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FARM LEVEL EFFICIENCY OF RUBBER AS A PERENNIAL CROP: A TRANSLOG PRODUCTION FRONTIER APPROACH

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ABSTRACT

This paper examines productivity of rubber in Peninsular Malaysia in a disaggregated form, since rubber is a perennial crop and grows in phases. Data collection was done on 327 smallholders among five districts of Negeri Sembilan state. However, only 307 observations were used in computing inferential statistics, because the young-age category has been removed due to statistically scanty nature of the sample size. The districts include Seremban, Tampin, Rembau, Kuala Pilah and Jempol. Both descriptive and inferential statistics were computed. The descriptive statistics revealed that 52.3% of the respondents were males, while 47.7% were females. 282 were Malays, while 7 and 2 were Chinese and Indians race respectively. Ninety three percent were married, almost 50% had secondary school certificate while only 2% were diploma holders. With regards to location, 41% ,32%,12.6%, 11% and 3.4% were from Jempol, Rembau, Kuala Pillah, Serembanand Tampinrespectively. The results further revealed that the mean rubber yield in kg/ha for the all-age, matured-age and old-age crops categories were 3,638 kg/ha, 4,611 kg/ha and 1,653 kg/ha respectively. This is an indication that matured-age category was found to be relatively higher in terms of rubber yield per hectare. The study also revealed that the mean technical efficiencies (TE) were 0.87, 0.91 and 0.65 respectively for all-age, matured-age and old-age crops. This means that there is actually a difference in mean TE between the all-age and the matured-age and old-age categories and thus, the study concludes that there is quite a difference between the aggregate and disaggregated forms as regards to both the yield and rubber efficiency. The study recommends that, number of household, tapping experience, farmers' age and level of education of smallholders should be given more attention to increase efficiency. Also, tapping system of one-half spiral cut and alternate daily tapping (S/2 d2) should be adopted. The study further recommends that the traditional concept of computing efficiency or productivity of rubber and other perennial crops in an aggregated form should be complemented with the disaggregated form as this eliminates any bias and gives meaningful results.

KEYWORDS: Efficiency, Parametric, Stochastic Frontier Analysis, Translog and Rubber

INTRODUCTION

A measure of overall efficiency, also known as economic efficiency (EE), was initially proposed and described as concept of production efficiency that is equal to the product of Technical efficiency (TE) and Allocative efficiency (AE) (Farrell, 1957). Specifically, economic efficiency is simply defined as the product of Technical and Allocative efficiency with the former being the firm's ability to maximize output given required inputs and technologies while the later conceptualized a measure of making optimum selection of inputs proportions (Ogundari and Ojo,2009). This simply means the efficiency consists of 3 components which include TE, AE and EE.

Technical efficiency could also be defined as the ratio of a realized output to expected maximum output given inputs and technologies. Defined in a different way, technical inefficiency means failure of firms' abilities to attain maximum output given sets of inputs and required technologies, while the ratio of input's marginal product to their respective prices is termed AE. Thus, according to Farrell, the overall performance which is also called economic efficiency of a firm is the product multiplication of the TE and AE. Following Farrell's work, a lot of researches have been developed which in turn led to the development of several frontier models. These models are then carefully sorted, grouped and classified into different types, categories on the basis of 3 distinct criteria. These criteria include, 1- Specification or functional form specification, 2- presence of statistical noise, 3-data type analyzed.

Functional form specification: This is the first criterion on which the models are classified into parametric and non-parametric frontier models. The parametric frontier model relies solely on functional form while the non-parametric has no business or connections with functional forms (Lin and Tseng, 2005)

The second criterion is the presence of statistical noise in which the frontier models are classified into deterministic and stochastic (non-deterministic) frontier models. The former has an assumption that, inefficiency is the results of any deviation away from the production frontier, while the later which is the stochastic frontier model, allows for statistical noise during estimation procedure (Bravo-Ureta and Pinheiro, 1997). This specifically means that, for deterministic (or non-stochastic) model, all observations belong to production

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set, while for the stochastic or non-deterministic model, some observations might lie outside the boundary of the production set.

The third criterion is based on data type analyzed. That is between cross sectional and pooled or panel data analyzed. In cross sectional form, the estimation procedure is done on observations of n firms in a single period of time usually one production season. In panel or pooled data model however, the observations are done on the number of firms over "t" period of time (measurement of efficiency). Panel data permits measurement of both efficiency change and technological progress. By articulating the 3 afore-mentioned criteria, numerous frontier models could possibly be realized. The possible realizable models included, cross sectional parametric deterministic, panel or pooled parametric deterministic, cross sectional parametric stochastic, panel or pooled parametric stochastic. Good examples of each of the above mentioned frontier models are shown in Table 1.

Table 1. Parametric Frontier Production Models

S/no	Types of frontier models	Example of authors	Date of publications
1	Cross sectional Parametric deterministic.	Aigner and Chu, Afriat	1968 1972
2	Pooled or panel parametric deterministic	Greene	1980
3	Cross sectional parametric stochastic	Aigner*et al* Meeusen and VandenBroeck	1977 1977
4	Pooled or panel Parametric stochastic.	Schmidt and sickles; Cornwell *et al* Park and Simar; Park *et al*	1984 1990 1994 1998

Having looked at the various frontier models used in the previous researches, the current study adapted the two most commonly used frontier models out of the 4 different ones listed above. The model used in this study is the cross sectional parametric stochastic model. Stochastic Frontier Analysis (SFA) is a cross sectional parametric stochastic frontier model. It is a cross sectional because the data used in this study are cross sectional data. Below is a brief explanation of Stochastic Frontier Analysis (SFA).

Stochastic Frontier Analysis (SFA)

Stochastic Frontier Analysis (SFA) which is a Non-linear Programming technique was initially used and presented in the seminal work of Aiger*et al* (1977) as well as Meeusen and Broeck(1977).Following vigorous and intensive research, the SFA model has been shaped,molded and re-molded by some authors including Schmidt (1985), Bauer (1990) and Battese (1992). The importance of SFA model was developed by Battese and Coelli (1995) which estimates both technical efficiency and the factors affecting the firms' inefficiency level. It was realized by Diaz and Sanchez (2005) and adapted by Liu(1995).The process of estimating technical efficiency using the parametric or stochastic model requires two most important factors. These factors include, the assumption of a particular functional form and also the inclusion of an additional error term in the production frontier to account for technical inefficiencies (Ogunniyi and Ajao, 2011). Thus, SFA is composed of two components in its disturbance term in which one expresses technical inefficiency and the other is for random events .This was the reason why the SFA model was viewed to have a significant improvement (Trans*et al* 1993).

There are about three (3) popular functional forms used in estimating a particular production function. These include Cobb-Douglas, Transcendental Logarithmic (Translog) and Constant Elasticity of Substitution (CES). However, only two of the three functional forms have been widely used in recent literatures. These include the simplest, Cobb Douglas Production Function and the relatively complex, Transcendental Logarithmic Technique (Coelli *et al*, 1998). It has been established that, stochastic frontier models were initially and originally formulated by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1988). Other similar models which were later developed, include the works of Olson *et al* (1980), Jondrow*et al* (1982), Pitt and Lee (1981) as well as Schmidt and Sickless (1984). Although the earlier work of Aigner (1977); Meeusen and VandenBroeck (1977) were specifically on cross sectional data, Panel data analysis using the stochastic frontier model was also exploited. Schmidt and Sickless (1984) and Pitt and Lee (1981) were the first to explore panel data analysis. Recently, Other later works of some authors such as Cornwell and Schmidt (1995), Greene (1995), Lovell (1993), Lovell and Schmidt (1988) and Battese and Coelli (1995) have critically looked at the panel data analysis.

However, an appreciable number of researches have also used cross section data in their analyses. Such can be viewed in the work of Kumbhakar*et al* (1991), Relfschneider and Stevenson (1991) as well as Liu (1995).

Objectives of the Study

The broad objective of the study was to analysis farm level efficiency of rubber as a perennial crop using Translog Production Frontier Approach while the specific objectives are to

Examine the socio-economic profile of the respondents

Investigate the technical efficiency of rubber smallholders in a disaggregated form.

Empirically analyze the determinants of technical efficiency of rubber smallholders in disaggregated form.

METHODOLOGY

This section discusses study area, data source and collections, sampling procedures, questionnaire designs and its administration, methods, materials and techniques used in sampling, collecting and analyzing the data.

Study Area and data Collection

Negeri Sembilan is one of the 13 states in Peninsular Malaysia with a total land area of about 6,641 square kilometers. The selection of Negeri Sembilan for this study was based on the intensity of rubber production in the area. The state consists of nine (9) Districts which include Seremban, Tanpin ,Rembau, Kuala Pillah, Jempol, Jelebu, Rasah, Telok and Kemong. In the present study, a total of five districts (Seremban, Tanpin ,Rembau, Kuala Pillah and Jempol) were purposely chosen and selected due to their high intensity and concentration of rubber smallholders. Accordingly, these five districts are believed to represent the Negeri Sembilan State fairly well. Negeri Sembilan is located between Latitude 2° 43' 6.9312N"and Longitude E 101° 56' 56.3564E" North and East of the Equator. It is bounded by Kuala Lumpur to the North and Pahang to the East. Melaka and Johor States are on its Southern part. It has an average annual temperature of 27.1^0 C and a mean annual precipitation of 1984 mm (Department of Statistics Malaysia,2015).The state is well suited for plantation farming such as oil palm, rubber and coconut plantations.

Figure 1 is a comprehensive map of Negeri Sembilan State where the research work was carried out.

Figure 1: Map of Negeri Sembilan showing Various Districts and towns.
Source:Open Clipart,2015

Sampling Procedure

A multistage sampling procedure was followed In the first stage, five 5 districts of Seremban, Tampin, Rembau, Kuala Pilah and Jempolwere selected purposively considering the intensity of rubber area coverage among the different districts.The second stage involved selection of two villages from each of the five districts, making a total of ten (10) villages. The third selection was based on randomly selecting 35 respondents' farmers from each village, making a total administered, 338 were retrieved for a total response rate of 96.6% and of the 338 returned questionnaires; 11 were carefully sorted and discarded due to incomplete information. Finally only 327 questionnaires were found to be useful for the research and hence formed the sample size of this study.Alsoout of the 327 sample size realized, only 307 observations were used in computing inferential statistics, because the young-age category, which has 20 respondents, has been removed due to statistically scanty nature of the sample size. However, whole sample size of 327 observations was used.Therefore, in analyzing inferential statistics, 307 rubber small holder farmers in five districts of Negeri Sembilan state with 307, 206 and 101 number of smallholder farms under all–age, matured-age (7-to-15yrs) and old-age (16-to-25yrs) categories respectively were applied.

Questionnaire Administration

During data collection, self-completion questionnaires were administered to respondents using three different strategies which involved (a)- One-to one contact, (b)- Group or mass contact with the aid of RISDA staff/extension officers and (c)“Drop off and collect” method as suggested by Brown, (1987). Using the structured questionnaires, information was collected on output and several inputs. The inputs data collected were categorized into seven variables which include farm size, rubber task, farm tools, chemical fertilizer, chemical herbicides, labour and rubber clones. Data was also collected on socio-demographic variables of the respondents.

Empirical Model

In using stochastic frontier production (SFP), the estimation of TE involves two functional forms which include Cobb Douglas (CD) and Translog functional forms. The former is linear in log while the latter is quadratic in log. The CD is relatively simple to estimate and easy to interpret while in the Translog, the reverse is the case. That is,it’s more flexible because of its small restrictions on elasticities and its findings are more complex and tedious to interpret. Translog also has so many parameters and this leads to multicolinearity problem.The present study used generalized likelihood ratio (LR) test in choosing between the two functional forms since the choice of functional form cannot just be made arbitrary.

The Translog model is displayed as shown below.

$$
\begin{aligned}
lnY_i = {} & \beta_0 + \beta_1 lnx_i + \beta_2 lnx_{2i} + \beta_3 lnx_{3i} + \beta_4 lnx_{4i} + \beta_5 lnx_{5i} + \beta_6 lnx_{6i} + \beta_7 (lnx_{1i})^2 + \beta_8 (lnx_{2i})^2 + \beta_9 (lnx_{3i})^2 + \beta_{10} (lnx_{4i})^2 \\
& + \beta_{11}(lnx_{5i})^2 + \beta_{12}(lnx_{6i})^2 + \beta_{13}(lnx_{1i})(lnx_{2i}) + \beta_{14}(lnx_{1i})(lnx_{3i}) + \beta_{15}(lnx_{1i})(lnx_{4i}) \\
& + \beta_{16}(lnx_{1i})(lnx_{5i}) + \beta_{17}(lnx_{1i})(lnx_{6i}) + \beta_{18}(lnx_{2i})(lnx_{3i}) + \beta_{19}(lnx_{2i})(lnx_{4i}) + \beta_{20}(lnx_{2i})(lnx_{5i}) \\
& + \beta_{21}(lnx_{2i})(lnx_{6i}) + \beta_{22}(lnx_{3i})(lnx_{4i}) + \beta_{23}(lnx_{3i})(lnx_{5i}) + \beta_{24}(lnx_{3i})(lnx_{6i}) + \beta_{25}(lnx_{4i})(lnx_{5i}) \\
& + \beta_{26}(lnx_{4i})(lnx_{6i}) + \beta_{27}(lnx_{5i})(lnx_{6i}) + v_i - u_i
\end{aligned}
$$

$$i = 1\,,2,3 \ldots 6;$$

Where

$y_i$is the output of the ith rubber farm

$x_{1i}\ ,x_{2i}, x_{3i}, x_{4i} \ldots., x_{27}$ are the input variables of the ith farm;

$v_i$are random variables assumed to be $iid\ N(0, \sigma_v^2)$ and independent of u_i

$u_i = \{exp[-\acute{\eta}(t-T)]\}u_i i = 1,2,3,4 \ldots 27$(Lin and Tseng, 2005)

RESULTS AND DISCUSSIONS

Socio-Demographic characteristics of the respondents

Table 2 consists of the descriptive statistics of socioeconomic factors of each of the three (3) age-categories of the smallholder farms and one with wholesome or aggregated age category for comparison purpose. The seven (7) socio-economic characteristics were solely expressed in terms of frequency and percentages. The variables include gender, race, marital status, educational level, topography, extension agent visits and location (districts).

Gender variable which was categorized in to male and female was found to have 52.3% males and 47.7% females. In terms of age group, Young-age group has seven (7) males and thirteen (13) females; Matured-age group has 108 males and 98 female respondents while old-age group of rubber plantations has 56 males and 45 female smallholders.

The second variable (Z_2) is race and this was categorized into 4 sub-variables in accordance with ethnicity traits. These include Malay, Chinese, Indians and others. Out of the total sample of 327 respondents, 282 were Malay, 7 were Chinese, 2 were Indians and 36 respondents were from other racial backgrounds. Regarding age group of the crops, old-age group had mostly Malay respondents with only 1 Chinese and no Indian smallholder. Matured-age group have Malay comprising 79.6%, Chinese, 1.94%, 0.97% Indians and 17.48% from other races. The young-age category of the plantations recorded only Malay and Chinese but no Indian and no any other racial backgrounds. This group was also dominated by Malay with almost 90% while Chinese have approximately 10% respondents.

The third socio-demographic variable is Marital Status (Z_3) and this was categorized in to ‘single’, ‘married’ and ‘other’. Out of the 327 respondents partitioned into 20, 206 and 101 number of individuals for the young-Age, Matured-Age and Old-age groups respectively, only 10 were single while 305 were married and this has about 93% of the sample size. The 305 married smallholder respondents were spanned over the three age groups with 17, 189 and 99 respectively for the young-age, matured-age and old-age groups for rubber farms.

Educational level which is the fourth socio-economic variable (Z_4) is categorized into four sub categories which include no education, primary, secondary and diploma levels of education. The highest number of the respondents was found to be secondary and primary schools leavers with 163 and 125 numbers of smallholders respectively. Only 7 respondents had diploma certificates and about 32 farmers had not gone to school at all. Under young-age group, all the 20 respondents attended school but only one (1) had diploma certificate. The remaining 6 diploma holders belong to matured-age group. None of the old-age category was having diploma certificate and about 14 of them had not attended any school. However, 39 and 48 have attended primary and secondary schools, respectively.

Topography which is the fifth variable (Z_5) composed of two sub-variables including gentle slope and hilly. Based on our analysis, about 160 respondents admitted that their farms were situated on a hilly land while 171 smallholders have gently-sloped rubber farms. Out of the 160 respondents of hilly land farms, 89 were under matured-age, 52 under old-age while 19 respondents under young-age category. The 171 gently-sloped lands composed of 117 from matured-age rubber farms, 49 from old-age rubber farms and only a single smallholder was found to be under young-age category rubber farm.

The sixth socio-demographic variable is the extension agent visits. This simply refers to a situation whereby a farmer or farmers have some physical contacts with the extension agents .The contacts could be either in a group(mass contacts) or one to one (individual) contact. The purpose of visits is usually to disseminate knowledge on newly improved techniques about rubber production. In this study ,the variable extension visits was subdivided in to “Yes “ and “No” to represent if there was a visit or no visit respectively. Both the matured-age and the old-age crop category farms had about 99% extension visits, while the young-age category had completely 100% extension visits.

The seventh socio-economic variable (Z_7) is location. Location here refers to the districts where the research was conducted and also the home of the smallholder rubber farms. The variable “location” was subdivided in to five (5) different districts of Negeri Sembilan. The districts include Seremban, Tampin, Jempol, Rembau and Kuala Pilah districts. It was observed that about 134(40%) of the respondents were from Jempol districts. This is followed by Rembau, Kuala Pilah, Seremban and Tampin having 104, 41, 37 and 11 number of smallholders respectively. Although the highest concentrations of respondents is from Jempol, then followed by Rembau but Rembau has high concentrations (about 45-50%) of smallholders under old-age and young-age categories of rubber farms. Jempol has only a little more than half (about 57%) of the respondents under matured-age category of rubber plantations.

Descriptive Statistics for the Variables Used in the Study

Table 3 explains the descriptive statistics of variable inputs and output used by each of the 3 age-categories of the smallholder rubber crops in the study. The variables used include the rubber yield (kg/ha) as the output variable, farm size (ha), number of rubber trees per ha which is often called rubber task, farm tools, fertilizer (kg/ha), chemical herbicides (lit/ha) and labour (man days) as the six inputs variables. The table specifically contains the mean and standard deviations of all the six independent (input) variables and the single dependent (output) variable used by each rubber crop age.

Table 2: Distribution of Socio-Demographics Profiles of Rubber Smallholders

Variables	**All-age**	**Young-age**	**Matured-age**	**Old-age**
Gender(Z1)	**Freq. (%)**	**Freq. (%)**	**Freq. (%)**	**Freq. (%)**
Male	171(52.30)	7(35)	108(52.43)	56(55.44)
Female	156(47.70)	13(65)	98(47.57)	45(44.55)
Race(Z2)				
Malay	282(86.24)	18(90)	164(79.61)	100(99.01)
Chinese	7(2.14)	2(10)	4(1.94)	1(00.99)
India	2(0.61)	0(0)	2(0.97)	0(00.0)
Other	36(11.0)	0(0)	36(17.48)	0(00.00)
Marital status(Z3)				
Single	10(3.06)	1(5)	8(3.88)	1(0.99)
Married	305(93.27)	17(85)	189(93.5)	99(98.02)
Other	12(3.67)	2(10)	9(4.37)	1(0.99)
Educational Level(Z4)				
No	32(9.79)	0(0)	18(8.74)	14(13.86)
Primary	125(38.23)	5(25)	81(39.32)	39(38.61)
Secondary	163(49.85)	14(70)	101(49.03)	48(47.52)
Diploma	7(2.14)	1(5)	6(2.91)	0(00.0)
Topography(Z5)				
Hilly	160(48.93)	19(95)	89(43.2)	52(51.49)
G.S	171(52.3)	1(5)	117(56.8)	49(48.51)
Extension Visit (Z6)				
Yes	325(99.4)	20(100)	205(99.5)	100(99.01)
No	2(0.6)	0(0)	1(0.5)	1(00.99)
Location (Z7)				
Seremban	37(11.0)	2(10)	7(3.4)	28(27.72)
Tamping	11(3.4)	0(0)	10(4.9)	1(00.99)
Jempol	134(41)	3(15)	118(57.28)	13(12.87)
Rembau	104(32)	9(45)	44(21.36)	51(50.50)
KualaPilah	41(12.6)	6(30)	27(13.11)	8(7.92)

Source: Field Survery, (2015).

Starting with the first category of all-age crops which has the total sample size of 307 smallholders, the mean value of the total output was found to be 3,638.28kg/ha/yr. of rubber. The average output of the matured-age category was estimated to be 4,611.34kg/ha/yr. while that of the old-age category was found to be 1,653.61kg/ha/yr. This is an indication that more rubber latex was produced by the more productive stage (matured-age category) while less latex was obtained from the relatively less productive stage (old-age category). This implies that less quantity of latex would be tapped from old rubber trees than the matured-age category (Shamsudin and Mohamed, 1993). So the yield and ages of perennial crops would always take a parabola shapes when plotted.

The average farm size of the all-age rubber crops was approximately 1.28 ha which has an average of 502 rubber plants per farm farmland. The mean quantity of fertilizer applied on the all-age rubber crops was 382kg/ha while the average chemical herbicides used was recorded to be 13 l/ha. For the matured-crops, the average farm size was found to be 1.19 ha while the variable inputs such as rubber task, fertilizer, herbicides were respectively estimated as 532 plants/ha, 356kg/ha and 12.66 l/ha. The old-age crop category has its respective rubber task, chemical fertilizer and herbicides as 441 plant/ha, 434 kg/ha and 12.28 l/ha. The reason behind the difference between rubber yield (kg/ha) of the matured-age and old age categories could be attributed to the effective utilization of the variable inputs. For instance, the average number of rubber trees of the matured –age was 532 per hectare which was higher than that of old-age having only 441 trees per hectare. Although the amount of chemical herbicides were apparently the same in volume but the average quantity of fertilizer differs with the old-age requiring greater quantity of fertilizer than the matured-age crops. The fertilizer might have been excessively applied .This is because old-age crops have enough nutrients trapped through long years of nitrogen fixation .So applying more quantity of fertilizer to the soil will turn out to be more toxic to the plants and this has negative effect of reducing the yield.

Regarding farm tools, the average farm tools for all-age rubber crops is 2.85 while that of matured-age and old-age rubber crops are 2.34and 3.89 respectively.

Table 3: Statistics of the Variables Used in the Study

Variables	**All-age**		**Matured-age**		**Old-age**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Yield (kg/ha/yr.)	3638.28	2899.88	4611.34	2913.36	1653.61	1550.47
Farm size(ha)	1.26	0.60	1.19	0.48	1.40	0.77
Rubber Task(per ha)	502.09	250.91	532.03	292.44	441.01	108.19
Farm Tools	2.85	1.78	2.34	1.60	3.89	1.68
Fertilizer (kg/ha/yr.)	381.76	317.72	356.35	298.57	433.59	349.45
Herbicides (lit/ha/yr.)	12.53	8.68	12.66	9.44	12.28	6.91
Labour(man days)	12.85	2.27	13.14	2.03	12.27	2.61

Estimates of Translog Production Frontier for the Three Crops' Age

Table 4 presents the results of summary estimation of Translog production frontier for the three different age-category rubber crops of all-age, matured-age and old-age crops of smallholders.

The table captured coefficients and t-values of all the variables under each of all-age, matured-age and old-age categories. The all-age category has five statistically significant variables which include, farm size, rubber task, farm tools, fertilizer and labour. The coefficient values of farm tools, fertilizer and labour are in conformity with the theory because they are positively significant. That means, they tend to increase the rubber yield when they are increased and vice versa. For instance, an increase of 1kg/ha of fertilizer results in about 2.1 kg/ha increase in rubber latex. Also, an increase of 13.41 kg/ha of rubber would be realized when a unit of,labour is added. The matured-age category has fourstatistically significant variables which consist of rubber task, farm tools, herbicides and labour. Apart from rubber task, the remaining three variables which include farm tools, herbicides and labour were found to be positively significant and hence in conformity with the priori expectations. The result explains that, an increase in a single unit of farm tools, leads to an increase of approximately 5kg/ha of rubber latex yield. Also, additional supply of a single labour leads to an increase in rubber yield by almost 9 kg/ha. When one l/ha of herbicides is applied to the farm, an increase of approximately 3kg/ha of rubber latex yield would be realized.

Variables which include rubber task, farm tools, fertilizer, herbicides and labour were found to be statistically different from zero under old-age category crops. However, only three of the variables were positively significant and in line with theoretical expectations. These include farm tools, fertilizer and labour. As already explained, being positively significant means that an increase or decrease in the magnitude of the said variable leads to an increase or decrease respectively in the yield of rubber. Essentially, an increase in 1kg/ha of fertilizer will lead to an increase in almost 9kg/ha of rubber output and vice versa. Also when a single labour is added, approximately 9kg/ha of rubber latex output will be tapped and decrease of a unit of labour will also downsize the rubber output by nearly 9kg/ha under old-age category crops.

In summarizing the outcome of all the three categories, it would be observed that only farm tools and labour were positively significant common to each of the three crop-age categories. We can conclude that critical factors that positively affect smallholder rubber production capacity in Negeri Sembilan are farm tools and labor supply.

Estimates of Inefficiency Model of Translog Production Frontier

Table 5 presents the summary of the estimations of inefficiency model of Translog production frontier of all the three crops' age categories of rubber smallholders.

Table 4: Estimates of Translog production frontier for the three crops' age

Variables	**All-age**		**Matured-age**		**Old-age**	
	Coef	**t-ratio**	**Coef**	**t-ratio**	**Coef**	**t-ratio**
Constant	-1.69	-0.44	1.12	1.26	-10.27***	-11.22
Farm size $(\ln X_1)$	-5.51***	-4.81	-0.10	-0.11	0.07	0.07
Rubber task $(\ln X_2)$	-4.35***	-2.70	-3.25***	-2.70	-2.46***	-3.02
Farm tools $(\ln X_3)$	2.80***	2.38	4.49***	3.27	4.69***	5.27
Fertilizer $(\ln X_4)$	2.09**	1.76	-0.73	-0.79	9.14***	11.72
Herbicides $(\ln X_5)$	-0.16	-0.11	2.46*	1.79	-1.71*	-1.75
Labour $(\ln X_6)$	13.41***	3.16	8.51***	8.89	8.72***	6.57
$(\ln X_1)^2$	1.40***	3.31	0.59	1.51	2.99***	6.07
$(\ln X_2)^2$	0.98 ***	3.00	-0.69	-1.52	2.09***	5.40
$(\ln X_3)^2$	-2.08***	-9.56	-3.13***	-11.34	0.27	0.83
$(\ln X_4)^2$	-0.23*	-1.68	-0.77***	-2.97	-0.08	-0.45
$(\ln X_5)^2$	-0.38	-1.35	-0.63***	-2.21	-0.94*	-1.68
$(\ln X_6)^2$	-7.16***	-5.89	-10.30***	-12.67	1.36	1.35
$\ln X_1 \ln X_2$	0.15	0.29	-2.88***	-6.08	0.61	0.96
$\ln X_1 \ln X_3$	-0.08	-0.25	-0.71	-1.36	0.06	0.15
$\ln X_1 \ln X_4$	-0.22	-0.67	0.69	1.36	-0.86	-1.66
$\ln X_1 \ln X_5$	1.51***	2.47	0.97*	1.63	2.93***	3.43
$\ln X_1 \ln X_6$	3.13***	2.98	4.36***	4.43	-3.36***	-3.45
$\ln X_2 \ln X_3$	-2.02***	-5.99	-2.34***	-4.22	-3.53***	-8.56
$\ln X_2 \ln X_4$	-0.07	-0.18	2.24***	4.25	-2.46***	-6.12
$\ln X_2 \ln X_5$	-0.27	-0.46	-2.57***	-3.95	1.81***	2.49
$\ln X_2 \ln X_6$	1.09	0.89	5.59***	7.26	-1.97***	-2.37
$\ln X_3 \ln X_4$	-0.14	-0.68	0.82***	2.26	0.46*	1.76
$\ln X_3 \ln X_5$	0.02	0.08	0.46	1.23	0.40	1.30
$\ln X_3 \ln X_6$	3.51***	5.94	0.88	1.08	2.30***	2.80
$\ln X_4 \ln X_5$	0.11	0.33	0.33	0.70	-0.18	-0.32
$\ln X_4 \ln X_6$	-0.93	-1.34	-2.12***	-2.86	-2.08***	-3.09
$\ln X_5 \ln X_6$	0.96	1.08	4.10***	4.94	-1.29*	-1.68

Source: Field Survey (2015)

Note:
1% level of significance = ***
5% level of significance = **
10% level of significance = *

Fifteen variables were used as determinants of the efficiency scores with four districts as dummy variables. The sigma squared and gamma values for each of the crop age categories were found to be significantly different from zero statistically at 1% level of significance (Giroh et al, 2014). That means, all the three inefficiency models are having goodness of fit and an indication that 86%, 46% and 100% of variation in output under all-age, matured-age and old-age categories respectively, are attributed to technical inefficiency.

The table also revealed that ten variables were statistically significant under all-age rubber crops category, four variables under matured-age and only three variables were found to be significant under old-age category. The log likelihood function for each of the all, matured and old crops categories are 169.36, 147.90 and 122.45 respectively. Their respective LR-tests are 89.78, 33.02 and 72.31. Majority of the significant variables have negative coefficients and this justified that they are in an indirect relationship with technical inefficiency or more precisely they contributes to the improvement of efficiency. These variables include race, house hold, tapping experience, level of education and farmers' age under all-age category. However, under matured-age crops, the variables include house hold number, level of education, extension visits and farmer's age. For the old-age category, the variables include tapping system and district Jempol.

Table 5: Estimates of determinants of efficiencyof rubber

Variables	**All-age**		**Matured-age**		**Old-age**	
	Coefficient	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**
Constant	0.73***	3.05	1.02***	3.38	0.26	0.84
Gender	0.08**	1.83	0.00	0.04	-0.01	-0.48
Race	-0.24***	-2.76	-0.07	-1.34	0.16	1.43
Marital status	0.32***	2.36	0.25	1.49	0.36***	3.36
Household	-0.07***	-2.79	-0.03***	-2.39	0.01	1.45
Tapping experience	-0.01***	-2.18	0.00	-1.00	0.00	1.24
Level of education	-0.26***	-2.72	-0.12***	-2.13	-0.02	-0.53
Topography	0.21***	2.65	0.07	1.54	0.04	1.09
Extension visits.	-0.17	-1.16	-0.69***	-2.33	-0.05	-0.50
Tapping system.	0.14	1.23	0.14	1.63	-0.35***	-2.04
Farmer's age	-0.01***	-3.20	0.00***	-2.45	0.00	-0.71
Farm distance	0.01***	2.35	-0.03	-1.28	0.00	-0.03
Seremban	0.32***	2.03	0.06	0.46	0.03	0.23
Jempol	-0.20	-1.26	-0.16	-1.63	-0.23**	-1.95
Rembau	-0.09	-0.46	-0.12	-1.23	0.09	0.68
Kuala Pilah	0.09	0.61	-0.06	-0.59	0.09	0.65
Variance parameters						
Sigma Square	0.06***	2.87	0.02***	3.96	0.01***	3.95
Gamma	0.86***	10.47	0.46***	1.60	1.00***	28.37
LLF	169.36		147.90		122.45	
LR-Test	89.78		33.02		72.31	

Source: Field Survey (2015)

Note:
1% level of significance = ***
5% level of significance = **
10% level of significance = *

Range, Frequency and Percentages of Efficiency Scores for the Translog

Table 6 reports a complete summary of range of efficiency scores, frequency of the farms and their respective percentages of the Translog production frontier for the three age-categories of rubber smallholder plantations. The mean technical efficiency for all-age, matured-age and old-age rubber crops are 0.87, 0.91 and 0.65 .Their corresponding SD are 0.11, 0.07 and 0.09. The maximum efficiency scores attained by each of the three crops age categories were found to be 0.98, 0.99 and 1.00 respectively while the minimum values stood at 0.45, 0.52 and 0.49 for all-age, matured-age and old-age rubber crops respectively. It would also be observed that, both all-age crops and matured-age crops have no single farm that is fully technically efficient, while the old-age crops category has only one farm that is on the frontier. However, majority of the matured-age rubber crops (about 70%) have technical efficiency scores more than 0.90 while the all-age crop category has about 55% of its farms scoring more than 0.90. These results are not the same with what was obtained under old-age crops category. This is because majority of the farms under old-age category rallied around score range of 0.41-0.70 and this constituted about 79 farms which is equivalent to approximately 78% of the farms under old-age category.

Bar charts Representing Technical efficiency of the three age categories of rubber crops

Figure 2 captures the graphical presentation of the technical efficiency scores of all-age, matured-age and old-age categories of rubber crops using Translog production frontier. From the figure, it would be realized that no single farm was found on 1.00 score range. That means that no farm was on the production frontier. All the farms scored less than 1.00. The Figure further indicated that more than 160 number of rubber farms under all-age category scored above 0.91, while more than 140 farms of matured-age category have this score (0.91). The old-age category has less than 10 farms.

Table 6 : Efficiency Scores for the All-age, Matured-age and Old-age Crops

Range	**All-age Frequency (%)**	**Matured-age Frequency (%)**	**Old-age Frequency (%)**
<=20	0(0.00)	0(0.00)	0(0.00)
0.21-0.30	0(0.00)	0(0.00)	0(0.00)
0.31-0.40	0(0.00)	0(0.00)	0(0.00)
0.41-0.50	3(0.98)	0(0.00)	2(1.98)
0.51-0.60	9(2.93)	1(0.49)	37(36.3)
0.61-0.70	30(9.78)	3(1.45)	42(41.58)
0.71-0.80	24(7.82)	14(6.80)	13(12.87)
0.81-0.90	74(24.10)	44(21.36)	4(3.96)
0.91-0.99	167(54.40)	144(69.9)	2(1.98)
1	0	0(0.00)	1(0.99)
Summary			
Mean	0.87	0.91	0.65
S.D	0.11	0.07	0.09
Max	0.98	0.99	1
Min	0.45	0.52	0.49

Source: Field Survey (2015)

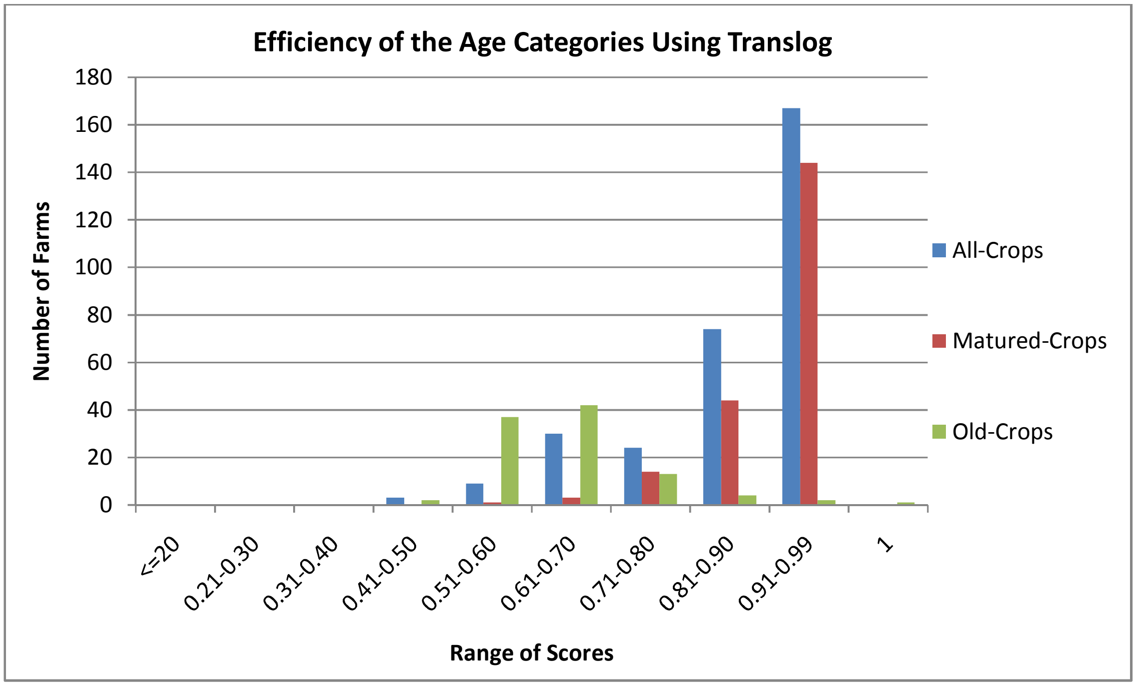

Figure 2: TE of Rubber Age Categories Using Translog Production Frontier.

CONCLUSION AND RECOMMENDATIONS

The study concludes that matured-age category of rubber crops was found to be relatively higher than the other two age categories (i.e. all-age and old-age) in terms of average yield in kg/ha of rubber latex from smallholder plantations. The study further concludes that, there is quite a difference between the aggregated (all-age category) and disaggregated (matured-age and old-age categories)as regards totechnical efficiency (TE) of rubber. The study therefore, recommends that the traditional concept of computing efficiency or productivity of rubber and other perennial crops in an aggregated form should be complemented and supplemented with the disaggregated form as this eliminates any bias and gives meaningful results as the perennial crops like rubber grow in phases. The study also recommends that the determinants of efficiency such as level of education of smallholders should be given more attention to increase efficiency. Another recommendation is that granting subsidy to the smallholders in terms of fertilizer and chemical herbicides should be encouraged as this helps to cut down the smallholders' production cost and hence improves efficiency.

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