



Management

## FREE DISPOSAL HULL (FDH), ODER-M AND ODER-ALPHA ( $\alpha$ ) EFFICIENCY ANALYSIS FOR RUBBER SMALLHOLDERS IN MALAYSIA

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### Abstract

The study examines the technical efficiency of rubber smallholders in Negeri Sembilan under 3 age categories using different method of efficiency analysis which include the Free Disposal Hull (FDH), Expected Oder-m (EOM) and Oder-Alpha ( $\alpha$ ) (O- $\alpha$ ). The analysis was done in such a way that the rubber age was categorized in to All-age, matured-age and Old-age categories. Multistage sampling procedure was used and 307 smallholders were used comprising 307,206 and 101 for all-age, matured-age and old-age categories respectively. The result of the analysis revealed that the mean technical efficiency of all-age, matured-age and old-age crops under FDH were 1.00, 1.00 and 1.00 while that of Order-Alpha and Expected Oder-m were 0.89, 0.89, 0.90 and 0.96, 0.97 0.98 respectively for the all-age, matured-age and old-age crops categories. The percentages of rubber crop farms that are on the FDH production frontier were 100%, 100%, and 100% while under Order Alpha ( $\alpha$ ) were 13%,10 and 20%. The ones under expected order-m frontier were 29%, 39% and 52% respectively for all-age, matured-age and old-age categories. The mean TE of FDH and mean TE of Order-Alpha were subjected under paired t-test and found to be statistically different from each other. It was revealed that mean TE of FDH was statistically greater than that of Order-M efficiency. Order- M and Order-alpha efficiencies were also subjected under paired mean t-test, and the results indicated that the two means were statistically different from each other. Expected Order-M was found to be statistically higher in magnitude than its counterpart Order Alpha. The study finally concludes that FDH has higher efficiency scores than the other two partial production frontiers. Also deduced from the study was that the old-age category has higher efficiency scores than both the matured-age and all-age categories under both the EOM and Oder Alpha production frontier techniques.. So conclusively the old-age is higher than the matured-age which in turn higher than the all-age category in both the Expected Oder-m and Oder-Alpha production frontiers. Most importantly, policy planners should be very cautious on specific techniques. They should as well be knowledgeable and comparatively minded on the results obtained from both the Expected Oder-m and Oder-Alpha production frontiers with regards to the policy selections on the rubber crop.

**Keywords:** Rubber; Smallholders; Technical Efficiency; Free Disposal Hull; Expected Oder-M and Oder-A.

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## 1. Introduction

The word 'Efficiency' has been widely and extensively used in economics since time immemorial. This has made its analysis to be an important issue in the field of economic studies (Ajibefun, 2008). From the seminal work of Farrell, (1957) the concept has been defined in form of technical efficiency, which means either producing output at optimal level using given inputs or producing a given amount of output with minimum quantities of input. The following are the basic theory of production economics in relation to efficiency or productivity. Before measuring efficiency of any data under cross sectional setting, there needs to initially determine the nature of the boundary of the production set, and there after the distance from observed point to the boundary of the production set is calculated or measured. Based on the workings of Simar and Wilson (2014) and also from the original work of Koopmans (1951), Debru (1951), Shepherd (1970) and Farrell (1957), Basic economic and production theory can be clearly described as shown below:

Let  $p$  and  $q$  represents input and output quantities and are expressed as  $x \in R_+^p$  and  $y \in R_+^q$  respectively.

Therefore, the of production becomes  $\Psi = \{(x, y) \in R_+^{p+q} | x \text{ can produce } y\}$   
Thus, the above describes the physically feasible and attainable production points  $(x, y)$ .

Since the boundary of the production frontier ( $\Psi$ ) is the most interested segment in any efficiency analysis, it is thus defined as  $\Psi^\partial = \{(x, y) \in \Psi | (\gamma^{-1}x, \gamma y) \notin \Psi \text{ for any } \gamma > 1\}$   
Before forging ahead with measuring technical efficiency, certain economics assumptions have to be considered and taken in to account. Such assumptions include the assumptions of free disposability, No free lunch assumption, Convexity assumption and Return to scale assumptions.

The assumptions are as displayed below.

1) Free Disposability assumption:

$\forall (x, y) \in \Psi,$

Any  $(x', y')$  such that  $x' \geq x$  and  $y' \leq y$ ,  $(x', y') \in \Psi,$

Although according to fare *et al* (1985), when the above assumption relaxed, it would allow for congestion, pollution and other noises.

2) "No free lunch" assumption: This assumption simply means that positive inputs quantities are required to be used by all production.

$(x, y) \notin \Psi$  if  $x = 0$  and  $y \geq 0, y \neq 0.$

3) Convexity assumption:

If  $(x, y), (x_2, y_2) \in \Psi,$  then for all  $\alpha \in [0, 1],$

$(x, y) = \alpha(x_1, y_1) + (1 - \alpha)(x_2, y_2) \in \Psi.$

4) Return to scale assumption

The returns to scale assumptions are in three folds. This includes Constant Return to Scale (CRS), Increasing Return to Scale (IRS and Decreasing Return to Scale (DRS) as shown below:

If the subset of  $\Psi^\theta$  is from  $\{(x, y) | (x, y) \in \Psi^\theta \text{ and } (x, y) \in V(\Psi^\theta)\}$ , then there exist Constant Return to Scale (CRS). And if the subset of  $\Psi^\theta$  emanating from or given by  $\{(x, y) | (x, y) \in \Psi^\theta, (\alpha x, \alpha y) \in \Psi, (\alpha x, \alpha y) \notin \Psi^\theta \text{ for some } \alpha \in (1, \infty)\}$

Then, there exist Increasing Return to scale (IRS),

While the sub set of  $\Psi^\theta$  given by

$\{(x, y) | (x, y) \in \Psi^\theta, (\alpha x, \alpha y) \in \Psi, (\alpha x, \alpha y) \notin \Psi^\theta \text{ for some } \alpha \in (0, 1)\}$ , exhibits Decreasing return to scale (DRS).  $\Psi^\theta$  Is said to be of varying Return to Scale (VRS), if  $\Psi^\theta$  composed of several regions or spaces that display IRS, CRS and DRS.

All the assumptions listed above are derived from “measurement of efficiency” written by Simar and Wilson (2000).

Although majority of the theories of efficiency came up with major different types of methods which include, parametric deterministic, parametric stochastic, non-parametric deterministic and non-parametric stochastic frontier techniques. However, this study only dealt with the non-parametric deterministic methods. A good example of the non-parametric deterministic is however categorized in to full and partial frontier methods. The full frontier method from the name implies that, such methods can envelop the whole data during analysis. Such include data envelopment analysis (DEA) and free disposal hull. The partial frontiers of the non-parametric deterministic methods do not envelop the entire data set in the process of analysis and this includes the expected Order-m and conditional Order-alpha( $\alpha$ ) methods. Each of these frontier methods were used to measure and estimate technical efficiencies of rubber smallholders under different age category farms.

### Free Disposal Hull (FDH)

Free Disposal Hull is a terminology first introduced by Mac Fadden in his work titled “cost, revenue and profit functions “in 1978. This was then used in labeling a reference technology by Deprins, Simar and Tulkens(1984). They actually encountered a bad data fit and used a third form of reference technology and labeled is as FDH production set (Tulkens,1993). From that time onwards, a lot of experimental findings regarding FDH have been investigated. Such experimental works include Tulkens, (1986), Tulkens, (1988), Tulkens, (1989) and in also Tulkens, (1993). Abbas *et al*, (2014) had, in evaluating congestion in Free disposal Hull (FDH), briefly described the characteristics property of FDH model using production possibility set T as  $T = \{(x, y) \in R_+^{m+s} | x \text{ produces } y\}$  They further revealed deductions from production possibility set as deduce by  $\lambda$  Deprins *et al* (1984) by regarding the free disposability and deterministic assumptions of the production technology.

### Expected Oder-M Frontier Analysis

Simar (2000) has indicated that the Free Disposal Hull (FDH), like other non-parametric estimators, has suffered from the obstacle of dimensionality because of its slow rate of convergence. Therefore, in order to curtail this problem, some additional requirements are needed and this tends to make the FDH more robust. This can easily be done through proposing a non-parametric estimator that is more robust to extreme values of outliers by using a concept of expected minimum/maximum input or output functions (Cezals, 2002). They proposed to estimate an expected frontier of order-M instead of estimating a full frontier and this is called an expected Order-m efficiency estimator.

### Conditional Oder- $\alpha$ Efficiency

Conditional Order- $\alpha$  estimator, is one of the recently developed non-parametric partial frontier estimators. As already pointed out or discussed earlier, that both the DEA and FDH are very sensitive to outliers or extreme values. Cezals, *et al* (2002) have developed a partial frontier of Expected Order-m estimator which overcomes the problem of sensitivity to outliers. However, the Order-m estimator works on a concept of discrete partial frontiers. Therefore, recently Aragon *et al* (2002) has proposed yet another partial frontier estimator that, apart from correcting the effects of outliers, it also uses the concept of “continues” Oder- $\alpha$  partial frontiers instead of discrete one.

## 2. Objective of the Study

The broad objective of the study is to determine technical efficiency of rubber smallholders in Negeri Sembilan, Malaysia using both the full and partial frontier methods.

While the specific objectives are to:

- Examine the technical efficiency of rubber smallholders using Free Disposal Hull (FDH).
- Analyze the technical efficiency of rubber smallholders using Expected Oder-M frontier method.
- Determine the technical efficiency of rubber smallholders using Conditional Oder- $\alpha$  method.
- To critically investigate the significant difference in efficiency scores between the full frontier and partial frontier methods

## 3. Hypotheses Statements of the Study

There is no significant difference in the technical efficiency (TE) scores of the smallholder rubber farms between the techniques of Free Disposal Hull (FDH) and Oder-Alpha Efficiency (OAE).

Ho:  $\delta_{FDH} = \delta_{Oder-\alpha} = 0$

There is no significant difference in the technical efficiency (TE) scores of the smallholder rubber farms between the techniques of Free Disposal Hull (FDH) and Expected Oder-M Efficiency (OM).

Ho:  $\delta_{FDH} = \delta_{Oder-m} = 0$

There is no significant difference in the technical efficiency (TE) scores of the smallholder rubber farms between the techniques of Oder-Alpha Efficiency (OAE) and Expected Oder-M Efficiency.

Ho:  $\delta_{Oder-\alpha} = \delta_{Oder-m} = 0$

## 4. Literature Review

### Empirical Studies on Non-Parametric Efficiency Estimators

Daouia and Simar (2003) has extended the work of Aragon *et al* (2000) and Cezal *et al* (2002) and produced a conditional  $\alpha$ -Quantile production frontier that is more robust in terms of outliers than the naïve envelopment estimators such as DEA and FDH. This was carried out through the use of probabilistic frame work for efficiency analysis in a multivariate setting. Their study also provided the asymptotic behavior of the  $\alpha$ -Quantile with numerical illustrations. The reason for the

extension of the  $\alpha$ -Quantile to multivariate set up was because there was nonexistence of ordering of Euclidean spaces of dimension greater than one.

Statistical inference for frontier models of non-parametric techniques was investigated and proposed by Simar and Wilson (2000). This was necessitated because several literatures regarding non-parametric estimators were more concerned on the idea of envelopment of full data (FDH/DEA). It has been advocated that no statistical inference in non-parametric frontier techniques. Thus this paper (Simar and Wilson, 2000) has provided the first insight that made it possible for determination of statistical properties of non-parametric estimators.

Tulkens (1993) made a detailed investigation on methodological issues of FDH and their applications to three sectors which include banking sector, judicial courts and urban transit in Belgium. The application of the FDH methodology was first used in comparison between the efficiency of private banks and public banks, the second application was on efficiency of judicial courts to find out what segment of the backlog could be cut down as a result of improvement in efficiency. The last application which was on urban transit, was extended to the treatment of time series data for the transit firms over twelve (12) years and this helped in estimating the technological progress of the urban transit firms over the 12 year period.

## 5. Research Methodology

### Analytical Framework

Almost all the shapes of the non-parametric data envelopment analysis are curved-shapes either output oriented or input oriented. The output oriented is a curved-shaped but is concave to the origin, while that of the input oriented, is convex to the origin. This could be as a result of convexity assumption of data envelopment analysis (DEA).

However, in free disposal Hull (FDH) where such constraint or convexity assumption is relaxed, only the free disposability assumptions that is taken in to account. The shape of the FDH production frontier is step wise (Lim *et al* 2013), as explained in the above diagram of input oriented FDH efficiency measurement.

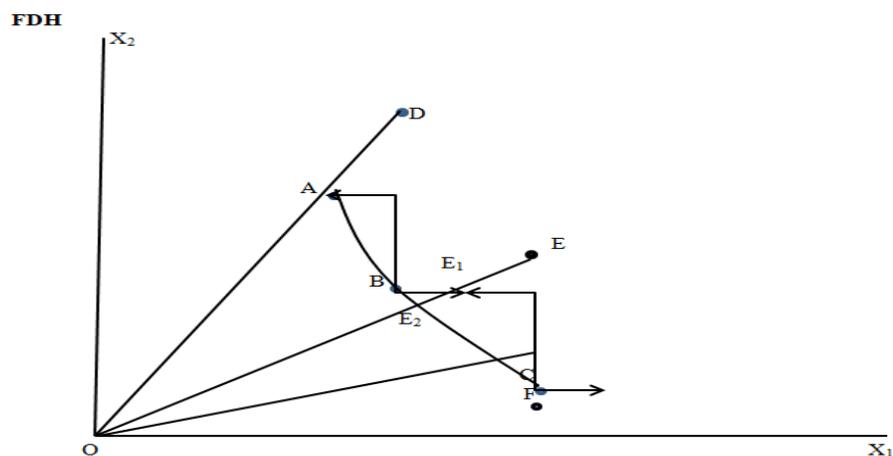


Figure 1: Technical and Allocative efficiency

Source: Lim *et al*, 2013

A careful examination of the diagram revealed that in terms of the BCC model which is a variable return to scale(VRS) Model, the production frontier is A,B,C while the production frontier under FDH model is A,B,C and F as shown in the diagram. Therefore, if the efficiency of observation point “E” is to be computed, the BCC or TE (VRS) is  $\frac{OE_2}{OE}$

While the efficiency of observation point E using FDH is calculated as  $\frac{OE_1}{OE}$

It would be observed that the technical efficiency scores of FDH is always greater than the T.E of DEA under Variable return to Scale assumption which in turn greater than the magnitude of technical efficiency of DEA under constant return to scale as shown below

$$\theta_{FDH,input} \geq \theta_{VRS,input} \geq \theta_{CRS,input}$$

### Data Source

Data were sourced from 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 and old-age categories respectively. The research data were from both primary and secondary sources. The primary source was through the distribution of structured questionnaires to the respondents, while the secondary data were generated from peer reviewed journals, Malaysian statistics department, books and other reputable articles.

### The Study Area

The study area encompasses five districts which include: Seremban, Tampin, Jempol, Rembau and Kuala Pilah districts. The selection of the districts was based on the proportion of rubber production in the states. Located between Latitude  $2^{\circ} 43' 6.9312N$  and Longitude  $E 101^{\circ} 56' 56.3564E$  north and east of the Equator, Negeri Sembilan is one of the Malaysian 13 States. It is bounded by Kuala Lumpur to the north; to the east is Pahang while its southern neighbors are Melaka and Johor States. It has an average annual temperature of  $27.1^{\circ}C$  and a mean annual precipitation or rainfall of 1984 mm. The land area was recorded to be around 6,641 square kilometers. The state is well suited for the plantation farming such as oil palm, rubber and coconut plantations. However, rubber and oil palm plantations dominate the agricultural activities in the state. This is because the bulk of plantation productions come from smallholders who cultivate it on a small scale. The name “Negeri Sembilan” which means Nine States composed of nine districts each ruled by a Malay Chieftain.

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



Figure 2: Map of Negeri Sembilan showing Various Districts and towns

### Sampling Procedure

A multistage sampling procedure was followed and employed to select rubber growing areas which has high rubber availability and intensity. In the first stage, five (5) rubber producing zones/districts of Seremban, Tampin, Rembau, Kuala Pilah and Jempol districts were selected purposively considering the intensity of rubber among 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 thirty five (35) respondents' farmers from each village, making a total of three hundred and fifty (350) respondents. However, of the three hundred and fifty questionnaires administered, three hundred and thirty eight (338) were returned (retrieved) for a total response rate of 96.6% and of the 338 returned questionnaires; eleven (11) questionnaires were carefully sorted, removed and discarded due to incomplete information or being returned empty. Finally only 327 questionnaires were found to be useful for the research and thus specifically formed the sample size of this study yielding a useable response rate of approximately 97%. The gap created between the numbers of questionnaires collected and the number of useable ones was due to the problem of incomplete responses and statements by some subjects that they were too busy or not interested in participating.

### Pre-testing of Questionnaire

The questionnaires were subjected to pre-testing with relatively small sample of 50 rubber smallholder farmers. The reason for conducting the pre-test was to identify problems related to questions format and layout as well as problems of readability and comprehension.

Based on the outcome of the pre-test, minor modifications regarding issues arising from the questions, were fully addressed before embarking on to the main study for data collection.

### Data Collection

During data collection, self-completion questionnaires were administered to respondents using three different strategies which involved One-to one contact, Group or mass contact with the aid of RISDA staff/extension officers and/or using the method of “Drop off and collect” as suggested by Brown, (1987). Most of the previous researches or investigations have also used the method of “drop off and collect” during questionnaire administration (Papadopoulos *et al* (1994), d’Astous and Ahmed (1999)). 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 and labour

### Analytical Techniques

The analytical technique for the study was in three folds viz: Free Disposal Hull (FDH), Expected Oder-m (EOM) and Conditional Oder- $\alpha$  (CO- $\alpha$ ).

Free Disposal Hull (FDH)

The FDH model as vigorously explained by Daraio and Simar (2007) in Advanced Robust and Non-Parametric Methods in Efficiency Analysis.

Let’s the efficiency points be

$$(x_0, y_0)$$

Let’s the sample  $\chi = \{(X_i Y_i), i = 1, \dots, n.\}$

Thus the FDH estimator is defined as follows:

$$\hat{\Psi}_{FDH} = \{(x, y) \in R_+^{p+q} | y \leq Y_i; x \geq X_i, (X_i Y_i) \in \chi\}$$

$$\hat{C}(y) = \{x \in R_+^p | (x, y) \in \hat{\Psi}_{FDH}\}$$

$$\hat{P}(x) = \{y \in R_+^q | (x, y) \in \hat{\Psi}_{FDH}\} =$$

$$\partial \hat{C}(y) = \{x | x \in \hat{C}(y); \theta x \notin \hat{C}(y) \forall 0 < \theta < 1\},$$

$$\partial \hat{P}(x) = \{y | y \in \hat{P}(x); \lambda y \notin \hat{P}(x) \forall \lambda > 1\}.$$

Therefore, the scores for input efficiency for two given points  $(x_0, y_0) \in \Psi$  is given below:

$$\hat{\theta}_{FDH}(x_0, y_0) = \inf\{\theta | \theta x_0 \in \hat{C}(y_0)\}$$

$$= \inf\{\theta | (\theta x_0, y_0) \in \hat{\Psi}_{FDH}\},$$

While that of output efficiency is as displayed below:

$$\hat{\lambda}_{FDH}(x_0, y_0) = \text{Sup}\{\lambda | \lambda y_0 \in \hat{P}(x_0)\}$$

$$= \text{Sup}\{\lambda | (x_0, \lambda y_0) \in \hat{\Psi}_{FDH}\},$$

Apart from the FDH estimator model shown above, it can also be expressed as shown

$$\hat{\Psi}_{FDH} = \left\{ (x, y) \in R_+^{p+q} \left| \begin{array}{l} y \leq \sum_{i=1}^n \gamma_i Y_i; x \geq \sum_{i=1}^n \gamma_i X_i, \sum_{i=1}^n \gamma_i = 1; \\ \gamma_i \in \{0,1\}, i = 1, \dots, n \end{array} \right. \right\}$$

Therefore, by using the integer linear programs below, would be used to estimate the efficiencies of both the input and output oriented cases. Regarding the input-orientation, the linear programs are:

$$\hat{\theta}_{FDH}(x_0, y_0) = \min \left\{ \theta \mid \begin{array}{l} y_0 \leq \sum_{i=1}^n \gamma_i Y_i; \theta x_0 \geq \sum_{i=1}^n \gamma_i X_i, \sum_{i=1}^n \gamma_i = 1; \\ \gamma_i \in \{0,1\}, i = 1, \dots, n \end{array} \right\}$$

While that of the output orientations is as shown below:

$$\hat{\lambda}_{FDH}(x_0, y_0) = \max \left\{ \lambda \mid \begin{array}{l} \lambda y_0 \leq \sum_{i=1}^n \gamma_i Y_i; x_0 \geq \sum_{i=1}^n \gamma_i X_i, \sum_{i=1}^n \gamma_i = 1; \\ \gamma_i \in \{0,1\}, i = 1, \dots, n \end{array} \right\}$$

### Expected Oder-M Frontier Analysis

An expected Order-m efficiency estimator is derived as shown below.

Input oriented derivation

$$\begin{aligned} \phi_m &= E[(X^1, \dots, X^m)] = \int_0^\infty [S_x(x)]^m dx. \\ \phi_m(y) &= E\{\min(X^1, \dots, X^m) | Y \geq y\} = \int_0^\infty [S_x(x|y)]^m dx. \\ \phi_{m,n}(y) &= E\{\min(X^1, \dots, X^m) | Y \geq y\}, \\ \phi_m(y) &= \int_0^\infty [S_x(x|y)]^m dx \end{aligned}$$

Output oriented derivation

$$\Psi_m(x) = E\{\text{Max}(Y^1, \dots, Y^m) | X \leq x\} = \int_0^\infty (1 - [F_c(y|x)]^m) dy.$$

The expression  $\Psi_m(x)$  as shown above, has its non-parametric estimator as

$$\Psi_{m,n}(x) = E\{\text{Max}(Y^1, \dots, Y^m) | X \leq x\}$$

And since its unknown, it can be expressed when the unknown population distribution is replaced by empirical distribution function and thus may be computed as

$$\Psi_{m,n}(x) = \int_0^\infty (1 - [F_c(y|x)]^m) dy.$$

### Conditional Oder- $\alpha$ Efficiency Estimator

The Oder- $\alpha$  estimator are as displayed below.

The  $\alpha$ -Quantile input efficiency score for  $(x, y) \in \Psi$  is defined as follows

$$\theta_\alpha(x, y) = \inf\{\theta | F_{X/Y}(\theta x | y) \tau > 1 - \alpha\} \dots\dots a$$

While that of output efficiency score for  $(x, y) \in \Psi$  is as shown below

$$\lambda_\alpha(x, y) = \text{Sup}\{\lambda | S_{Y/X}(\lambda y | x) \tau > 1 - \alpha\} \dots\dots b$$

The Estimator of the  $\alpha$ -Quantile efficiency score is generated by replacing or plugging  $\hat{H}XY_m(x, y)$  in each of the above two formulae for the input and output case respectively.

Plugging the empirical  $\hat{H}XY_m(x, y)$ , we have:

$$\hat{H}XY_m(x, y) = \inf\{\theta | F_{X/Y}(\theta x | y) \tau > 1 - \alpha\} \dots\dots c$$

$$\hat{H}XY_m(x, y) = \text{Sup}\{\lambda | S_{Y/X}(\lambda y | x) \tau > 1 - \alpha\} \dots d$$

## 6. Results And Discussions

### Frequency and Percentages of Free Disposal Hull (FDH) Scores

Table 1 presents range of efficiency scores measured using a relaxed convexity technique known as FDH. The result of the FDH has shown that all the rubber farms were technically efficient with 100% efficiency. The mean Technical efficiency under all the age categories, were found to be 1.0 and all the farms, regardless of age-groups, are found on the production frontier.

Table 1: Free Disposal Hull (FDH) Efficiency Scores

T.E Range	All crops	Matured crop	Old crops
< 0.2	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	0(0.00)	0(0.00)	0(0.00)
0.51-0.60	0(0.00)	0(0.00)	0(0.00)
0.61-0.70	0(0.00)	0(0.00)	0(0.00)
0.71-0.80	0(0.00)	0(0.00)	0(0.00)
0.81-0.90	0(0.00)	0(0.00)	0(0.00)
0.91-0.99	0(0.00)	0(0.00)	0(0.00)
1	307(100)	206(100)	101(100)
Summary			
Mean	1.00	1.00	1.00
S.D	1.00	1.00	1.00
Max	1.00	1.00	1.00

Source: Field Survey (2015)

Figure 2 envelops the technical efficiency graph of all-age, matured-age and old-age categories of rubber smallholders using Free Disposal Hull approach. The figure specifically indicated that all the bars are clustered on a scale of 1.00. This translates that the bars representing the number of farms of the all-age, matured-age and old-age categories are having magnitude of 307, 206 and 101 respectively. All the farms are 100% efficient. That is they are all concentrated on the production frontier.

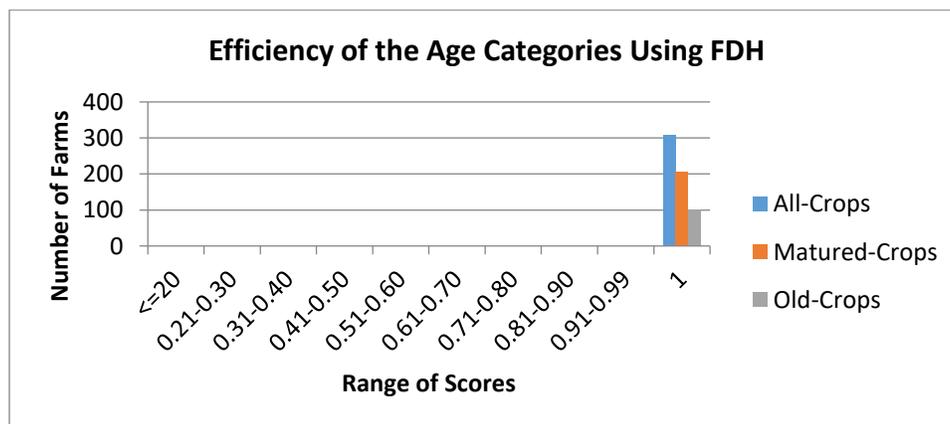


Figure 2: TE of Rubber Age Categories Using FDH

### Frequency and Percentages of CO- $\alpha$ Efficiency Scores

Table 2 presents the technical efficiency scores measured using Conditional Order-alpha ( $\alpha$ ) efficiency. The mean TE as measured by order-alpha is found to be 0.89 and 0.90 under matured-age group and old-age group respectively. The mean T.E when a whole sum data (n=307) was used, it was also found to be 0.89. Ninety nine (39) farms (12.70%) of the all-age category farm was technically efficient. While under both matured-age and old-age categories, 20 farms each was found to be on the production frontier. One hundred and fifty (150) rubber farms under

matured-age category were found to have score range of 0.90-0.91 as against 53 rubber farms under old-age group. About 10 farms were found to have recorded low efficiency scores under all the age groups.

Table 2: Conditional Order Alpha ( $\alpha$ ) Efficiency Scores

T.E Range	All crops	Matured crops	Old crops
< 0.2	3(0.98)	2(0.98)	1(0.99)
0.21-0.30	3(0.98)	2(0.98)	0(0)
0.31-0.40	3(0.98)	2(0.98)	1(0.99)
0.41-0.50	5(1.62)	3(1.46)	2(1.98)
0.51-0.60	7(2.28)	4(1.94)	2(1.98)
0.61-0.70	11(3.58)	8(3.9)	3(2.97)
0.71-0.80	18(5.86)	12(5.8)	7(6.93)
0.81-0.90	46(14.98)	33(16.1)	12(11.90)
0.91-0.99	172(56.03)	120(58.3)	53(52.48)
1	39(12.70)	20(9.71)	20(19.8)
Summary			
Mean	0.89	0.89	0.90
S.D	0.16	0.16	0.15
Max	1.00	1.00	1.00
Min	0.06	0.09	0.17

Source: Field Survey (2015)

Figure 3 encloses technical efficiency chart for the all-age, matured-age and old-age rubber categories using Conditional Oder-Alpha method. The blue-coloured bars represent the all-age crops, the red-coloured bars represent the matured-age crops and the green-coloured bars represent the old-age crops. The figure indicated that higher bars on 0.91-0.99 scale range while average-height bars are on the scale range of 0.81-0.90. Also reflected in the figure, is the number of bars on the 1.00 efficiency. Theses bars include 40 for all-age category, 20 for each of matured and old-age categories.

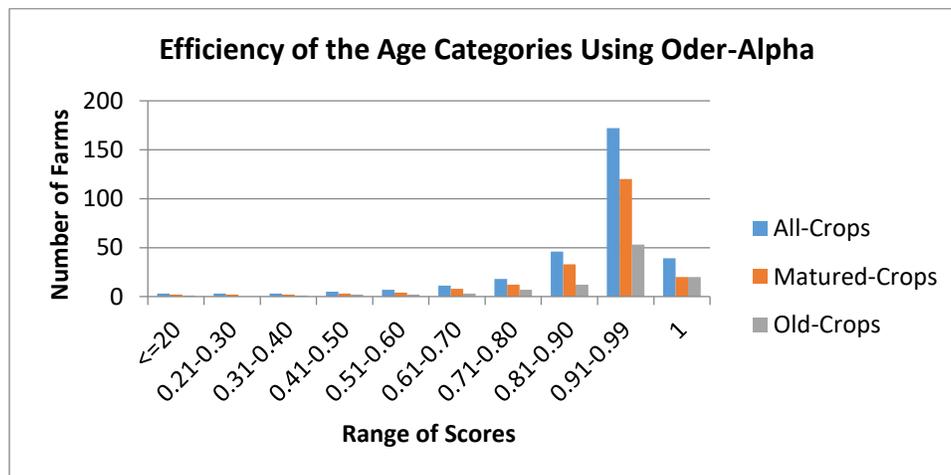


Figure 3: TE of Rubber Age Categories Using Oder-Alpha.

### Frequency and Percentages of EOM Scores

Summary of the Technical efficiency scores measured using a technique known as Expected order-M, was presented in table 3. A careful observations of the table revealed that all the rubber farms have efficiency score s more than 0.8 or 80%. The Mean technical efficiency was found to be 0.96, 0.97 and 0.98 respectively under all-age, mature-age and old-age categories. Their standard deviations were 0.04, 0.03 and 0.03 respectively. About eighty (80) rubber farms were on the production frontier under matured-age category, while old-age category has 53 farms that are regarded as technically efficient farms. On all-age category analysis, we obtain 88 (28.67%) farms on the production frontier.

Table 3: Expected Order-M efficiency scores.

T.E Range	All crops	Matured crops	Old crops
< 0.2	1(0.33)	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	0(0.00)	0(0.00)	0(0.00)
0.51-0.60	0(0.00)	0(0.00)	0(0.00)
0.61-0.70	0(0.00)	0(0.00)	0(0.00)
0.71-0.80	0(0.00)	0(0.00)	0(0.00)
0.81-0.90	42(13.68)	14(6.8)	3(2.9)
0.91-0.99	176(57.33)	111(53.9)	45(44.6)
1	88(28.67)	81(39.3)	53(52.5)
Summary			
Mean	0.96	0.97	0.98
S.D	0.04	0.03	0.03
Max	1.00	1.00	1.00
Min	0.84	0.87	0.89

Source: Field Survey (2015)

Figure 4 below corralled the technical efficiencies of all-age, matured-age and old-age categories using an Expected Oder-M frontier approach. The figure clearly showed that most bars are tied down along the high efficiency score ranges of 0.91-0.99 and 1.00. This is an indication that farms have very good efficiency scores. In fact more than 85 farms for all-age, 80 farms for matured-age and more than 50 farms for old-age categories are on the production frontier.

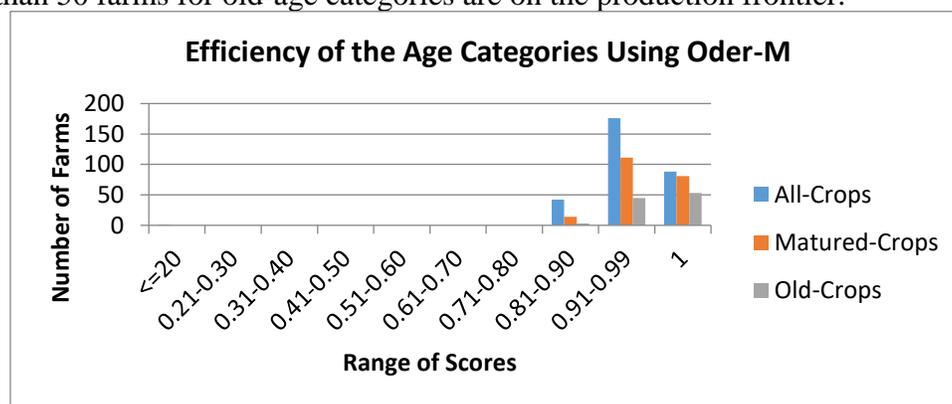


Figure 4: TE of Rubber Age Categories Using Expected Oder-M.

### Statistical Test for Hypothesis of all the Farms under Different Techniques

Table 5 composed of three (3) different pairs of hypothesis test for mean difference between the frontiers methods of FDH, Oder-m and Oder- $\alpha$

The 3 different hypotheses test including the following

- 1) Ho:  $\delta\text{FDH} = \delta\text{Oder-}\alpha = 0$
- 2) Ho:  $\delta\text{FDH} = \delta\text{Oder-m} = 0$
- 3) Ho:  $\delta\text{Oder-}\alpha = \delta\text{Oder-m} = 0$

The first Hypothesis test which was between the mean TE of FDH and mean TE of Order-Alpha, were subjected under paired t-test and the results revealed that the two means are different. The mean TE of FDH is greater than the mean TE of Order-alpha (i.e 1.00 as against 0.89). The reason for higher FDH could still be surrounded the possession of relaxed convexity nature of FDH, unlike Order-alpha. When mean TE of FDH and that of Order-M in the ninth hypothesis were tested, it was found that they are statistically not the same. It was revealed that mean TE of FDH is statistically greater than that of Order-M efficiency. The last but not the least was the tenth hypothesis between Order-Alpha and Order-M techniques. Order-M and Order-alpha efficiencies were also subjected under paired mean variations t-test, and the results indicated that the two means were statistically different from each other. The results clearly indicated that Order-M (0.96) is statistically greater than mean TE of Order-alpha.

Table 5: Hypothesis between Various Techniques Used in the Study

Hypothesis	Group	Mean	S.D	SE	T-ratio	Decision
	te-FDH	1.00	0.00	0.00		
Ho:Diff=0					(12.091)***	Reject Ho
	te-OD- $\alpha$	0.89	0.16	0.01		
	te-FDH	1.00	0.00	0.00		
Ho:Diff=0					(18.22)***	Reject Ho
	te-ODM	0.96	0.04	0.00		
	te-OD- $\alpha$	0.89	0.16	0.01		
Ho:Diff=0					(-9.387)***	Reject Ho
	te-ODM	0.96	0.04	0.00		

Source: Field Survey (2015)

Note:

1% level of significance = \*\*\*

5% level of significance = \*\*

10% level of significance = \*

## 7. Conclusion and Recommendation

The mean technical efficiency of all-age, matured-age and old-age crops under FDH are 1.00, 1.00 and 1.00 while that of Conditional Order-Alpha are 0.89, 0.89 and 0.90 respectively. The mean technical efficiency scores for the 3 age-categories under expected Oder-M are 0.96, 0.97 and 0.98 respectively for the all-age, matured-age and old-age crops categories respectively. The percentages of rubber crop farms that are on the FDH production frontier are 100%, 100%, and

100% while under Order Alpha ( $\alpha$ ) were 13%, 10 and 20%. The ones under expected order-m were 29%, 39% and 52% respectively for all-age, matured-age and old-age categories.

The mean TE of FDH and mean TE of Order-Alpha were subjected under paired t-test and the results revealed that the two means are different. It was revealed that mean TE of FDH is statistically greater than that of Order-M efficiency. Order- M and Order-alpha efficiencies were also subjected under paired mean variations t-test, and the results indicated that the two means were statistically different from each other. Expected Order-M was found to be statistically higher in magnitude than its counterpart Conditional Order Alpha.

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