MEASUREMENT OF TECHNICAL EFFICIENCY IN PERENIAL CROPS: Case in Rubber Farming in Batang Hari Regency

PENGUKURAN EFISIENSI TEKNIK DALAM TANAMAN TAHUNAN Kasus Pada Usahatani Karet Kabupaten Batanghari

By: Aulia Tasman*)

Abstrak

Studi ini bertujuan mengukur efisiensi teknis dan perubahan teknologi pada usahatani karet dan menguji determinan efisiensi teknis. Pengumpulan data dilakukan di Kabupaten Batang Hari, Jambi, dari petani yang termasuk kepada kelompok tradisional dan perkebunan pemerintah. Data cross section digunakan untuk mensimulasi perilaku data time series, yang didasarkan kepada potensi tanaman dan usia tanaman. Fungsi produksi translog frontal yang dimodifikasi disusun untuk mengestimasi efisiensi teknis.

Efisiensi teknis rata-rata (TE) masing-masingnya adalah 88.0 \%, 87.9\% dan 88.7 pada kelompok usia 1, 7-13 tahun), 2 (14-17 tahun), dan 3 (18-30 tahun). Didapat petani yang masing-masingnya 29.0\%, 27.7\%, dan 30.3\% mencapai indeks TE 96\% - 100\% pada usia 1, 2 dan 3. Artinya 69.7\% to 71.0\% petani kurang efisien. Tapi banyak petani yang memakai bibit lokal, sehingga diantara kelompok ini ada suatu campuran teknologi yang dapat membingungkan analisis. Program perbaikan efisiensi teknis harus difokuskan kepada petani kelompok 2 dimana didapat sekitar 11\% hingga 15\% kemungkinan meningkatkan hasil yang dapat membantu petani memperoleh hasil potensial dari tanamannya.

II. INTRODUCTION

Indonesia is the second largest natural rubber producer in the world after Thailand. It accounted for around 26 percent of total world production of 5.50 million tons in 1993. During the period 1980-1993, rubber plantations in Indonesia had moderately increased in area by an average of 2.4 percent per year, from 2.38 million ha in 1980 to 3.23 million ha in 1993. Natural rubber output of Indonesia mainly comes from the smallholder sector who in 1993 accounted for 72 percent of total production and 84 percent of total plantation area. The government and private estates respectively contributed 15 percent and 13 percent to total output (AJDF-PNEC, 1995).

In terms of production, the smallholders registered an overall growth of 3.0\% per year, from 714,500 tons in 1980 to about 1.0 million tons in 1993. On the overall, production of government estates slightly increased by an average of 1.1\% per year during the same period, from 186,000 tons in 1980 to 211,600 tons in 1993. Production from the private estates had increased at higher rate during the last five years, averaging 7.0\% per year, although on the overall, production increased by an average of 3.7\% per year, increasing from 120,000 tons in 1980 to 183,000 tons in 1993.

By type of producers, the government estates still had the highest average yield per hectare of 1,132 kilograms in 1993, reflecting a decline from 1989 to 1993 by around 2.0% per year. Yield of the private estates stabilized at around 1,100 kilograms per hectare during the last five years. Yield of smallholder was the lowest at 639 kilograms, with slight improvement from its former level of 542 kilograms in 1980.

Comparing the yields among three type of rubber farming practices, the smallholder estates have the lowest yield. Several questions can therefore be raised such as:

1. Why is there a big difference between the yields of the smallholder compared to the yields of government and private estates?
2. What are the dominant factor sources of lower yield of the smallholders?
3. What factors determine the level of technical efficiency?
4. Are there any feasible and efficient solutions to overcome these problems?

To answer these problem, the study will be focused in one particular regencies in Jambi province. The study will conduct a comparative analysis to the type of rubber farming between the smallholder and the government estates in Balang Hari regency, while the private estates is not included because the private estates for rubber plantation does not yet established in this regency.

This study aims to provide information to policy makers to be used in formulating an appropriate policy. The expected set of information to be gathered consists of the elasticity of factor demand, output supply and production, as well as economic efficiency by region. The knowledge of economic efficiency by commodities is information that can be used for optimal consolidation and efficient allocation of existing resources in order to maximize economic gain in rubber farming. If there is a significant difference of economic efficiency among farming practices, then the government can set up differential extension, education and training, as well as budget allocation policies to improve the economic efficiency and farmer welfare.

The general objective of this research is to assess the production models in rubber farming and based on the findings, develop the appropriate policy to improve farmer welfare, and to meet other government objectives such as to increase employment and farmer income. Specific objectives of this study are:

1. to derive the absolute technical efficiency relative to the best practice of individual farmer of the plasma from the government estates and the traditional smallholder estates.
2. to estimate the average technical efficiency for the overall farmers.
3. to analyze the nature of technological change.
4. to offer some appropriate policy implications relevance to the research findings.

II REVIEW OF LITERATURE AND METHODOLOGY

2.1 Construction of Life Time Matrix of Perennial Crops

Precise estimation of economic parameters necessitates availability of data on prices and quantities of inputs and outputs for the entire life span of perennial crops, which in some cases exceeds many decades. Moreover, Chand (1994) said that many inputs applied to perennial crops in one period affect the output in following periods also. Any data collected by conducting survey can cover only some years of the total lifetime of such crops and it is nearly impossible to get data on lifetime input use, output and corresponding prices from the farmers growing these crops, especially the farmers who do not keep farm records to supply such fast information. There are at least two main problems related to perennial crops. First, the consequences of inputs applied in the initial period cannot be
seen directly for the next periods. Second, it is difficult to determine precisely the future inputs and outputs.

Chand (1994) proposed other procedures/methodologies to study the economics of perennial crops by constructing a lifetime matrix for a given data. The data on quantity and value of inputs and output are obtained for each age year/group by dividing the total life of perennial crop in homogeneous periods. Based on these quantities, a single value of each parameter under study such as yield, return, profitability, etc. is obtained. The advantages of this approach are:

1. It gives complete information of output and inputs, and the distribution for total life span of perennial crop for each producing unit rather than getting a single value for each variable.
2. The implicit restrictive assumption of previous approach is that in the past and in future, the individual has the same value of variable and the restrictive assumptions can be relaxed.
3. The statistical tools which require data on individual observation can be applied. Similarly, the tools of production economics such as resource use efficiency, production function analysis, factor share can also be applied to analyze the production behavior.
4. Estimates of expected cost of production, return and profit can be obtained for individual units based on total life span. Intuitively the estimates are expected to be more reliable sense compared to those obtained by using the previous approaches.

The tools of economics as applicable in the case of annual crops cannot be applied directly as such in the case of perennial crops until these have been postulated into economic problems. Precise estimation of economic parameters necessitates availability of data on prices and quantities of inputs and output for the entire life span of the perennial crops of more than three years. Chand (1994) proposed an alternative methodology to estimate production parameters by including some additional variables in the production function.

Let:

- \( N \) the total life of perennial crops
- \( n \) the units for each age year or age group
- \( S_j \) the average of sub-sample at the \( j^{\text{th}} \) year
- \( Y_{ji} \) the value of variable at the \( i^{\text{th}} \) sample unit which belongs to \( j^{\text{th}} \) year
- \( K_i \) the index for the value of variable for individual \( i \) which is the unit of sub-sample in \( j \) the age year,

then the computation of the ratio (index) between the value of variable for the individual and sub-sample average is

\[
K_j = \frac{Y_{ji}}{S_j} \quad (1)
\]

where \( K_i \) indicates that the value of variable \( Y \) for \( i^{\text{th}} \) unit is \( K_i \) times the sample average. Thus it can be deduced that \( i^{\text{th}} \) unit used \( K_i \) times more input or produced \( K_i \) times more output compared to the average of the sample. Based on this, the missing values of variable for \( i^{\text{th}} \) unit in the past and the future life of the perennial crop can be obtained by multiplying the average value of each sub-sample by \( K_i \).

The construction of the lifetime index is shown in Table 3.1.
Table 3.1: Construction of lifetime matrix of variable (Y) of a perennial crop for each sample unit

<table>
<thead>
<tr>
<th>Sample number</th>
<th>AGE YEAR / GROUP</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Y_11</td>
<td>K_1S_2</td>
<td>K_1S_3</td>
<td>K_1S_4</td>
<td>K_1S_5</td>
<td>K_1S_6</td>
</tr>
<tr>
<td>2 Y_21</td>
<td>K_2S_2</td>
<td>K_2S_3</td>
<td>K_2S_4</td>
<td>K_2S_5</td>
<td>K_2S_6</td>
</tr>
<tr>
<td>3 Y_31</td>
<td>K_3S_2</td>
<td>K_3S_3</td>
<td>K_3S_4</td>
<td>K_3S_5</td>
<td>K_3S_6</td>
</tr>
<tr>
<td>4 K_4S_1</td>
<td>Y_4</td>
<td>K_4S_2</td>
<td>K_4S_3</td>
<td>K_4S_4</td>
<td>K_4S_5</td>
</tr>
<tr>
<td>5 K_5S_1</td>
<td>Y_5</td>
<td>K_5S_2</td>
<td>K_5S_3</td>
<td>K_5S_4</td>
<td>K_5S_5</td>
</tr>
<tr>
<td>6 K_6S_1</td>
<td>Y_6</td>
<td>K_6S_2</td>
<td>K_6S_3</td>
<td>K_6S_4</td>
<td>K_6S_5</td>
</tr>
<tr>
<td>7 K_7S_1</td>
<td>Y_7</td>
<td>K_7S_2</td>
<td>K_7S_3</td>
<td>K_7S_4</td>
<td>K_7S_5</td>
</tr>
<tr>
<td>8 K_8S_1</td>
<td>Y_8</td>
<td>K_8S_2</td>
<td>K_8S_3</td>
<td>K_8S_4</td>
<td>K_8S_5</td>
</tr>
<tr>
<td>9 K_9S_1</td>
<td>Y_9</td>
<td>K_9S_2</td>
<td>K_9S_3</td>
<td>K_9S_4</td>
<td>K_9S_5</td>
</tr>
<tr>
<td>N-1</td>
<td>S_1</td>
<td>S_2</td>
<td>S_3</td>
<td>S_4</td>
<td>S_5</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Y_j = Value of variable (input use or output, etc.) at jth farm having j years old plantation or tree.

K_j = Y_j/S_j
K_i = Y_i/S_i;
S_i = (Y_11 + Y_21 + Y_31)/3

In this table the size of sub-sample is taken to be 3.

2.2 Efficiency Measurement

The concept of efficiency as usually used to measure the economic performance and hence as guide to policy formulation, has been questioned. Farrell (1957) classified economic efficiency into types: (i) Technical Efficiency is defined as the ratio of actual to maximum output, given the input vector used. Maximum output is calculated from the frontier. It reveals possibilities for increasing output without increasing cost and/or re arranging input combination; (ii) Allocative Efficiency is defined as the ratio of actual output to output obtained with the same level of total cost but with inputs used so as to equate MRS with input price ratios. It measures the degree to which the firm is operating at points other than those implied by the expansion path in factor space. It indicates whether marginal productivity and resources are correctly taken into account in determining pattern of resources use. In other words, allocative inefficiency generally refers to failure to meet the marginal condition of profit maximization, an (iii) Economic Efficiency is the product of the combination of the technical and the allocative efficiency.

The measurement of technical efficiency has been dealt with in the literature, in a broad sense, using a relative concept. This means that the performance of an economic unit is compared with a standard measure. Various assumptions and methods have been used to establish such a standard measure. Following the pioneering work of Farrell (1957), estimation of econometric frontier production functions has been carried out and they are being used as standard measure to analyze technical efficiencies of economic units such as firms. The implication is that the firm will be technically efficient if the difference between the actual output and the frontier estimated output is insignificant. The difference between the firm’s actual production and its potential output under certain assumption, enables one to arrive at a measure of the firm's technically efficiency. This measure of technical efficiency therefore, is in absolute term which is specific to the particular firm in question and not relative to any other firms (Kalirajan, 1986). Shand et al. (1993) define technical efficiency as the ability and willingness of producers to obtain the maximum output at a given level of conventional inputs and technology, which is the ratio of a farmer's actual output to the technically maximum possible output at a given level of resources. Allocative efficiency is the ability to obtain the maximum profit from the application of conventional inputs with a given set of firm-specific input and output prices and a given technology, which is
the ratio of the technically maximum possible profit at a farmer's level of resources to the output obtainable at the optimum level of resources. The profit can be estimated either on the best proactive frontier production function, or in the field’s own (possibly technically inefficient) current practice production function. Shand et al. (1993) define economic efficiency as the product of technical and allocative efficiency. A farmer who is both technically and allocatively efficient is also economically efficient.

The technically inefficient firms will produce below TPPm. The profit maximization criterion suggests that the optimum level of input uses is \( X_1 \) with the output level of \( Y_1 \), at point A. At point C, which firms produce \( X_2 \) and \( Y_2 \) exhibits technically and allocatively in efficient and the technically efficient firms is \( Y_2/Y_1 \). In other words, the firms that produce \( Y_2 \) by using input \( X_2 \) at point B are technically efficient but allocatively inefficient. Thus, the allocative efficiency is \( Y_2/Y_1 \), while the economic efficiency is measured by \( Y_2/Y_1 \).

The statistical stochastic frontier (sometimes called the pseudo-frontier model) is the model of estimation of efficiency suggested by Aigner et al. (1977) by relaxing the assumption that all deviations from the frontier are due to technical efficiency. In the stochastic model, the error term is decomposed into two parts as follows:

\[
Y = f(X) e^{-u}
\]

which is transformed into logarithmic form as

\[
\ln Y = \ln f(X) + v_i - u_i; u_i > 0
\]

where \( \ln Y = \ln f(X) + v_i \) represents the stochastic frontier and \( u_i \) represents the technical inefficiency. Under the error structure

\[
e_i = v_i + u_i; i = 1, 2, \ldots, n
\]

The error component \( v_i \) represents the symmetric disturbance and is assumed to be independently and identically distributed as \( N(0, \sigma^2_v) \). The error component \( u_i \) is assumed to be distributed independently of \( v_i \), and to satisfy \( u_i < 0 \). The model collapses to a deterministic frontier when \( \sigma^2_v = 0 \). Note that \( Y_i < f(X_1\beta) + v_i \), so that the frontier itself is now clearly stochastic.
The mean weakness of the stochastic frontier model is that it is not possible to decompose the individual into its two components, therefore, it is not possible to estimate the individual inefficiency. The best that one can do is to estimate the average inefficiency over sample and its variance, free of \( \nu \), using the following formula:

\[
E(\mu) = \mu = \sigma \left( \frac{2}{\pi} \right)^{0.5} \quad (4)
\]

\[
V(\mu) = \sigma^2 \left( \frac{\pi - 2}{\pi} \right) \quad (5)
\]

Jondrow et al. (1982) was the first to demonstrate how individual farm-specific estimates of inefficiency may be calculated. By assuming \( \nu_i \) and \( \mu_i \) to be independent, a normal distribution for \( \nu \), and a half normal distribution for \( \mu \), the expected values of firms specific inefficiency \( \mu_i \), given \( \nu_i \) or \( (\nu_i + \mu_i) \), is formulated as follows:

\[
E\left( \frac{\mu_i}{\nu_i} \right) = \sigma^* \left( \frac{f(.)}{1 - F(.)} \right) - \left( \frac{\mu_i}{\nu_i} \right) \quad (6)
\]

where

\[
\sigma^* = \left[ (\sigma^2_\nu \sigma^2_\nu) (\sigma^2_\mu + \sigma^2_\nu)^{-1} \right]^{0.5} \quad (13)
\]

\[
\sigma^* = \left( \sigma^2_\mu + \sigma^2_\nu \right)^{0.5} \quad (7)
\]

\[
\lambda = \frac{\sigma^*_\nu}{\sigma^*_\mu} \quad (8)
\]

The samples of \( f(.) \) and \( F(.) \) represent the standard normal density (pdf) and cumulative distribution function (cdf), respectively, estimated at \( (\nu_i, \lambda/\sigma) \).
3.5 Sources of Data and Methodology

The study was conducted in Batang Hari regency, Jambi province. There were two kinds of data collected: first, the time series data used for describing the study area, and second, the cross-sectional data, which were collected using the purpose random sampling technique gathered from farmers in all four districts in Batang Hari regency which consist of households in hilly and flatter areas of plantation. The respondents were taken randomly from the member of SES and NES, while PES was not included in the study because it was not yet established at the time of the study. The number of sample was limited according to size of the representative type of farming practices. This sampling technique was chosen by considering that all those villages and districts chosen are the main areas of rubber production, and considering the limited financial support and time constraint.

The data included sizes of operation, seedling varieties, quantity of fertilizer, quantity of herbicides, number of labor, number of adult family members involved in the process of production, yield, and price of each input. The qualitative data consisted of farmer’s experience, formal education, wife education, family size and other related information. These data were used to estimate the individual production function relationship and individual farm-specific technical efficiency through stochastic frontier production function.

*Jurnal Manajemen dan Pembangunan, Volume 9, 1998*
3.5 Empirical Model of Analysis

The study used the cross-section data and time-series data and followed two steps of estimations: First, using Jondrow et al. (1982) techniques to estimate individual firm specific technical, allocative, and economic efficiencies from the neutralized-dynamic translog production function. The farm-specific dummy variable was introduced into the cross-sectional data and time series data to avoid a specification bias in the model (Lingard et al., 1983). Second, the modified translog production frontier function was used to estimate the overall technical, allocative, and economic efficiencies. The dynamic translog cost function was applied to estimate the technological change with including effect of time into the system and the conditional input demand function. These may be assumed to affect all farms equally and may be incorporated by considering time-specific dummy variables. The analysis of this study is divided into three steps:

Step one: construction of lifetime matrix of perennial crop

The data used for the estimation of the production function was first normalized by using equation (9), and following the procedure of transforming the data into the lifetime matrix for output and input, as presented in Table 3.1. This lifetime matrix of input reflects the behavior and the quantity of input and output through out the lifetime of perennial crop. Unrecorded input during the early period can be provided through the lifetime matrix indicator. The effect of previous inputs in the early stage of plantation can also be reflected through the matrix.

Output and input in all range of lifetime of tree age can easily be tracked, so that the biased effect of unrecorded information from the early period will not become a problem for data gathered only in one specific time period. The reason for the manipulation of the data is such that the inputs used in resent period do not completely affect next period. Rather, it is the accumulated effect of input from the early to the harvesting period, even for future effects.

By this computation, the perennial crop can be classified into several time periods according to the age of the tree. The classification of the tree age into several categories provides for a possibility to examine technological change and other comparison of production and economic behavior of perennial crop using cross section data. This data set now behaves like the time series data. Moreover, by these data, the production, cost and profit functions can be computed, and other analysis can also be applied.

In this particular study, the range of lifetime crop is divided into three, based on the classification of the potential yield of each type of rubber variety: (i ) the group age 1, T1 the age of rubber tree ranged from 7 to 13 years when the potential yield of rubber increases before reaching the peak, (ii) the group age 2, T2, the age of rubber tree at age 14 to 17 year when the potential yield reached the peak at 2 ton per hectare, and (iii) the group age 3, T3, the tree age from 18 to 30 year old when the potential yield decreases overtime. Under this classification, the comparative study on technical efficiency, elasticity of production, input demand function, technological change and total factor productivity growth can be estimated.

All data on quantity and value of inputs and output, were obtained for each age group by dividing the total life of perennial crop in homogeneous periods. Some fixed inputs like farmer education, experiences, tapping ages, number of family, area operated by farmer and tree age were excluded from the matrix. Based on these quantities or values, a single value of each parameter under study such as yield, returns, profitability, etc. is obtained.

Step two: analyzing the technical efficiency using values in the lifetime matrix and other fixed inputs. First, considering the dynamic Cobb-Douglas production function