frontier model may be obtained using the computer program 'FRONTIER' (Coelli, 1992). This program uses a grid search followed by an iterative maximisation process to obtain maximum likelihood estimates. It uses the

parameterisation of the model suggested by Battese and Corra (1977) to simplify the grid search. The parameters s_v^2 and s^2 are replaced with:

$$s_s^2 = s_v^2 + s^2$$

and

$$G = s^2 / (s_v^2 + s^2)$$

The parameter G must lie between 0 and 1 and, hence, this range can be searched to provide a good starting value for an iterative procedure. The model proposed by Battese and Coelli (1992), which is estimated in this paper, is a very general model which incorporates many of the specifications used by past authors as special cases. Likelihood ratio tests can be used to determine whether a less general formulation of this model is appropriate for these data. A number of restricted forms of the model can be considered. For example, setting h to be zero provides the time-invariant model set out by Battese, Coelli and Colby (1989). Restricting the formulation to a full (balanced) panel of data gives the model of Battese and Coelli (1988). The additional restriction of m equal to zero reduces the model to model I in Pitt and Lee (1981). A fourth restriction of $T = 1$ returns the model to the original formulation of Aigner, Lovell and Schmidt (1977). If all these restrictions except $m = 0$ are imposed, the model suggested by Stevenson (1980) results.

MODEL ESTIMATION

Estimation of the stock of rubber trees

One of the most difficult aspects of modelling the production technology of a perennial crop, such as rubber, is the treatment of the capital input of tree stock. As mentioned above, the amount of latex produced from a tree will vary with the age of the tree. Sepien (1978) included a variable 'age of trees' along with the number of trees in his production function model of the rubber production of smallholders in Malaysia to account for this effect. He was able to use this method because most smallholders had trees of a single age. His approach does not appear practical in our study as each farm has trees of varying ages, and hence the definitions of a tree age variable for a particular farm would be difficult.

Instead, we defined a variable 'total weighted trees' which would reflect the higher production capacity of mature trees relative to the young and very old trees. To this end, each farm manager was asked to specify the number of trees being tapped in the following age classes: $T_2 = 6$ to 12

years old, $T_3 = 13$ to 20 years old, $T_4 = 21$ to 30 years old, and $T_5 = $ greater than 30 years old. The total weight of trees variable was then defined as:

$$\text{TW } T_{it} = g_2 T_{2it} + g_3 T_{3it} + g_4 T_{4it} + g_5 T_{5it}$$

for the ith farm in the tth year, where the g's are unknown parameters (or weights).

Three alternative methods of setting the values of the weights (g_2, g_3 and g_5) were considered, assuming $g_4 = 1$:

(a) Assume all trees are equally productive, and set $g_2 = g_3 = g_5 = 1$.
(b) Use experimental estimates of the yield profiles of the two most popular clones, GT 1 and RRIM 600, as reported by Smit (1984), to derive values for the weights. The values were calculated as $g_2 = 0.45$, $g_3 = 0.99$ and $g_5 = 0.40$.
(c) Allow the sample data to determine the weights by estimating a model in which both the β's and g's appear as unknown parameters.

The Cobb–Douglas functional form with Hicks-neutral technical change is assumed in this study. The model in equation (2) may thus expressed as follows:

$$
\begin{aligned}
\ln Y_{it} = \beta_0 &+ \beta_1 \ln(g_2 T_{2it} + g_3 T_{3it} + T_{4it} + g_5 T_{5it}) && i = 1, \ldots, 33 \\
&+ \beta_2 \ln L_{it} + \beta_3 \ln \text{UR}_{it} && t = 1, \ldots, 5 \qquad (3) \\
&+ \beta_4 \ln \text{TR}_{it} + \beta_5 t + E_{it}
\end{aligned}
$$

where L_{it} is labour, measured in days; UR_{it} is kilograms of urea; TR_{it} is transport, measured in litres of fuel; and all other symbols are as previously defined. The potassium and stimulant variables were omitted because of their statistical insignificance in this model.

The model in equation (3) will be linear in parameters under options (a) and (b), listed above, as they involve fixed values of the g's. Option (c), however, requires the unrestricted estimation of equation (3), which is not linear in parameters. The FRONTIER program cannot accommodate a model which is non-linear in parameters. We therefore used least squares to estimate this model under options (a) and (b) and used the non-linear least squares routine in SHAZAM (see White, 1990) to estimate the model under option (c). As least squares estimation of a stochastic frontier model provides unbiased estimates of all β parameters with the exception of the intercept term, these estimates should provide a reasonable avenue for testing between the three alternatives.

The models using the TW T variable defined by options (a) and (b) are restricted forms of option (c), where the restrictions are upon the values that the g's may take. These restrictions were tested using an asymptotic chi-square test.

Estimation of a stochastic frontier production function

The stochastic frontier production function defined in equation (3) contains six β-parameters and the four additional parameters associated with the distributions of the V_{it} and U_{it} random variables. The model is based on unbalanced panel data with time-varying technical efficiency and a truncated normal technical efficiency distribution with a non-zero mode. Estimates of mean and individual technical efficiencies were calculated according to the expressions presented by Battese and Coelli (1992). An estimate of technical efficiency was to be calculated for each farm for each year, and a mean technical efficiency of all farms for each year.

If h is restricted to be zero, technical efficiency is assumed time-invariant. Hence, single estimates of technical efficiency can be calculated for each firm as well as a single estimate of mean technical efficiency.

The frontier function estimates were used to test five different assumptions about the disturbance terms:
- Model 1.0 assumes all parameters are estimated.
- Model 1.1 assumes that $m = 0$.
- Model 1.2 assumes that $h = 0$.
- Model 1.3 assumes that $m = h = 0$.
- Model 1.4 assumes that $G = m = h = 0$.

RESULTS AND INTERPRETATION

Results of the estimated model based on equation (3) are presented in Table 1. A comparison of alternative specifications of the total weighted trees variables indicated that the unconstrained model, in which this

TABLE 1

Non-linear least square estimates

Parameter	Coefficient	Standard error
β_0	-5.39	0.41
β_1	0.60	0.08
β_2	0.26	0.07
β_3	0.08	0.01
β_4	0.09	0.05
β_5	0.02	0.03
g_2	0.18	0.06
g_3	0.66	0.37
g_5	1.14	0.31
	Adjusted $R^2 = 0.936$	
	Log likelihood function $= -49.25$	

variable was derived from non-linear least squares, is preferred to the two constrained models. This choice is further supported by the observation that the unconstrained model has the highest adjusted R^2 and log likelihood values of all three models (see Tran, 1992).

Rejection of the restriction $g_2 = g_3 = g_5 = 1$ was not unexpected given that mature trees are more productive than young and very old trees. Rejection of the second set of weights derived from experimental trials may be due to the effect of locational factors and/or differences between experimental and commercial conditions of production.

All estimates with the exception of that of b_0 are unbiased estimates of the parameters of the frontier model. Estimates of the g's are used to construct the variable TW T_{it} to be used as an input in the maximum likelihood estimations of the frontier model using the program FRONTIER. Thus, we use a two-stage estimation method, with the g's determined in the first stage and the remaining parameters in the second stage.

Frontier production function analysis

Five models were estimated to enable tests of the different assumptions about the disturbance terms, listed above. Maximum likelihood estimates of these five models are presented in Table 2. Tests of hypotheses involving the parameters of the distributions of the U_{it} random variables (farm effects) are obtained by using the generalised likelihood-ratio statistic. These tests indicate that Model 1.3, with an efficiency distribution that is half normal ($m = 0$) and time invariant ($h = 0$), is preferred.

This model thus rejects the more general truncated-normal distribution for the firm effects in favour of the simpler half-normal distribution. Such a result is consistent with results obtained by Battese et al. (1989), but differs from those obtained by Stevenson (1980) and Battese and Coelli (1988). This range of results, we believe, provides a strong argument for assuming the more general specification to begin with, and then allowing the data to decide whether it is necessary.

The choice of Model 1.3 also involves acceptance of the hypothesis of time-invariant efficiency. This implies that, on average, the farms are getting no closer to (nor further away from) the frontier as time progresses from 1986 to 1990. However, the positive and significant coefficient of the time trend in the second last column of Table 2 indicates that this frontier is shifting out each year, thus indicating technical change. Firms are thus, on average, keeping up with the observed advances in technology.

The total elasticity of this frontier production function is 1.054, slightly higher than the total output elasticity of 1.03 computed by using OLS. Both estimates indicate slightly increasing returns to scale. As a comparison, the

TABLE 2

Maximum likelihood estimates of the parameters of the stochastic frontier production function

Coefficient	Model				
	1.0	1.1	1.2	1.3	1.4
β_0	−5.19	−5.10	−5.25	−5.16	−5.40
	(0.28)	(0.30)	(0.30)	(0.29)	(0.32)
β_1	0.74	0.74	0.72	0.74	0.60
	(0.06)	(0.06)	(0.07)	(0.07)	(0.06)
β_2	0.06	0.06	0.06	0.05	0.26
	(0.07)	(0.07)	(0.07)	(0.08)	(0.07)
β_3	0.015	0.015	0.014	0.014	0.080
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
β_4	0.27	0.24	0.28	0.25	0.09
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
β_5	0.02	0.03	0.05	0.05	0.02
	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)
s_s^2	0.27	0.54	0.29	0.64	0.13
	(0.06)	(0.12)	(0.11)	(0.19)	
G	0.89	0.94	0.89	0.95	0
	(0.03)	(0.01)	(0.04)	(0.02)	
m	0.60	0	0.67	0	0
	(0.21)		(0.23)		
h	0.04	0.04	0	0	0
	(0.02)	(0.04)			
Log-likelihood	−9.66	−10.49	−10.24	−11.47	−49.25

The estimated standard errors are in parentheses.

total elasticities of output computed by Sepien (1978) using OLS for independent rubber smallholders and smallholders under government support in Malaysia are 1.12 and 0.83, respectively. These figures are lower than those exceeding 2.0 obtained by Teo (1976, p. 77), also for Malaysia, estimates approaching 2.0 obtained by Chandrasiri, Carrad, Teo and Weerasingh (1977, p. 407) on Sri Lankan rubber smallholdings, and around 1.5 for rubber producers in Papua New Guinea, calculated by Whitlam (1976, p. 8).

Given the specifications of Model 1.3, the technical efficiency indices of the individual rubber farms were calculated using the predictor defined by Battese and Coelli (1992). The individual farm technical efficiency indices obtained, together with the estimated mean technical efficiency, are presented in Table 3.

The frequencies of the predicted values of technical efficiency show a bimodal distribution, with a group of farms with high technical efficiency

TABLE 3

Technical efficiency estimates for 33 state rubber farms in Vietnam [a]

Farm number	Technical efficiency
1	0.38
2	0.33
3	0.74
4	0.82
5	0.53
6	0.48
7	0.47
8	0.38
9	0.40
10	0.35
11	0.59
12	0.95
13	0.60
14	0.48
15	0.40
16	0.37
17	0.50
18	0.18
19	0.16
20	0.51
21	0.75
22	0.67
23	0.80
24	0.91
25	0.43
26	0.93
27	0.51
28	0.55
29	0.89
30	0.61
31	0.88
32	0.52
33	0.59
Mean technical efficiency = 0.59	

[a] One farm which has only one year of observation (1990) was removed due to a zero value for fuel and urea.

and the bulk of the remaining farms with low technical efficiency. [1] Thirty-nine percent of farms have a technical efficiency index below the mean figure, while another 40% attain technical efficiency of more than

[1] This bimodal distribution provides an explanation for the acceptance of the hypothesis that $G = 0$ when the mean level of technical efficiency is estimated to be quite low.

average but less than 0.8. Only 21% of farms attain a high level of technical efficiency (assumed to be more than 0.8).

On the evidence presented above, the overall level of technical efficiency is low, given a mean index of only 0.59. A common explanation for dispersed technical efficiency is that the assumption of common technology across observations is violated. However, this explanation is unlikely to be relevant in this study. The production technologies are fairly similar across the sample of four companies and over time, although the relative use of labour and machinery varies.

As mentioned earlier, the major variations in operations between farms are considered to be in management methods. The variations could be due to managerial rigidities which restrict the decision-making flexibility required to permit production on or near the isoquant. Observed changes in the labour and transport coefficients between the OLS and frontier production functions could well be explained by this factor. Firms operating near the frontier would appear to rely less heavily on labour as a factor of production per tonne of latex produced, and more heavily on mechanical operations, particularly in transporting the latex.

Test of hypotheses

Tests of the five hypotheses outlined above are reported in Table 4. The first hypothesis, that there are no differences in technical efficiency between farms under study, was tested in our model selection process and rejected (chi-square statistic of 79.18 compared with a critical chi-square value of 7.81 at 95% significance level and 3 degrees of freedom). [2] It is clearly seen from Table 3 that these farms operate at widely different levels of technical efficiency (the range is 0.16 to 0.95).

Hypothesis 2, that there is no difference in the mean technical efficiency between farms in the four different companies under study, is also rejected using the chi-square statistic (see Table 4). We can conclude that mean technical efficiencies of farms in different companies are not equal. The mean technical efficiency of Dong-Nai Rubber Company is 0.527, and that of Tay-Ninh Company is 0.538; Dong-Phu Rubber Company has the smallest mean technical efficiency of 0.304, and the highest mean technical efficiency is 0.721 for Dau-Tieng Rubber Company.

The third hypothesis is that there is no difference in the mean technical efficiency between farms in red and grey soil regions. The chi-square value reported in Table 4 shows that this hypothesis cannot be rejected. It is

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[2] The fact that the frontier model was chosen in preference to the OLS model is an indication of significant variation in technical efficiencies.

TABLE 4

Tests of hypotheses for parameters of the distribution of the farm effects, U_{it}

Assumption	H_0	Chi-square value	Table value (95%)	Decision
Model 1.0	$G = m = h = 0$	79.18	7.81	Reject H_0
Model 1.0	$m = h = 0$	3.62	5.99	Accept H_0
Model 1.0	$m = 0$	1.16	3.84	Accept H_0
Model 1.0	$h = 0$	1.66	3.84	Accept H_0
Model 1.3	$G = 0$	75.56	3.84	Reject H_0

concluded that there is no difference in mean technical efficiency between farms in the red and grey soil regions.

Fourth, the hypothesis that there is no difference in the mean technical efficiency between farms of Dong-Nai Rubber Company (French management) and other companies was tested. Again, the hypothesis could not be rejected on the basis of the chi-square test, and it is concluded that there is no difference in mean technical efficiency between farms of Dong-Nai Rubber Company and other companies. This result is not surprising as it was observed in the results of the second hypothesis that the Dong-Nai Rubber Company was neither best nor worst in terms of technical efficiency.

Finally, the result of the fifth hypothesis in Table 4 indicates that it is rejected: the parameter G is significantly greater than zero at 1% significance level. This indicates that the stochastic frontier production function (Model 1.3) is preferred to OLS estimation (Model 1.4). The intercept parameter, and the elasticities of output with respect to trees, urea, transportation and the time trend are all significantly greater than zero at the 5% level of significance using a t-test. The low t-ratio of the elasticity of output with respect to labour indicates it is not significantly different from zero in this frontier estimation, although it is highly significant using OLS estimates. This inconsistency suggests that the same technology may not be applicable to all farms in the sample, or that the amount of fuel used is more a function of the distance from farms to the factory rather than the use of mechanised assistance in latex collection.

IMPLICATIONS FOR FURTHER POLICY RESEARCH

The main implications from this study are in terms of suggestions for further policy research rather than definitive policy recommendations. While the study is valuable in providing an overall measure of technical efficiency, and identifying differences in technical efficiency among state

rubber farms, it does not provide explanations of why some farms are more or less technically efficient than others. In particular, we did not include management as a factor of rubber production, yet this is likely to be a major factor explaining variations in technical efficiency between farms, and should be taken into account. It would have been desirable to account for different management and field husbandry methods in this study. However, simply including some proxy variable for management in the model is a simplistic and inadequate option. Management factors are very complex matters to study, and are deserving of analysis in a separate study.

While no definitive policy recommendations are made, some observations can be made to guide future studies. These recommendations are directed at gaining a better understanding of why variations in technical efficiency do or do not occur, particularly when they do not correspond with conventional wisdom. Five suggestions of areas for further research present themselves from the results obtained in the current study: mean technical efficiency and the attractiveness of investment in the rubber industry; unexpectedly high technical efficiency in rubber production by Dau-Tieng Rubber Company; unexpectedly ordinary technical performance by Dong-Nai Rubber Company; differences in the ways in which farm managers make decisions on the mix of inputs they use to produce rubber output; and unexpectedly insignificant differences in technical performance between farms in red and grey soil areas.

In respect of the first area for future research, the mean technical efficiency of the 33 farms under study provides an initial basis for considering prospects for investment in the rubber industry in Vietnam. At 0.59, it is clearly not very attractive from the viewpoint of a potential investor. It is tempting to conclude from this result that there is much to be gained from abandoning the state farm mode of production. Yet, there are also very high levels of technical efficiency achieved by more than 20% of farms. Hence, wholesale abandonment of the state farm system may not be a desirable, at least in the short term.

Certainly, a shift back to the old plantation mode of production and management is not guaranteed to improve technical efficiency. The company with the French management style and purportedly the most impressive performance in the industry, the Dong-Nai Rubber Company, was shown to be only an average performer in terms of technical efficiency.

Best performance, on the other hand, has been achieved by the company that has relied most on expertise from the former USSR. Dau-Tieng Rubber Company was the first rubber company to undertake a joint venture with the former USSR government in planting new rubber trees during the 1980s. Many USSR engineers were sent to this company to supervise the use of mechanisation and other productive activities in the

plantations. While it might be appropriate to ditch the socialist approach to the rubber industry given the obviously low general level of technical efficiency, there is a real risk of 'throwing the baby out with the bath water' by doing so.

The second and third areas of future research flow from these rather unexpected observations. First, the government needs to see what Dau-Tieng Rubber Company is doing right, particularly on its highly technically efficient farms, and see if it can keep these attributes in any attempt to transform the industry. Second, it should examine why the performance of Dong-Nai Rubber Company has not matched its reputation as the most technically efficient rubber producer.

The fourth area of future analysis concerns a search for explanations of why input usage varies so much between rubber farms operating with low technical efficiency and those operating with high technical efficiency. Evidence shows the former achieve low rubber yields per hectare and per tree, have low labour usage per hectare, and use little urea and a lot of fuel. By contrast, high technical efficiency farms achieve high yields, have a high labour usage per hectare, and use more urea and less fuel (due to relatively short distances from farm to factory). This most likely reflects differences in management decisions on the way farm managers combine various inputs which show up in differences in technical efficiency (distinct from the issue of allocative efficiency, as defined by Farrell (1957), which is not studied here).

The utilisation of urea on high-technical efficiency farms is five times that on low-technical efficiency farms. This indicator leads to a suggestion that an increase in urea dosage on farms which have low technical efficiency might increase their technical efficiency. However, further analysis would be needed on the implications of this increase for allocative efficiency of urea usage.

The utilisation of fuel on low-technical efficiency farms is many times that on high-technical efficiency farms. This can be explained by either the overuse of fuel or the distance of the former farms from the processing factory. The network of transportation between farms and processing factories needs to be investigated in order to determine which of these explanations is most important.

The model results suggest there is considerable scope to improve the technical efficiency of rubber farms. The most obvious is to increase rubber yields which are four to five times higher on high than low-technical efficiency farms. These yield variations are caused by many factors, such as varieties or clones, fertilizer and planting density. The suitability of technology should be studied carefully in order to increase productivity. In the past, due to the high target rubber areas set from above by VNRC and the

rubber companies, many farms had to collect varieties or clones from many sources without scrutiny in selection. This led to a mix of low-yielding and uncontrolled varieties on these farms. The ability to implement effectively development plans is a key to solving this problem, especially in the varieties or clones acquired. The establishment stage evidently has considerable effects on the productivity of the trees.

Labour productivity estimates on farms with high levels of technical efficiency are on average more than double those on farms with low technical efficiency (Tran, 1992, p. 127). A study of the supervisory and motivation techniques used on farms achieving high technical efficiency, especially those employed by Dau-Tieng Rubber Company, could lead to appreciable increases in technical efficiency by raising labour productivity.

The final issue for future research derives from the failure of red soil farms to perform more efficiently than grey soil farms in technical terms. This result needs further investigation as it was quite unexpected: it was felt that farms in the red soil region would have major productivity advantages over those in grey soil regions. If rubber production does not respond significantly to the type of soil, and other farming activities do, then locating future rubber plantings in grey soil areas might well have the advantage of lower opportunity costs.

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