Determinants of Technical Efficiency Among Coconut Smallholder Production in Johor, Malaysia: A Cobb Douglas Stochastic Frontier Production Approach

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Abstract. This study highlights technical efficiency of crop production as an important aspect of pursuing output growth in agriculture and smallholders’ farming. Using a randomly selected sample of 152 smallholder coconut in Johor, Malaysia, a stochastic frontier production model was applied, using Cobb–Douglas production function to determine the production elasticity coefficients of inputs, technical efficiency and the determinants of efficiency. The study reveals that coconut production responds positively to increases in fertilizers, fungicides and the area planted. The study also found that transportation, education and experience were the significant determinants of technical efficiency. The technical efficiency analysis suggests that about 60% of smallholders in the sample are below 70% efficient and suggesting that opportunities still exist for increasing technical efficiency among smallholders through better use of existing resources and technology. The results highlight some recommendations in improving efficiency by promoting access to productive resources, education and more reliable transportation systems.

Keywords: Stochastic Frontier Analysis; Productivity; Fertilizers; Fungicides

1. Introduction
The plantation industry plays an integral role in the economy, considering that a vast majority of growers are small and marginal smallholders which may impact the livelihood of around 80,000 growers and an equal number of labours who depend on the plantations for permanent employment. The industry, together with other sectors in agriculture are crucial for economic growth and development, poverty alleviation, sustainable environment and food security. To date, agriculture remains the third engine growth to Malaysian economy with a significance of 8.2% of the Gross Domestic Products and contributed about 13.5% to export earnings in 2017. The composition of agricultural crops can be divided into two categories which are plantation crops (including palm oil, rubber, coconut, cocoa, tea) and food crops which are mainly paddy, vegetables, fruits, ruminants, fisheries and others.

*Cocos nucifera L* is the scientific name for coconut palm and it is called as a ‘Tree of Life’ due to its various uses and purposes. Coconut leaves were usually used for roofing and mats, while the trunk of coconut can provide wood for furniture. Besides that, coconut oil was popular for making cooking oil, virgin coconut oil and soap for human uses. The coconut industry has supported many byproduct industries as well as rural livelihoods. The coconut fiber (obtained from husk) production, for example, could be used for rope while charcoal could be produced from the shell. The crop can produce any product such as food, non-food and for agriculture. Products food from coconut are desiccated milk, milk powder and other product that can be used for cooking and drinking [1].
It is noted that coconut processing has become one of the important downstream activities that contributes to the agricultural sector and supports economic activities in Malaysia. Coconut is a multiuse crop that can produce many downstream products such as coconut coir that are commonly used for car parts. The components such as floorboard and an interior door covers on cars are the new and latest technology that are mainly produced from coconut fibre. Coconut fibre have been used to replace synthetic fibres in compression moulded composites [2].

Malaysia strands 11th in term of the production of coconut worldwide, and coconut ranked 4th in the country as a major industrial crop after oil palm, paddy and rubber. The total of coconut production in Malaysia, is mainly for domestic consumption which accounts 63% and the balance of 37% are mainly for exports and industry processing. Over 90% of coconut farm are classified as smallholders that usually own under one hectare. Coconut areas under the smallholding can be mostly found in Peninsular Malaysia, followed by Sabah and Sarawak which were consisted of between 90,000 to 100,000 families [3]. According to the Food and Agricultural Organization of the United Nations (FAO), Malaysia has produced about 555,120 tons of coconut per year. Malaysia has progressively increased production of coconut for local and international markets. In 2010, the country’s production of coconut was 550,140 metric tonnes and in 2013, it then increased to 624,152 metric tonnes before it remained stable at 550,00 metric tonnes in the following years.

**Table 1.** Distribution of Coconut Production of Selected Countries by Ranking from 2010 until 2016 (in Metric Tonnes)

| RANKING | COUNTRY       | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  |
|---------|---------------|-------|-------|-------|-------|-------|-------|-------|
| 1       | Indonesia     | 1.8   | 1.75  | 1.94  | 1.83  | 1.83  | 1.66  | 1.77  |
| 2       | Philippines   | 1.55  | 1.52  | 1.58  | 1.53  | 1.46  | 1.47  | 1.38  |
| 3       | India         | 1.08  | 1.02  | 1.05  | 1.19  | 1.1   | 1.12  | 1.11  |
| 4       | Brazil        | 0.28  | 0.29  | 0.29  | 0.28  | 0.29  | 0.26  | 0.26  |
| 5       | Sri Lanka     | 0.19  | 0.2   | 0.22  | 0.25  | 0.28  | 0.28  | 0.25  |
| 6       | Thailand      | 0.12  | 0.015 | 0.10  | 0.10  | 0.10  | 0.09  | 0.081 |
| 7       | Papua New Guinea | 0.12 | 0.089 | 0.12  | 0.12  | 0.11  | 0.11  | 0.11  |
| 8       | Vietnam       | 0.11  | 0.12  | 0.12  | 0.13  | 0.13  | 0.14  | 0.14  |
| 9       | Mexico        | 0.11  | 0.11  | 0.11  | 0.11  | 0.11  | 0.11  | 0.11  |
| 10      | Tanzania      | 0.057 | 0.055 | 0.052 | 0.053 | 0.054 | 0.055 | 0.055 |
| 11      | Malaysia      | 0.055 | 0.056 | 0.062 | 0.062 | 0.059 | 0.05  | 0.05  |
| 12      | Myanmar       | 0.0428| 0.042 | 0.049 | 0.051 | 0.05  | 0.051 | 0.053 |

Source: Food and Agriculture Organization of the United Nation (FAO) (2010-2016)

In Malaysia, although contribution of smallholders in plantation sector is significant, they however, constitute the lower income groups and face production inefficiency due to uneconomic size of land, fluctuation in price of commodities, increasing cost of production and enduring low productivity and income [4]. The success of coconut plantation was rather limited and many suffered from multiple problems including low yielding variety of coconut, limited seedlings, weak links to markets, low price and labour problems. Labour shortages in parts of Malaysia, Indonesia and Thailand have resulted in the increase of idle agriculture land, a rise in land prices and a conversion of land use or crops [5] [6].

[3] stated that coconut processing in Malaysia has low supply of raw materials which leads to low production of coconut. These include coconut oil and non-edible material such as wood, shell and husks materials. To consistently meet the demand of coconut production, Malaysia has to increasingly import raw supply and reduce its exports for coconut product due to lack of material supply [7].

It was found that lack of infrastructure development between urban and rural area is another challenge in the coconut sector. According to [8] the mobility in rural area usually faced with poor transportation, infrastructure and logistics. Lack of transportation has affected marketing channel and long-term productivity of output. The length and time of the journey will affect cost of transportation
and efficiency of marketing channel. Additionally, smallholders with limited access to physical infrastructure and financial resources may restrict their abilities to expand and adopt new technologies that can increase their efficiency and add value to their production [9]. Many smallholders have limited technical skills to improve their production practices due to lower access to information and markets.

Until recently, there has been a growing focus by Malaysian government to improve agricultural production and improvements on modern technologies [10]. Although efforts to improve production have been widely promoted, there has been a declining trend in coconut production (refer to Table 1). Targeting at improving the efficiency of inefficient smallholders are therefore important rather than only focusing on improvement of technologies. Theoretically, agricultural productivity and production can be improved by introducing new and modern technologies. However, in areas where inefficiency occurs due to existing inputs and technologies are not efficiently utilized, trying to introduce new technologies may not provide results as expected. Apparently, the level of smallholders’ technical efficiency has substantial implications for the country’s agricultural development strategy [11].

[12] defined technical efficiency (TE) as the ability of a firm using a minimum input with minimum cost to produce maximum of output. In contrast, [13] mentioned that technical inefficiency would occur when producer or production had overused all the inputs. The stochastic frontier approach is preferred when assessing agricultural efficiency because of the inherent stochasticity involved [14].

Stochastic Frontier Analysis (SFA) method allows growth changing input used, changes in technology and change in efficiency. SFA method makes the assumption of data and impose of functional production. SFA will determine the level of efficiency of data and the usefulness of each source in the data. In addition, SFA will identify each of source which include inefficiency and error data. In most cases, SFA models commonly employ the functional forms of Cobb Douglas and translog production function [15].

Given the importance of coconut in view of their domestic consumption, export potential, income generation and livelihoods of many smallholders as well as poverty alleviation, it is therefore imperative to empirically analyse the relationship between technical efficiency and socio-economic variables among coconut smallholders. Yet, empirical evidences on the farm level of technical efficiency in coconut production is limited and knowledge of smallholders’ production situations are scanty particularly in Malaysia.

Therefore, our study fills this gap in the literature of efficiency, based on its technical component and on some important variables used to explain technical efficiency. Determining the existing level of efficiency will be useful to improve technical efficiency of smallholders to better allocate their resources and also to assist the government in designing and searching for new policy tools to specifically target to the sector-specific scenario. Furthermore, such analysis will help formulating effective agricultural policies that aimed at improving the welfare and income of smallholders. By undertaking empirical works on farm level technical efficiency, the results will further guide food security developments and enhance agricultural productivity, improve the critical factors that impede productivity as well as enhance smallholders’ livelihoods.

2. Materials and Methods
The study was conducted in Batu Pahat, a district in the state of Johor in Peninsular Malaysia. The reason why Batu Pahat has been chosen due its largest production of coconut in Johor and its highest contribution in the production of coconut by smallholders. The total production by smallholders in Batu Pahat was about 43 644 mt [16]. The samples were taken from three districts in Batu Pahat, which were Peserai, Parit Raja and Rengit. The total population of smallholders was approximately 341 involved in the coconut industry, according to the Department of Agriculture in Batu Pahat. Peserai, Rengit and Parit Raja were the total population from three areas of Batu Pahat. The sample size is 152 given the population of smallholders of coconuts in Batu Pahat by using a survey random sampling. The data for this study were obtained through a household survey that was conducted in March until May, 2019.

The main instrument for the data collection was a structured questionnaire and face to face interview. The questionnaire was divided into several sections, which consisted of socio-demographics section and
the costs of inputs for coconut production such as fertilizer, fungicide, planting area, cost of labour and cost of transportations.

The Stochastic Frontier Analysis (SFA) production function was used to estimate the technical efficiency of coconut production in Johor, Malaysia. SFA was introduced by [17] and estimation of the technical efficiency and stochastic model independently was formulated by [18] and [19]. SFA is an econometric and parametric model. The approach is stochastic as it considers adding a random variable. SFA treats deviations from production function as both random error (or noise) and inefficiency. This would allow us to make a distinction between a random component which accounts for measurement errors and stochastic effects (for example weather or climate change) and a deviation component which represents the inefficiency. The general form of the SFA by [20] and the production frontier stated by [21] for the panel data is represented as:

\[ \ln y_{it} = f(x_{it}; \beta) + e_{it} \]  

(1)

where \( f \) is a suitable functional form (e.g. Cobb-Douglas or Translog), \( y_{it} \) represents the output of the \( i \)-th (firm) at time \( t \), \( x_{it} \) is the corresponding level of input of the \( i \)-th (firm) at time \( t \), and \( \beta \) is a vector of unknown parameters to be estimated. The error term \( e_{it} \) can be composed of two elements:

\[ e_{it} = v_{it} - u_{it} \]  

(2)

where \( u_{it} \) is a nonnegative variable associated with technical inefficiency while \( v_{i} \) is a symmetric random error which accounts for statistical noise or unsystematic deviations from the frontier.

Further, we can estimate \( TE \) which is measured by the ratio of the observed output \( y_{it} \) (equation 1) to the maximum feasible output, \( y_{max} = \exp(x_{it}; \beta) \ast v_{it} \) in an appropriate environment. Using output-oriented measure of technical efficiency, the ratio of observed output to the corresponding stochastic frontier output can therefore be illustrated as:

\[ TE = \frac{y_{it}}{\exp(x_{it}; \beta) \ast \exp v_{it}} = \frac{\exp f(x_{it}; \beta \ast \exp v_{it}) \ast \exp(-u_{it})}{\exp f(x_{it}; \beta \ast \exp v_{it})} \]  

(3)

\[ TE = \exp(-u_{it}) \]  

(4)

As a parametric approach, SFA requires an assumption on a specific functional form, whereby the frontier is estimated econometrically using last squares or maximum likelihood [22]. The SFA is based on econometric regression model where the frontier is smooth and curved.

A production function model is required under SFA which includes Cobb-Douglas, CES, translog, generalised Leontief or normalised quadratic and its variants. However, the translog and the Cobb-Douglas production functions are the two most common functional forms which have been used in many empirical studies on production and frontier analyses [15].

Although there are different function forms of stochastic frontier, the data was fitted to Cobb Douglas production function using STATA15 application software. The empirical model of stochastic frontier Cobb Douglas production function in the analysis of technical efficiency of coconut production is specified as below:

\[ \ln y_{i} = \beta_{o} + \beta_{1} \ln x_{1} + \beta_{2} \ln x_{2} + \beta_{3} \ln x_{3} + v_{i} - u_{i} \]  

(5)

where, \( \ln \) is Denoted logarithms, \( Y_{i} \) is Output of coconut (nut) of the \( i \)-th smallholders, \( X_{1} \) is Planting area in acre, \( X_{2} \) is Quantity of fertilizer in kilogram, \( X_{3} \) is Quantity of fungicide in litre, \( V_{i} \) is Random variability in production that cannot be influenced by the smallholders, \( U_{i} \) is Deviation from maximum potential output attributable to technical inefficiency, \( \beta_{o} \) is Constant, and \( \beta_{1}, \beta_{2}, \beta_{3} \) is Vector of production function parameters to be estimated.

Identifying the determinants of efficiency is a major task within efficiency analysis. In order to determine factors contributing to the observed technical efficiency of coconut production in the study area, this study used the two-stage estimation procedure in which first the stochastic production function is estimated (as in Eq. 5), from which efficiency scores are derived, then in the second stage, the derived
efficiency scores are regressed on explanatory variables using ordinary least square (OLS) methods. The TE of \( i \)th farm on \( t \)th period is defined as:

\[
TE_i = a_0 + a_1Z_1 + a_2Z_2 + a_3Z_3 + a_4Z_4 + a_5Z_5 + a_6Z_6
\]

where, \( TE_i \) is Technical efficiency of the \( i \)th smallholders, \( Z_1 \) is Cost of transportation, \( Z_2 \) is Year of experience, \( Z_3 \) is Gender (1=male, 0=female), \( Z_4 \) is Secondary education, (0=primary education), \( Z_5 \) is Tertiary education, (0= primary education), \( Z_6 \)is Extension visits, \( a_0 \) is Constant, and \( a_1-a_6 \)is Estimated regression parameters.

3. Results and Discussion

3.1 Description of respondents

The findings of the socio-economic variables for coconut farmers indicate that the majority of farmers of coconut production in Batu Pahat are male which represent 77.6% while the other 22.4% are females (refer to Table 2). The complex harvesting tasks, which require a lot of energy, might be the deterrent for female smallholders to be involved in the activities [23].

The result also indicates that most of the smallholders in the Batu Pahat, which involved 114 respondents were between 50 years old and 69 years old, while another 3 aged between 19 and 29 years old. On the other hand, the oldest smallholders involved in the industry was aged around 70 to 79 years old. There were 27 smallholders who were 30 to 49 years old. Older people might not have the capability to be committed in this industry due to lack of energy and ability to perform heavy harvesting activities. According to [23], the heavy tasks are more appropriate for the younger people, who have more energy and are physically stronger.

| Variable          | Categories | Number of respondents | Percentage (%) |
|-------------------|------------|-----------------------|----------------|
| Gender            | Male       | 118                   | 77.6           |
|                   | Female     | 34                    | 22.4           |
| Age (years old)   | 19-29      | 3                     | 2.0            |
|                   | 30-49      | 27                    | 17.7           |
|                   | 50-69      | 114                   | 75.0           |
|                   | 70-79      | 8                     | 5.3            |
| Marital Status    | Married    | 151                   | 99.3           |
|                   | Single     | 1                      | 0.7            |
|                   | Separated  | 0                      | 0              |
| Education Level   | Primary    | 55                     | 36.2           |
|                   | Secondary  | 95                     | 62.5           |
|                   | University | 2                      | 1.3            |
| Race              | Malay      | 138                    | 90.8           |
|                   | Chinese    | 14                     | 9.2            |
|                   | Indian     | 0                      | 0              |
|                   | Others     | 0                      | 0              |
| Planting Mode     | Full time  | 143                    | 94             |
|                   | Part time  | 9                      | 6              |
| Experience (year) | 0-10       | 17                     | 11.2           |
|                   | 11-20      | 16                     | 10.5           |
|                   | 21-30      | 21                     | 13.8           |
|                   | 31-40      | 45                     | 29.6           |
|                   | 41-50      | 48                     | 31.6           |
|                   | More than 51 | 5                   | 3.3            |
The results also revealed that most of the smallholders were married. This is common as the age of the smallholders were in the range of between 19 and 79 years old. However, there was only one smallholder who was still single. Since most of them were married, there were about 4 to 6 members in their family. Most of the coconut smallholders possessed secondary education which accounted for 62.5% (95). The remaining 36.2% (55) of coconut smallholders had primary education and only 1.3% (2) of the coconut smallholders had completed university education. It indicates that smallholders with a professional background in education are more likely to accept new technologies adoption. The higher level of smallholder’s education, the more responsive smallholders to receive an innovation that was introduced by development and research agency.

The majority of the smallholders were Malays, 90.8% and only 9.2% were Chinese. Based on the table, it reveals that for the coconut industry, most smallholders were in full-time planting mode. The percentage of full-time respondents is 94.5% and part-time smallholders is 5.5%. Some of the part-time respondents worked as driver, administrative officer, accountant and lecturer. In addition, 31.6% of the smallholders had 41-50 years of experience or involvement in activities related to coconut industry. This is in line with the fact that most of the smallholders in the three villagers were moderate generation. As the activities were still being carried out in the locations under study, it was learned that the older generation had passed the knowledge related to coconut production activities to the younger generation so as to continue the tradition and satisfy the demand. About 11.2% smallholders had the experience of 1 to 10 years, and the lowest percentage was 3.3% with more than 51 years of experience. An average experience of respondents were 11 to 12 years and 21 to 30 years which were 10.50% and 13.8% respectively.

Besides that, the highest land size for the majority of smallholders were 1.0 to 2.0 acres which were 84 respondents. Only 1 smallholder had more than 7 acres of field size. The second highest of field size among smallholders in Batu Pahat were 50 respondents and only 17 smallholders had 3.0 to 6.0 acres field size of coconut. All the smallholders originated from Malaysia and 99.3% of smallholders owned their land holdings. Only one smallholder had a shared land. Majority of smallholders had 4 to 6 people in a household and only six (6) smallholders have 7 to 10 households.

### 3.2 Estimated Production function.

The Stochastic Frontier Analysis (SFA) estimates using Cobb-Douglas stochastic frontier parameter for coconut production are presented in Table 3. Hypothesis tests were conducted to select the functional form using the likelihood ratio (LR). The likelihood ratio tests (based on log likelihood values for Cobb-Douglas and Translog models) lead to acceptance of the null hypothesis that confirms Cobb-Douglas is an appropriate functional form (equation 5). Therefore, the empirical results show the estimation from only the Cobb-Douglas function which are reported in Table 3. The greatest elasticity observed is the planting area (0.419). This indicates that the greatest relationship exists between the production of the coconut and planting area. An additional increase in planting area will increase about 42% in production of coconut. Next, the production of fertilizer has the second highest elasticity which is 0.375, confirming its importance in the agriculture sector. In this case, an additional increase in kg of fertilizer, will enhance

| Field size  | 1.0 – 2.0 | 84    | 55.3 |
|-------------|-----------|-------|------|
|             | 3.0 – 4.0 | 50    | 32.9 |
|             | 5.0 – 6.0 | 17    | 11.2 |
|             | More than 7 | 1    | 0.6  |

| Nationality | Malaysian  | 152   | 100  |
|-------------|------------|-------|------|
|             | Non-Malaysian | 0   | 0    |

| Land Type  | Own        | 151   | 99.3 |
|------------|------------|-------|------|
|            | Sharing    | 1     | 0.7  |

| Number of Household | 1-3 | 61   | 40.1 |
|---------------------|-----|------|------|
|                     | 4-6 | 85   | 55.9 |
|                     | 7-10 | 6    | 4.0  |

Source: Field Survey (2019)
productivity by 38%. Lastly, assuming a positive elasticity in relation to the other relevant factors, the fungicide contributes the least to the productivity of coconut in which an increment of 1 litre of fungicide will increase production of coconut by 12%. The estimation of the ratio of the standard deviation of the inefficiency component to the standard deviation of the idiosyncratic components, $\lambda = \frac{\sigma_u}{\sigma_v}$, is labelled as lambda. The variability of the two sources of error (white noise disturbance and unilateral error) are calculated to estimate the parameter $\lambda = \frac{\sigma_u}{\sigma_v}$, which results in the value of 4.49e+0.7. This result means that there is about 4.49e+0.7 of total variance of the composed error of the production function can be explained by the variance, in term of technical inefficiency. This represents the importance of incorporating technical inefficiency in the production function.

| Table 3. Coconut Production Estimation Results of Cobb Douglass using Ordinary Least Square (OLS) |
|---------------------------------------------------------------|
| **Inproduction** | **Coefficient $\beta$** | **$z$** | **Standard error** |
| Constant | 7.390469*** | 7.0e+04 | 0.0001054 |
| Inplanting area/acre | 0.4186173*** | 4.6e+04 | 9.01e-06 |
| Infertilizer /kilogram | 0.3751274*** | 1.9e+04 | 0.0000198 |
| Infungicide /litre | 0.1160138*** | 6032.84 | 0.0000192 |
| $\ln \sigma_v^2$ | -35.46459 | -0.12 | 296.5403 |
| $\ln \sigma_u^2$ | -0.2262249 | -1.97 | 0.1147079 |
| $\sigma_v$ | 1.99e-08 | | 2.95e-06 |
| $\sigma_u$ | 0.8930502 | | 0.0512199 |
| $\sigma_v^2$ | 0.7975387 | | 0.091484 |
| $\lambda = \frac{\sigma_u}{\sigma_v}$ | 4.49e+0.7 | | 0.0512199 |
| Log likelihood | -93.27194 | | |
| likelihood-ratio test | 91.56 | | |
| p-value | 0.000 | | |

***Significant at 1% level; **Significant at 5% level; * Significant at 10% level

3.3 Sources of Technical Efficiency
The estimated determinants for the technical efficiency of coconut production activities are presented in Table 4. The transportation cost parameter indicates that technical efficiency increases when the transportation cost increases at 5% level of significance. The increment of 1% of the transportation or infrastructure cost will increase the technical efficiency for about 0.009824. The result indicates that if the smallholder is situated in a remote area, but has greater market access, this will lead to reduction of technical inefficiency. [24] as cited in [25] argued that more efficient farmers usually have to bear the high cost of transportation to purchase superior quality inputs even from distant markets and rely less on middlemen when they try to market their outputs. The use of better-quality inputs would naturally result in higher productivity than those farmers who relied on existing or common inputs from the dealers. Thus, it is more likely that such farmers are said to be more technically efficient. Moreover, farmers may gain higher and better price even marketing their produce in markets rather than selling to the middlemen or dealers.

| Table 4. Technical Efficiency Estimation Result |
|-----------------------------------------------|
| **Parameter** | **Coefficient $\beta$** | **$t$** | **Standard error** |
| Constant | $a_0$ | 5.93307*** | 6.11 | 0.9703193 |
| Transportation / RM | $Z_t$ | 0.0009824*** | 1.99 | 0.0004926 |
| Experience/years | $Z_2$ | 0.0198122*** | 4.84 | 0.0040973 |
| Secondary | $Z_3$ | 0.3296789* | 2.82 | 0.1169032 |
Besides that, the coefficient for experience by farmers was positive and highly significant at a 1% level. This implies than an increase in year of experience leads to increasing in technical efficiency. This is because experience farmers have well knowledge, leading to higher productivity and higher technical efficiency. The coefficient for education level was positive for secondary school while negative for university level. The secondary school has a statistically significant effect at a 10% level. This showed that smallholders who completed secondary school were more technically efficient than that primary level. This is as expected since more educated smallholders tend to work full-time on their fields and have better knowledge to adopt good agricultural practices. According to [26] smallholders that have higher education level have more opportunities in employment.

In addition, the next variable that affect the coconut production among the smallholders is the experience. The experience variable has a positive coefficient and strong statistical significant. A positive experience will give positive impact to the decision-making process among the smallholders. Majority of the smallholders have more experiences, which ensure that most of them to possess good knowledge about the coconut production. The increase of 1% of the experience of the smallholders will increase the coconut production for about 0.02.

The frequency distributions for technical efficiency are presented in Table 5. The distribution of the technical efficiency scores ranges from 0.10 to 0.99. About 52% of the smallholder farmers have technical efficiency scores between 0.20 and 0.69. While 32.3% of the coconut smallholders were found to have technical efficiency greater than 80%. The mean level of technical efficiency for the sample of smallholder farmers is 0.60 (60%), with a standard deviation of 0.2687. This implies that, on the average, smallholders could only achieve about 60% of the potential maximum output from a given production inputs. These results suggest that coconut smallholders are constrained by a number of factors, such as low experience and technical knowledge, less extension, higher transportation costs, smaller farm sizes (about 1-2 ha on average), relatively large household sizes (about 4-6 on average), and low agricultural potential in some areas. The potential for increasing the average efficiency among smallholders in the area is significant, at 40%. This would require improving farmer-specific efficiency factors by improving the ways in which resources are used at the farm level.

### Table 5: Frequency Distribution and Technical Efficiency Indices

| Technical Efficiency | Frequency | % |
|----------------------|-----------|---|
| 0.00-0.09            | 2         | 1.3 |
| 0.10-0.19            | 10        | 6.6 |
| 0.20-0.29            | 31        | 20.4 |
| 0.30-0.39            | 0         | 0   |
| 0.40-0.49            | 0         | 0   |
| 0.50-0.59            | 19        | 12.5|
| 0.60-0.69            | 29        | 19.1|
| 0.70-0.79            | 12        | 7.9 |
| 0.80-0.89            | 27        | 17.8|
| 0.90-1.00            | 22        | 14.5|
| Total                | 152       | 100 |
4. Conclusions

This study has analysed the determinants of technical efficiency among smallholder coconut farmers in Batu Pahat, Johor, Malaysia. The quantity of fertilizer applied, the use of fungicides, and the land area allocated to coconut production have positive effects on output, and their coefficients are statistically significant at 1% respectively. The study found that the most important factors that are positively associated with technical efficiency levels are transportation, experience of smallholders and education level. The results show that these coconut smallholders are not fully technically efficient. The mean level of technical efficiency for the sample of smallholder farmers is 0.60 (60%), with a standard deviation of 0.2687. The policy implications of these findings are that technical efficiency in smallholder coconut production could be increased by 40% on average through better use of available resources (e.g. land, fertiliser, fungicides), given the current state of technology. This could be achieved through improving farmer-specific efficiency factors, which include better and more frequent extension services by providing technical knowledge and education, attending seminars to ensure effective delivery and communication, and upgrading transportation or infrastructure as well as greater market access. Efficient extension services would improve crop management practices, for instance, by advising farmers on proper weeding regimes. More research and development (R&D) are needed to improve better quality harvesting and upgrading transportation as to help the smallholders to gain greater market access.

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