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Determinants of Technical Efficiency among Rubber Smallholders Production in Lipis, Pahang: a Cobb Douglas Stochastic Frontier Production Approach

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Abstract

This study highlights the technical efficiency of crop production as an important aspect of pursuing output growth in agriculture and smallholder farming. Using a randomly selected sample of 370 rubber smallholders in Lipis, Pahang, Malaysia, a stochastic frontier production model was applied, using the Cobb-Douglas production function to determine the production elasticity coefficients of inputs and technical and the determinants of efficiency. The study reveals that rubber production responds positively to an increase in fertilizers, planting areas, and tapping areas. The study also found that respondent status, land ownership status, and education (primary school) were significant determinants of technical efficiency. The technical efficiency analysis reveals that the current level of efficiency among rubber smallholders is about 70% and suggests that opportunities still exist for increasing technical efficiency among smallholders through better use of existing resources and technology. The results highlight some recommendations for improving efficiency through knowledgeable extension agents, good agricultural practices which are weeding and fertilizing, and good clones recommended by Malaysia Rubber Board should be selected.

Keywords: Stochastic Frontier Analysis, Productivity, Fertilizers, Planting Area, Tapping Area.

Introduction

The rubber industry began in the year 1878 with the first rubber tree planted in Kuala Kangsar, Perak. Therefore, it can be seen obviously that rubber production had been existing in the country for more than a century. It has become the backbone of the agricultural landscape in Malaysia and one of the key agricultural sectors which contributes to the nation's prosperities and Malaysia's gross domestic product (GDP) (RISDA, 2016). Since its establishment, Malaysia had been the third-biggest producer of natural rubber (NR) in the world and the rubber industry had produced a broad range of products from natural rubber to rubberwood products and superior quality which were widely used as a benchmark in the international market (Rubber Institute Smallholders Development Authority, 2016).

Over the years, the Malaysian government had invested heavily in research and development (R&D) in the rubber industry to develop innovative and new uses for its rubber (Rubber Institute Smallholders Development Authority, 2016). With the availability of quality raw materials, political stability, and modern infrastructure together with research and development (R&D) and support from the Malaysian Rubber Board (MRB) and the Tun Abdul Razak Research Centre (TARRC), Malaysia can remain a global player in rubber, supplying the world market with a wide range of rubber products. Malaysia is currently the world's fifth largest producer of NR after Thailand, Indonesia, Vietnam and China. The Malaysian rubber products industry is made up of more than 500 manufacturers producing latex products; tyres and tyre-related products; and industrial and general rubber products. The industries contributed 18.1 billion to the country's export earnings in 2011. Rubber products accounted for 3.9 percent of Malaysia's total exports for manufacturing products. The natural rubber-consuming industries for 2011 are latex products (80.3 percent), tyres (9.2 percent), general rubber products (7.2 percent), industrial rubber products (3.2 percent), and others (0.2 percent). The rapid growth of the industry had enabled Malaysia to become the world's largest consumer of natural rubber latex (Department of Statistics Malaysia, 2018).

Despite being among the top producers of rubber in the world, rubber production in Malaysia has shown a fluctuating growth since 2000 (Refer to Table 1). In 2010, the total natural rubber production stood at 882 thousand metric tonnes (MT) and exhibited a positive and increasing trend until the late 20s. However, this trend started to decline in 2010 in which Malaysia produced about 996 thousand MT of natural rubber and continued to register stable growth in the following year, before it gradually declined until 2015, increased again in 2015 and 2017, and finally showed a significant decline in 2018. Following this trend, during the first six months of 2018, rubber production declined by 18.5% to 361.3 thousand MT from 443.5 thousand MT in 2017. Natural rubber made up 79.5% of the total production of rubber in the first six months of 2018 with 287.1 thousand MT before it declined by almost 24% from 378.7 thousand MT in the corresponding period last year. The production of synthetic rubber, on the other hand, rose sharply by 33.4% to 39.7 thousand MT in the first three months of 2018 from 29.8 thousand MT in 2017 (Malaysian Rubber Export Promotion Council, 2018). Malaysia produced a total of 740,138 MT of natural rubber in 2017, of which only 5.2% or 38,600 MT were latex, while the remainder came from dry rubber (Malaysian Rubber Board, 2018).

Table 1
Natural Rubber Statistics in Malaysia, 2001-2018

Year	Production (Tonnes)		
	Dry	Latex	Total
2001	761,584	120,473	882,067
2002	775,334	114,498	889,932
2003	854,619	131,028	985,647
2004	960,841	207,894	1,168,735
2005	935,529	190,494	1,126,023
2006	1,073,698	209,934	1,283,632
2007	1,023,190	176,363	1,199,553
2008	918,656	153,709	1,072,365
2009	746,106	110,913	857,019
2010	846,813	92,428	996,210
2011	916,270	79,940	996,210
2012	846,813	75,985	922,798
2013	753,472	72,949	826,421
2014	598,608	70,005	668,613
2015	676,260	45,862	722,122
2016	628,219	45,294	673,513
2017	701,537	38,600	740,138

Source: Malaysian Rubber Board, 2018

In 2015, exports of natural rubber were 706,501 MT as compared to 900,770 MT in 2010 with an annual growth rate of -4.7 percent. Almost half of the natural rubber was exported to China at 49.3 percent. These were followed by Germany (12.8%), Iran (5.6%), the U.S.A. (5.1%), Brazil (2.4%), and other countries (24.8%). Malaysia imported 957,300 MT of natural rubber in 2015, mainly from Thailand (52.9%) and Vietnam (19.7%). On the other hand, the domestic consumption of natural rubber in 2015 was 474,773 MT. Malaysia remains the world's largest exporter of natural rubber for medical gloves, catheters, and latex thread. From the finished rubber products, rubber gloves were Malaysia's biggest export product. For example, the well-known producers of rubber gloves in Malaysia are Top Glove, Oon, Comfit, Profeel, Dermagrip, Supergloves, and RadiaXon. It was estimated that over 60% of the rubber glove market at the international level is dominated by the Malaysian rubber industry. In 2016, the major export destination of Malaysia's natural rubber was China with about 48.1 percent (Rubber Institute Smallholders Development Authority, 2016).

Several reasons lead to the variability of production and trade or imports and exports of rubber in Malaysia. These factors include the world price of natural rubber, the world price of synthetic rubber, and the exchange rate. The unstable growth of rubber production is greatly influenced by price volatility in the world market. Theoretically, the country would reduce their import if the price is high. The difference in the world price of synthetic rubber will likely increase the import. While if there is any appreciation value in the exchange rate, this will reduce the cost which later makes the import of goods lower and cheaper (Ludin *et al*., 2016).

For SITC-231 (Natural Rubber, Natural Gums, and in Primary Forms), China is the most potential market with a percentage of 92.49%. Portugal and Netherlands are 2nd and 3rd potential countries respectively for rubber export from Malaysia. Portugal's net percentage is 15.5% and the Netherlands is 20.2%. As for SITC-232 (Synthetic Rubber, Reclaimed Rubber, Waste, Parings and Scrap of Unhardened Rubber), Thailand is the most potential market for the Malaysian rubber exporter with 43.14%, followed by Sri Lanka and Indonesia. Sri Lanka and Indonesia's net shares are 29% and 12.80% respectively. Although Malaysia exports huge volumes to different countries, it is facing huge competition from other South East Asian countries. They should maintain the specific standard for each type of rubber quality and features so that they can carry on the export and at the same time explore more to determine eligible candidates for Malaysian rubber export (Rahman et al. 2009).

The latex products sub-sector was the largest sub-sector within the rubber products industry and comprises 125 manufacturers producing gloves, condoms, catheters, latex thread, and others. This sub-sector accounted for 81 percent of the rubber total value of exports, largely contributed by gloves, catheters, and latex threads. Malaysia continued to maintain its position as the world's leading producer and exporter of catheters, latex threads, and natural rubber medical gloves. There were currently 120 companies in the tyres and tyre-related products sub-sector comprising nine tyre producers while the remaining companies produce retreads, tyre treads for retreading, valves, and other accessories. There were three major tyre producers producing passenger car tyres, commercial vehicle tyres and earthmover tyres, and another nine manufacturing other types of tyres (Rubber Institute Smallholders Development Authority, 2016).

The smallholding sector was the main contributor to the production of natural rubber at 665,301 MT or 92.1 percent of the total production while the rest of 7.9 percent was from the estate sector (Rubber Institute Smallholders Development Authority, 2016). The rubber planted areas in 2015 were registered at 995,733 hectares. A large percentage of rubber planted area was owned by the smallholding sector which covered about 919,901 hectares (92.4%) while 75,832 hectares (7.6%) were from the estate sector. Similarly, rubber plantation is a prominent crop of considerable significance to the Malaysian economy. Until 2017, Malaysia is the fifth largest producer and exporter of natural rubber. Malaysia is the leader in the production and export of rubber products. Malaysia accounts for 46 percent of the world's total rubber production and produces roughly 1-5 million tons of rubber annually. The rubber estate consists of 1.07 million hectares, of which plantation companies represent about 7.21 percent while 90 percent of production is calculated by smallholders who generally hold less than 40 acres of agricultural land. These statistics remain a major concern for the industry as these smallholders tend to move to other economic activities when rubber prices go down (Jeffrey et al.2018).

Nowadays, rubber tappers are only led by the elderly while the young generations are more likely to work in the city because of their lucrative pay. Therefore, the production of rubber decreases from time to time. Malaysia is also competing with other neighboring countries such as Thailand and Indonesia. To date, Malaysia is in the fifth ranking in the world in rubber production (LGM, 2018). To ensure the development and assist the modernization of the rubber industry in Malaysia, several agencies have been introduced including the Malaysian Rubber Board (MRB), Rubber Industry Smallholders Development Authority (RISDA), and other related agencies and research institutes. The research and development excellence in natural rubber, accomplished by the Rubber Research Institute Malaysia (RRIM), had an impact on the Malaysian NR industry and other NR-producing countries. The Malaysian Rubber Board (MRB) is the custodian of the rubber industry in Malaysia. Established on 1 January 1998, it had under its fold three well-established agencies (RRIM, MRRDB, and MRELB), which are now merged into one, and had contributed significantly to the development of the rubber industries for the last 78 years. The primary objective of MRB was to assist in the development and modernisation of the Malaysian rubber industry in all aspects from the cultivation of the rubber tree, the extraction and processing of its raw rubber, manufacture of the rubber products, and the marketing of rubber and rubber products (Malaysian Rubber Board, 2018).

The yield achievement target initiated by MRB's initiatives is to improve national productivity to 2,000 kg/ha/year which is in line with what Malaysia's National Key Economic Area (NKEA) wants to achieve in 2020 (Malaysian Rubber Board, 2018). The fundamental reason for considering the productivity achievement target in the inefficiency model is to find out whether such a target could motivate rubber smallholders to increase their yield above the average productivity of their counterparts (Mustapha et al. 2011).

Materials and Methods

The study was conducted in Lipis, a district in the state of Pahang in Peninsular Malaysia. The reason why Lipis has been chosen is due to its highest contribution to the production of rubber by smallholders in Pahang. The samples were taken from eight districts in Lipis, which were Benta, Cheka, Jalai, Jelai, Kuala Lipis, Padang Tengku, Penjom and Ulu Jelai.The total number of rubber smallholders involved in the rubber industry in Lipis was approximately 10,500 according to the Malaysian Rubber Board (MRB). The sample size is 370 based on the population of rubber smallholders in Lipis and the sampling was conducted by using a simple random sampling. The data for this study were obtained through a household survey that was conducted from June until December 2020.

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 a socio-demographics section, the costs of inputs for rubber production such as fertilizer, fungicide, planting area and cost of labour, and the last section are factors that contribute to the production.

The Stochastic Frontier Analysis (SFA) production function was used to estimate the technical efficiency of rubber production in Lipis, Pahang. SFA was introduced by Aigner, 1977 and Meeusen, 1977. 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 that accounts for measurement errors and stochastic effects (for example weather or climate change) and a deviation component that represents the inefficiency. The general form of the SFA by (Aigner *et al*., 1977) and the production frontier stated by (Coelli *et al*., 1998) 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 β 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_i is a non-negative variable associated with technical inefficiency while v_i is a symmetric random error that 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}; β) $*v_{it}$) in an appropriate environment. Using an output-oriented measure of technical efficiency, the ratio of observed output to the corresponding stochastic frontier output can therefore be illustrated as:

$TE = Y_{it} = \exp f(x_{it};\beta) * \exp v_{it} * \exp(-u_{it})\ \exp f(x_{it};\beta) * \exp v_{it} \exp f(x_{it};\beta) * \exp v_{it}$ *(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 least squares or maximum likelihood (Coelli et al. 2005). The SFA is based on an 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.

Although there are different function forms of the stochastic frontier, the data were fitted to the Cobb-Douglas production function using STATA15 application software. The Stochastic frontier production function model is the single Cobb-Douglas form for cross-sectional or panel data. It can be described as follows;

Now, if we also assume that $f(x_i, \beta)$ takes the log-linear Cobb-Douglas form, the model can be written as:

$$\ln y_i = \beta_O + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + \beta_5 \ln X_{5i} + \beta_6 \ln X_{6i} + \beta_6 \ln X_{6i} + V_i - U_i \quad (5)$$

Where Y = output of rubber (kg)
X_1 = Age of plantation (year)
X_2 = Environmental Effect
X_3 = Labor (RM/day)
X_4 = Farm Size (hectare)
X_5 = Fertilizer (kg/year)
X_6 = Clone

where,
y_{it} is the output production of rubber of the *i*-th unit in year t,x_{it} is the observed input variables of the *i*-th unit in year t, v_{it} is random variables assumed to be *i*-th unit in the year t, reflecting statistical noise; u_i is non-negative time-invariant random variables capturing time-invariant technical efficiency, $\varepsilon_i = v_i - u_i$, ε_i is a disturbance term; β_k is an unknown parameter to be estimated, k = 0, 1, ... 7; ή is an unknown scalar parameter 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 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:

$$TE_i = a_O + a_1 Z_1 + a_2 Z_2 + a_3 Z_3 + a_4 Z_4 + a_5 Z_5 + a_6 Z_6 \quad (6)$$

where TE_i is Technical efficiency of the *i*th smallholders, Z_1 is Fertilizer, 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_O is Constant and a_1–a_6 is Estimated regression parameters.

Results and Discussion

Description of respondents

The findings of the socio-economic variables for rubber smallholders indicate that the majority of rubber smallholders in Lipis, Pahang consist of owners and entrepreneurs which represent 49.1% while the second category is entrepreneurs not owners which represent 43.8%, and the other is 5.3% (refer Table 2). In rubber plantations, the owner mostly manages their own land, and this might be because they do not have any other jobs.

Table 2
Descriptive Analysis of Smallholders' Demographic

Variable	Categories	Number of respondents	Percentage (%)
Respondent Status	Owner not entrepreneur	20	5.3
	Owner and entrepreneur	185	49.1
	Entrepreneur not owner	165	43.8
Land Ownership Status	Sole ownership	251	66.6
	Partnership	119	31.6
Age (years old)	19-29	17	4.0
	30-49	171	45.0
	50-69	151	40.0
	70-89	31	8.0
Gender	Male	291	78.6
	Female	79	21.4
Race	Malay	181	48.0
	Chinese	6	1.6
	Indian	8	2.1
-	Native people	175	46.4
Main job	Rubber tapper	320	84.9
	Oil palm	4	1.1
	Forest products collector	2	0.5
	Farming	6	1.6
	Salary workers	27	7.2
	Businessman	3	0.8
	Housewife/Not working	8	2.1
Experience (years)	0-10	19	5.0
	11-20	218	57.8
	21-30	120	31.8
	31-40	37	9.8
	41-50	2	0.5
Education Level	No School	12	3.2
	Primary School	112	29.7
	Secondary School	243	64.5
	University/College	3	0.8
Marital Status	Single	4	1.1
	Married	363	96.3
	Separated	3	0.8
Numbers of Household	1-3	1	0.3
	4-6	310	82.2

	7-9	59	15.6
Farm Size	0.0-1.0	209	55.4
	1.01-2.0	88	23.3
	2.01-3.0	57	15.1
	3.01-4.0	10	2.7
	4.01-5.0	3	0.8
	5.01-6.0	1	0.3
	6.01-7.0	1	0.3
	7.01-8.0	0	0.0
	8.01-9.0	1	0.3

According to the results, it is shown that most of the smallholders which involved 171 respondents were between 30 years old and 49 years old, while another three were between 19 to 29 years old. On the other hand, the oldest smallholders were around 70 to 89 years old. There were 151 smallholders who were 50 to 69 years old. This indicated that the middle age people might have the capability to be committed to this industry because they can perform harvesting activities.

The majority of the rubber smallholders were Malay with 48.0%, while 8% were Indian and only 6.0% were Chinese. The native people were the second highest at 46.4% where they are provided with land from the government. Based on the table, it is shown that most of the smallholders were full-timers. 84.9% of people became the rubber tapper and 27% were part-time smallholders. Some of them have other side jobs such as being security guards, teachers, drivers, and administrative officers. In addition, 57.8% of respondents had 11 to 20 years of experience or involvement in activities related to the rubber industry. This is in the line with the fact that most of the rubber smallholders were middle generations. As the activities were still being carried out in the locations under study, it was confirmed that the older generation had passed the knowledge related to rubber plantation activities to the younger generation to continue the tradition and satisfy the demand. About 31.8% of smallholders had experience of 21 to 30 years, and the lowest percentage was 0.5 % with more than 41 years of experience. The average experience of respondents was 31 to 40 years and 1 to 10 years which were 9.8% and 5.0% respectively.

This also indicates that the majority of the rubber smallholders are male with 78.6% (291) while 21.4% (79) are females. This shows the male monopoly of the rubber industry in Lipis, Pahang. Heavy activities such as fertilizing, tapping, and harvesting might be the reason why females took down this job. Although they have their own land or farm, they will hire the other tapper to manage theirs. Besides that, most of the rubber smallholders were married, involving 363 rubber smallholders. Four smallholders were still single and three of the rubber smallholders were separated. Most of the rubber smallholders possessed secondary education which stated at 64.5%. The remaining 29.7% of rubber smallholders had primary education, only 0.8% of the rubber smallholders had completed tertiary education and 3.2% of rubber smallholders did not attend school. Thus, it is shown that smallholders with a high-level background in education are more easily adapting to new technologies. The higher level of smallholder education, the more likely they will accept and adapt innovations that were introduced by a research agency such as Lembaga Getah Malaysia and RISDA.

The result also revealed that the highest farm size for the rubber smallholders in Lipis, Pahang was below 1 hectare which was 55.4% (209). The second highest farm size is between 1.01 to 2.0 hectares involving 88 smallholders. Besides that, 57 rubber smallholders own a farm size between 2.01 to 3.0 hectares. Only 2 rubber smallholders had 5.01 to 7.0 hectares of farm size. There are only 3 smallholders that acquire 4.01 to 5.0 hectares farm size. All the respondents of this study are Malaysian citizens. The result also indicates that most of the smallholders in Lipis, Pahang which involved 251 respondents were sole ownership while the other 119 are a partnership. This shows that the sole owners can easily decide on matters regarding their own land.

Estimated Production Function

The results related to the estimation of Stochastic Frontier Analysis (SFA) using the Cobb-Douglass production function are presented in Table 3. This finding uses the Ordinary Least Square (OLS). In the case of a Cobb-Douglass model, the significant variables were the fertilizer, planting area, and tapping area. The likelihood statistic, which involves the chi-square, is 84.89, while the p-value of 0.000 for the half-normal model.

Table 3
Rubber Production Estimation Results of Cobb Douglass using Ordinary Least Square (OLS)

Inproduction	Coefficient	z	Standard error
Constant	5.360599***	17.83	0.0531192
Infertilizer/kilogram	0.1998854***	23.76	0.0675656
Inplanting area/hectare	0.2648003***	3.92	0.0887623
Intapping area/panel	0.2232105***	2.51	0.3006782
In$\sigma_v{}^2$	-1.935295	-7.16	0.2701393
In$\sigma_u{}^2$	-1.43683	-3.02	0.475966
σ_v	0.3799759		0.0513232
σ_u	0.4875245		0.1160225
σ^2s	0.3820618		0.0808549
$\lambda(=\sigma_u / \sigma_v)$	1.28304		0.1630856
Log-likelihood	-201.1213		
likelihood-ratio test	84.89		
p-value	0.000		

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

The greatest elasticity observed is the planting area (0.265). This indicates that the greatest relationship exists between the production of the rubber which is cup lumps and the planting area. A larger area will contribute to a higher production of cup lumps. An additional increase in planting area will increase about 27% in the production of cup lumps. There is a linear relationship, with farms over 500 ha becoming more productive than medium-sized farms (Helfand et al. 2020).

Next, the tapping area has the second-highest elasticity which is 0.223, confirming its importance in the production of the rubber sector. In rubber plantations, high production of latex is produced when the rubber tree becomes older. In this case, an additional increase of years in the age of rubber trees will enhance productivity by 22%. Lastly, assuming a positive elasticity in relation to the other relevant factors, the fertilizer contributes the least to the productivity of rubber in which an additional increase in 1 kg of fertilizer will increase productivity by 20%. The average productivity was highest over the first year of tapping and the trend was similar over the fourth year. During open tapping for eight years, the total average was around 2700 to 3200 kg/ha/year, followed by the third year with 1900 to 2500 kg/ha/year, and the first year around 1800 kg/ha/year (Shuib et al.2015).

The third elasticity is 0.1998, concluding that the fertilizer plays an important role to get the high production of latex. Mostly, the smallholder should fertilize their rubber tree to enhance the yield. In this case, fertilizer will increase about 20% in the production of latex. The efforts to increase rubber production are optimizing the use of labor both in the context of tapping, weeding, fertilizing, and controlling pests and weeds; second is by improving agricultural technology, such as using the recommended clones; third is by rejuvenating less productive crops through business partnerships with private companies and the state; and lastly is the significant government support in providing fertilizers and encouraging farmers to increase their production (Kuswanto et al. 2019).

Sources of Technical Efficiency

The estimated determinants of technical efficiency of rubber production are shown in Table 4. The status of respondents shows that technical efficiency increases at a 5% significance level when the land is managed by the owner. Economic performance and viability are affected when farm households hire permanent labor for their small, medium, or large farm (Pochanasomboon *et al*., 2020).

Table 4
Technical Efficiency Results

TE	**Parameter**	**Coefficient** β	**t**	**Standard error**
Constant	a	0.5144621***	7.12	0.0722328
Respondent status	*Z1*	0.1062162**	2.03	0.0523534
Land ownership status	Z2	0.1050432*	2.22	0.0473173
Primary school	Z3	0.1427278***	2.61	0.0547636
Secondary school	Z4	0.0259953	0.34	0.0775745
University	Z5	0.0750348	1.57	0.0477649
Male	Z6	0.0119691	0.87	0.013728
Clone	Z7	0.0059228	2	0.0029588
Experience/years	Z8	0.0001241	0.15	0.0008422
Extension visit	Z9	0.114291	0.91	0.0125325
Rainfall frequency/month	Z10	0.0019058	0.3	0.0062551
Frequency of weeding	Z11	0.0188769	1.67	0.0113265
Weed control method	Z12	0.0082604	0.91	0.001275
Frequency of fertilizer	Z13	0.0014359	0.19	0.0077089
Number of observations	370			
Breusch-Pagan (chi-square)	116.48			
F (13, 356)	1.66			
R-squared	0.0571			

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

Next, the land ownership status increases at a 10% significance level when the land was owned by sole ownership. This indicated that the owner of the land can fully manage the farm without a lot of interference. They can give the best choice to fulfill the sequence of rubber plantation activities. The review of family involvement gives effect to the output contribution of labor and capital, but the evidence is primarily anecdotal (Barbera *et al*., 2011).

Besides that, the coefficient for education level was positive for primary school. Primary school has a statistically significant effect at a 1% level. This shows that smallholders who completed primary school were more technically efficient than those at secondary and tertiary levels. This reveals that the rubber smallholders were not required to have a high-level education to survive in this rubber industry. The rubber smallholders will learn to manage their farms from the older generation. The employees who have shares in the company will spread the risk to the company (Jonathan, 2002). The frequency distributions of technical efficiency are presented in Table 5. The distribution of the technical efficiency scores is between 0.20 to 1.00. About 43.2% of the rubber smallholder have technical efficiency scores between 0.20 and 0.69. Besides that, 17.6% of the rubber smallholders were found to have technical efficiency greater than 80%. While the highest technical efficiency is between 0.70 to 0.79 with 39.2%. The mean level of technical efficiency for the sample of rubber smallholders is 0.70 (70%), with a standard deviation of 0.1042. This suggests that on average, rubber smallholders could only achieve about 70% of the potential maximum output from a given production input. These results suggest that rubber smallholders are affected by various factors, such as low experience in managing the farm, fewer extension agent visits, higher cost of fertilizer, higher rainfall frequency, not using the recommended clone, and low agricultural practices which are weeding and fertilizing. The average efficiency among rubber smallholders will increase by improving the efficiency in the area is significant, at 30%. This would require improving the efficiency factors by improving how resources are used at the farm level.

Table 5
Frequency Distribution and Technical Efficiency Indices

Technical Efficiency	Frequency	%
0.0 - 0.19	0	0.00
0.20-0.29	1	0.27
0.30- 0.39	2	0.54
0.40- 0.49	12	3.24
0.50-0.59	46	12.43
0.60-0.69	99	26.76
0.70-0.79	145	39.19
0.80-0.89	64	17.30
0.90-1.00	1	0.27
Total	370	100
Mean	0.70	
Max	0.90	
Min	0.20	

Conclusion

This study has analyzed the determinants of technical efficiency among rubber smallholders in Lipis, Pahang, Malaysia. The frequency of fertilizer applied, the size of the planting area, and the tapping area have positive effects on output, and their coefficient is statistically significant at 1% respectively. The study found that the most important factors that are positively associated with technical efficiency levels are respondent status, land ownership status, and primary school. The results also revealed that these rubber smallholders are not fully technically efficient. The mean level of technical efficiency for the sample of rubber smallholders is 0.70 (70%), with a standard deviation of 0.1042. These findings show that technical efficiency in rubber smallholder's production could be increased by 30% on average through better use of fertilizer, planting area, and tapping area. This could be achieved by improving smallholder-specific efficiency factors, which include better and more frequent extension agent visits to provide technical knowledge and education advice from the government, attending seminars to ensure effective delivery, and a communication platform to share information among rubber smallholders. Efficient extension agents would improve Good Agricultural Practices (GAP), by advising smallholders about weeding proper methods to achieve higher productivity. More research and development (R&D) are needed to improve better quality of harvesting by using good clones and technology to help rubber smallholders to gain more production and be able to survive in the rubber industry.

In term of theoretical contribution, this study would advance academic comprehension of efficiency drivers in agriculture, while the practical contribution would offer practical insights tailored to rubber smallholders, potentially impacting policy and practice in real-world agricultural contexts. The project would contribute significantly to current knowledge by deepening the comprehension of technological efficiency in an underexplored industry, specifically rubber smallholder production. Furthermore, it would provide a practical context to this information, hence having tangible real-world ramifications. The local context greatly relies on its role in setting agricultural policy, enhancing smallholder competitiveness, and advocating for sustainable practices, all of which are essential for economic and rural development.

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