Estimating the Efficiency of Pahang Rubber Smallholders Using Data Envelopment Analysis Approach

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Abstract

RISDA has targeted for the income of each smallholder to be at least RM2500 per month by the end of 2015. However, approximately almost 90% of the smallholders' monthly income is still below the target. Hence, in order to observe if this target is achievable, a study was conducted to evaluate the efficiency level of producing rubber among 95 rubber smallholders in Pahang. In addition, the study also investigated if there was any opportunity for increment of production among the rubber smallholders. Therefore, the Data Envelopment Analysis (DEA) model, under the assumption of Variable Return to Scale (VRS) and Constant Return to Scale (CRS), was used to analyse the scale and the technical efficiency of the smallholders. Scale Efficiency was measured in order to estimate the return to scale of the smallholders. As a result, the study found that the average Overall Technical Efficiency (OTE) and Pure Technical Efficiency (PTE) scores of the smallholders were 43.47% and 43.78%, respectively. Thus, the majority of the smallholders were not technically efficient in producing rubber. Furthermore, based on the return to scale estimated, 41% of the smallholders were operating under the Increase Return to Scale (IRS), which implied that the smallholders had a sub-optimal scale size. The results obtained had been useful as the optimal input-output for the efficient rubber yield can be determined and may help RISDA, as well as agricultural planners, to devise a strategy in order to increase the productivity of rubber smallholders in Malaysia.

Keywords: Rubber smallholders, Data Envelopment Analysis (DEA), Constant Return to Scale (CRS), Variable Return to Scale (VRS), Pure Technical Efficiency (PTE)

1.0 INTRODUCTION

Natural Rubber is a solid product obtained from coagulation of latex through rubber tapping process. The increased production of rubber in Asia resulted Malaysia as the largest natural rubber producer in the world from the 1930s to 1980s. However, Malaysia started to fall back due to alterations in its production profile, which began to stress non-agricultural investments, specifically towards export-oriented manufacturing activity. The shift gave a huge impact on the agricultural sector, particularly the rubber sector, giving Malaysia's position as the world's largest natural rubber producer to Thailand in 1992 [1]. Nevertheless, rubber production has remained as one of the vital components in the natural economy. As present, Malaysia is the world's fourth largest

producer of natural rubber after Thailand, Indonesia, and Vietnam, with a total production of 922.8 thousand tonnes in 2012, reflecting a decline by 7.4% from 996.2 thousand tonnes in 2011. Moreover, the Malaysian natural rubber has been contributed from two sources, which are smallholdings sector and estates sector. In addition, at present, the smallholdings sector is the major contributor to Malaysian natural rubber with 93.6% of the production compared to estates sector with 6.4% [2].

The Rubber Industry Smallholders Development Authority (RISDA) is a federal statutory body under the Ministry of Regional Development (MRRD). RISDA is responsible in taking care of the rubber smallholders and guiding them towards progress and development, economically and socially; in ensuring the national rubber production's growth. RISDA

covers three main functions; which are administration of the Rubber Industry (Replanting) Fund, established under section 3 of the Ordinance of the Rubber Industry (Replanting) 1952, successfully manage and operate plans approved under the provisions of Part III of the Ordinance of the Rubber Industry (Replanting) 1952; as well as planning and implementing reforms; and researches in the smallholder sector.

Over the years, the Malaysian rubber industry has evolved and transformed itself into a more integrated industry. Besides that, RISDA has targeted for the income of each smallholder family to be at least RM2500 per month by the end of 2015. However, almost 90% of the smallholders' monthly incomes are still below the target.

Even though the efficiency and the productivity of rubber smallholders have naturally improved [3] after efforts taken by RISDA, there is still the question: how efficient are the smallholders in producing rubber? Therefore, the study was conducted in order to measure the achievement of rubber smallholders in Pahang in order to provide significant information for RISDA to plan strategies to aid in achieving their objective for the smallholders' family to earn better income. On top of that, the increase of smallholders' efficiencies have been believed to increase the rubber production, thus increasing the earnings of the smallholders. Therefore, the objectives of this study have been: (i) To evaluate the efficiency of producing rubber for the rubber smallholders in Pahang through their relative efficiency estimates obtained from Data Envelopment Analysis, and (ii) To identify the opportunity for increment in production of the smallholders based on the return to scale estimations.

One of the simplest and most frequently used estimates of efficiency is the ratio or index analysis [4]. Ratios are measured by the relationship between any two parameters to explain the different aspects of the operation. The limitation of this approach is that it provides a single dimensional image of the figure without any specific reasons for good or bad performance [5]. This limitation has led to the development of the frontier approach, which has become a popular approach among researchers nowadays. The frontier approach measures the performance of firms with the "best practice" frontiers, which consist of the performance of other firms in the industry. The benefits of applying the frontier approach, are among others, is because it is easier to identify the best practice firms within the industry. It also provides a number of efficiency scores, identifies areas of inputs overused and/or outputs underproduced and relates the efficiency score with any policy or research interest, especially for the individual who does not have any knowledge concerning the frontier analysis [6].

The Data Envelopment Analysis (DEA) proposed by [7] is the approach that is frequently used in non-parametric techniques. DEA does not require an explicit specification of the production function form that expresses how inputs are transformed into outputs [8]. [8] describes the handling of decision making units (DMU) in DEA as a 'black box' whereby no assumptions are specified for the production process while observing inputs and outputs. Another advantage of using DEA is that it does not require parametric assumptions, such as normality and equal variance [9]. In addition to that, unlike the parametric approach, DEA is also less data demanding as it works fine with a small sample size ([10], [11]), which is very relevant to this study. In this study, the efficiency measurement is obtained through the DEA method that is described in greater detail in the next section.

There are limited studies in literature that have analysed the technical efficiency of the rubber smallholders, particularly with the DEA model. Nonetheless, a study that was discovered to employ a similar model was conducted by [12]. This study exploited the DEA model to measure the efficiency of rubber smallholders in the Gampaha district, Sri Lanka. From the results, they found that the average technical efficiency of the rubber smallholding sector was 49.8%. However, this score was considerably less than the other study carried out by [13] for other districts in Sri Lanka.

In the study of technical efficiency for rubber smallholders under Risda's supervisory system, [3] used the stochastic frontier analysis to determine technical efficiency of 35 supervised rubber smallholders. In the study, it was found that there was positive coefficient of capital-land ratio which are represented by the number of trees cultivated per hectare which denoted intensity of cultivation, such as increase in the intensity of trees reduced latex production. The study also revealed a negative coefficient value in the yield-tapping ratio in representing the yield attainment per tree tapped, which would elevate latex production with every additional increase of projected yield. Meanwhile, in the study of analysis on productivity achievement in the rubber industry in Selangor, [14] considered six factors that contributed to the achievement of rubber productivity, which were age of the rubber tree, the number of rubber trees tapped per year, type of clone used, usage of stimulation, lot area, and rubber land area. These factors were chosen based on a previous study conducted by [15]. The output used for the study had been smallholder achievement to target productivity. Moreover, with logistic regression method, the productivity achievement of rubber tappers was analysed. The results from the study identified four factors, which were, lot area, age of the rubber tree, rubber land area, and usage of stimulation as contribution factors to the achievement of productivity among rubber tappers.

2.0 METHODOLOGY

2.1 Data Envelopment Analysis (DEA)

In this study, the Data Envelopment Analysis (DEA) is employed to estimate the efficiency of rubber smallholders in Pahang. DEA is a methodology based upon application of the linear programming technique for measuring the efficiency performance of organizational units [16], which are termed as Decision-Making Units (DMUs). The DEA method which is pioneered by [7] and extended by [17], [18], and [19] construct a non-parametric piecewise surface or frontier over the data. This technique aims to measure how efficiently a DMU uses the resources available to generate a set of outputs [7]. The DEA technique is chosen in this study since it has become a popular approach in measuring efficiency. Among others, the DEA can be viewed as a benchmarking technique, as it allows decision makers to locate and understand the nature of the inefficiencies of a decision making unit (DMU) by comparing it with a selected set of efficient DMUs with a similar profile. Beyond the efficiency measure, DEA also provides other sources of managerial information related to the performance of DMUs.

The efficiency analysis in the study is run under the analysis option of output oriented model where the aim of the study is to maximize the output production. The efficiency scores of the smallholders were calculated under both constant return to scale (CRS) and variable returns to scale assumptions (VRS). CRS gives the assumption that there are no significant relationship between the scale of operations and efficiency. Under the VRS assumption, a rise in input is expected to result in a disproportionate rise in outputs. VRS efficiency scores represent pure technical efficiency (PTE). PTE is the efficiency measure that ignores the impact of scale size by comparing a DMU only to other units of similar scale.

The primal model is the basic DEA model called the CCR (Charnes-Cooper-Rhodes) proposed by [7]. In this model, the denominator has been set equal to 1 and the numerator is being maximized. The output oriented CCR primal model can be represented as follows:

$$Min \sum_{i=1}^{I} u'_{im}x_{im}$$
$$Subject\ to$$
$$\sum_{j=1}^{J} v'_{jm}y_{jm} = 1$$
$$\sum_{j=1}^{J} v'_{jm}y_{jn} - \sum_{i=1}^{I} u'_{im}x_{in} \leq 0\ ; n = 1,2\ldots N$$
$$v'_{jm}, u'_{im} \geq 0\ ; i = 1,2\ldots I\ ; j = 1,2\ldots J \tag{1}$$

N = number of smallholders, m = the smallholders whose relative efficiency is being measured, I = number of inputs, J = number of outputs, y_{jm} =

quantity of output j used by smallholder m, v_{jm} = weight for output j of the smallholder m, x_{im} = quantity for input i used by smallholder m, u_{im} = weight for input i of the smallholder m.

The dual model for a given unit using input and output values of other units tries to construct a hypothetical composite unit out of the existing units. The dual for Model 1 can be stated as follows:

$$Max\ \emptyset_m$$
$$Subject\ to$$
$$\sum_{n=1}^{N} y_{jn}\mu_n \geq \emptyset_m y_{jm}\ ; j = 1,2\ldots J$$
$$\sum_{n=1}^{N} x_{in}\mu_n \leq x_{im}\ ; i = 1,2\ldots I$$
$$\mu_n \geq 0\ ; n = 1,2\ldots N$$
$$\emptyset_m\ Unrestricted \tag{2}$$

Where μ is the weights to the smallholders, whereas $\emptyset_m$ is the efficient rate of smallholders m. The smallholder is CCR efficient if the optimum value of the Model 2 objective function equals one. Otherwise, the unit is inefficient. The Overall Technical Efficiency (OTE) can be distinguished into Pure Technical Efficiency (PTE) and Scale Efficiency (SE). PTE refers to variable returns to scale (VRS). The VRS models can be used by adding a restriction:

$$\sum_{n=1}^{N} \mu_n = 1 \tag{3}$$

The restriction ensures that each inefficient DMU is being compared with DMUs of similar size.

Scale Efficiency (SE) of each DMU can be obtained by the ratio of its CRS efficiency to its VRS efficiency.

$$SE = \frac{CRS}{VRS} \tag{4}$$

A DMU with SE = 1 operates in optimal scale, while DMU with SE < 1 has a sub-optimal size and it either overproduces or under produces compared to its size. The CRS efficiency of a firm is always less than or equal to the pure technical (VRS) efficiency, the equality holds when the scale efficiency is unity, or when the DMU is operating at Most Productive Scale Size (MPSS). To determine whether scale inefficiency can attribute to increasing returns to scale (IRS) or decreasing returns to scale (DRS), the sum of the optimal values of all the μ when the CCR envelopment version is solved, considers the DMU in question as the reference DMU. Thus, if:

$$\sum_{n=1}^{N} \mu_n^* < 1 \tag{5}$$

then the reference DMU is expected to exhibit IRS. If

$$\sum_{n=1}^{N} \mu_n^* > 1 \tag{6}$$

then the reference DMU is expected to exhibit DRS.

[20] stated that DMU will exhibit DRS when a proportionate increase in all of its inputs results in a less than proportionate increase in its outputs. Whereas, DMU is said to operate at IRS if a proportionate increase in all of its inputs results in a greater than proportionate increase in its output. The smallholder scale efficiency of 1 can be considered optimal. With DEA, efficiency is measured against feasible frontiers, thus the improvement of each smallholder is also feasible through better management inputs. The synthesis of DEA will provide the best practise frontier represented by a piecewise linear empirical envelopment surface.

2.2 Description of Variables

The data for the observed period in 2012 on input and output variables were obtained from the Rubber Productivity Improvement Program (PPG). This consisted of 95 smallholders from 8 different regions in Pahang, which were Bentong, Bera, Lipis, Raub, Jerantut, Pahang Timur, Maran, and Temerloh. One output and six inputs were used in the study. Age of tree, lot area, rubber land area, number of trees planted per hectare, and number of trees tapped per year were used as the inputs. The only output used in this study was rubber yield per unit area (kg ha-1) in the year 2012. The variables used in the study were selected based on the previous studies done by [14] and [15]. All the variables used in this study are described in Table 1.

Table 1 Description of variables

Variable	Type of Variable	Description
Age of tree	Input	Age of the rubber trees in year 2012
Lot Area	Input	Area of Lands (hectares)
Rubber Land Area	Input	Lands with matured rubber trees (hectares)
Number of tree planted per hectare	Input	The number of trees that are planted in a unit (hectare) of land.
The number of rubber tree tapped per year	Input	The number of trees tapped per year. The value is calculated with multiplying the number of trees tapped per day and days tapped per year.
Rubber Production	Output	Rubber yield per unit area (kg/ha/yr) in the year 2012

3.0 RESULTS AND DISCUSSION

3.1 Overall technical Efficiency (OTE)

The Overall Technical Efficiency (OTE) scores of the smallholders have been based on the CRS assumption, which can be found in Table 2. CRS gave an average OTE for the smallholders at approximately 43.5% (sd= 17%), which indicated that they could increase yield of rubber by approximately 56.5% while maintaining their current level of inputs in order to be efficient. Out of the 95 smallholders, only 11% (10 smallholders) were found to be fully efficient (100% efficient rate). This result showed that only limited smallholders had been using the input effectively while yielding the expected output. These efficient smallholders were selected as peers for the inefficient smallholders. Based on the results, the majority of the smallholders (70.53%) obtained the efficiency score of less than 50%, which indicated a low level of efficiency. This result is quite consistent with the results reported by [12] and [13] whereby the efficiency score is not very high. The low scores in OTE for inefficient DMUs portrayed that the DMUs failed to produce output as expected and used excessive input in yielding rubber compared to the efficient DMUs (peers). The inefficiency of the smallholders, as estimated by the Overall Technical Efficiency (OTE) could be due to the lack of input and output configurations when compared to the smallholders with a similar scale.

Table 2 Overall Technical Efficiency using CRS

Efficiency Score (χ)	SH	%			
		Per	Cum	AE	SD
$6.5 \leq \chi < 10$	1	1.05	1.05	6.59	-
$10 \leq \chi < 20$	9	9.47	10.53	18.74	0.71
$20 \leq \chi < 30$	20	21.05	31.58	26.76	2.07
$30 \leq \chi < 40$	24	25.26	56.84	34.05	2.83
$40 \leq \chi < 50$	13	13.68	70.53	46.46	2.70
$50 \leq \chi < 60$	7	7.37	77.90	55.08	2.89
$60 \leq \chi < 70$	4	4.21	82.11	61.32	0.84
$70 \leq \chi < 80$	4	4.21	86.32	76.01	2.62
$80 \leq \chi < 90$	2	2.11	88.42	83.73	2.36
$90 \leq \chi < 100$	1	1.05	89.47	93.23	-
100	10	10.53	100	100	0
Total	**95**			**43.47**	**17.035**

SH = Number of Smallholders, Per = Percentage, Cum = Cumulative, AE = Average Efficiency, SD = Standard Deviation

3.2 Pure Technical Efficiency (PTE)

In this study, Pure Technical Efficiency (PTE) was also calculated by estimating the efficient frontier under the assumption of Variable Returns to Scale (VRS). PTE only reflected the technical efficiency of the smallholders, which was the effectiveness of

smallholders in managing inputs regardless of the scale. Table 3 presents the PTE scores for the smallholders.

Table 3 Pure Technical Efficiency using VRS

Efficiency Score (χ)	SH	%			
		Per	Cum	AE	SD
6.5 ≤ χ <10	1	1.05	1.05	6.59	-
10 ≤ χ < 20	8	8.42	9.47	18.88	0.64
20 ≤ χ < 30	16	16.84	26.32	26.82	2.31
30 ≤ χ < 40	23	24.21	50.53	33.24	2.00
40 ≤ χ < 50	10	10.53	61.05	46.17	3.18
50 ≤ χ < 60	11	11.58	72.63	54.75	2.57
60 ≤ χ < 70	5	5.26	77.89	63.50	2.60
70 ≤ χ < 80	3	3.16	81.05	78.45	1.59
80 ≤ χ < 90	4	4.21	85.26	83.03	2.96
90≤ χ <100	1	1.05	86.32	97.67	-
100	13	13.68	100	100	0
Total	**95**		**Mean**	**43.78**	**17.855**

SH = Number of Smallholders, Per = Percentage, Cum = Cumulative, AE = Average Efficiency, SD = Standard Deviation

The average PTE score for the smallholders was approximately 44% which was relatively low in level for pure technical efficiency. This result indicated that the smallholders could increase their output in average at 56% by using the same level of input in order to be fully efficient. Based on the PTE score, 13.7% of the smallholders were estimated to operate in full efficiency. The results also showed that more than half of the smallholders (61%) yielded rubber in a low level for pure technical efficiency (PTE<50%). Meanwhile, 24% of the smallholders scored from 30% to 40%, 17% of the smallholders scored 20% to 30%, while approximately 9% of the smallholders operated at very low technical efficiency (less than 20%). Based on the results, it can be seen that the average scores for both OTE and PTE had been quite similar. However, there were still differences discovered between the scores obtained by DMUs for OTE and PTE. Under PTE, 13 smallholders were estimated to operate in full efficiency, while in OTE, 10 smallholders had been estimated to operate in full efficiency. As for the percentages that depicted poor efficiency among smallholders (score less than 50%), the PTE obtained was approximately 61% while the OTE obtained was approximately 71%.

3.3 Scale Efficiency

The differences of the scores calculated from both methods (OTE and PTE) suggested that a part of the overall inefficiency could be ascribed to scale

inefficiency as 3 smallholders obtained OTE<1 and PTE=1. Thus, Scale Efficiency (SE) and the types of return were calculated to provide more insight on the impact of the size of the rubber plantation on efficiency.

Table 4 Scale Efficiency

Efficiency Score (χ)	SH	%			
		Per	Cum	AE	SD
30 ≤ χ < 40	2	2.11	2.11	31.03	0.56
40 ≤ χ < 50	1	1.05	3.16	48.00	0.00
50 ≤ χ < 60	1	1.05	4.21	57.67	0.00
60 ≤ χ < 70	0	0.00	4.21	0.00	0.00
70 ≤ χ < 80	3	3.16	7.37	78.72	1.88
80 ≤ χ < 90	7	7.37	14.74	86.54	3.31
90 ≤ χ <100	71	74.74	89.47	97.55	2.59
100	10	10.53	100	100	0
Total	**95**		**Mean**	**34.41**	**8.35**

SH = Number of Smallholders, Per = Percentage, Cum = Cumulative, AE = Average Efficiency, SD = Standard Deviation

Table 4 shows that the average Scale Efficiency (SE) among the smallholders was (34.41%) and varied from 30% to 100%. Besides that, 71 smallholders (75%) had smaller or bigger extent of sub-optimal size. Moreover, although the majority of the smallholders did not achieve scale efficiency and operated at optimal size, only 3% of the smallholders experienced intense problems (SE<40%), either because it was operating under increasing returns to scale (IRS) or due to the decreasing returns to scale (DRS).

Apart from that, the types of return to scale obtained by the smallholders are shown in Table 5. It shows that 10 smallholders (10.5%) had a scale efficiency of 100%, which indicated that the smallholders had the most productive size for the particular input-output combination.

Table 5 Scale Efficiency Summary

Return to Scale	SH	%			
		Per	Cum	LA	MO
Constant	10	10.53	10.53	1.98	6616.58
DRS	46	48.42	58.95	2.89	3199.96
IRS	39	41.05	100	1.86	3168.56

SH = Number of Smallholders, Per = Percentage, Cum = Cumulative, LA = Mean Lot Area (ha), MO = Mean Output (kg/ha/yr)

As shown in the table, for the optimal smallholders, the mean values for lot area and output were 1.98 ha and 6616.58 (kg ha-1 yr-1). Nevertheless, the remaining smallholders failed to obtain a similar score for efficiency as the smallholders were found to be

scale inefficient, either because it was operated under increasing returns to scale (IRS) or decreasing returns to scale (DRS). Based on the results obtained, 39 smallholders (41%) were operated under IRS which implied that the smallholders had a sub-optimal scale size, whereby an increase in the inputs by the smallholders would result in an increase in their outputs beyond proportion. As for the remaining 46 smallholders (48%) who operated under DRS, which implied that the smallholders had supra-optimal scale, an increase in the inputs by the smallholders would result in an increase in their outputs below proportion. Thus, for the inefficient DMUs that are operating in their most productive size, smallholders with DRS should scale down their inputs, whereas, smallholders with IRS should increase their inputs and outputs. Overall, DRS had been observed to be the majority form of scale inefficiency in rubber production among the smallholders. Besides that, a comparison between the average scale efficiency (34.41%) and the average of technical efficiency (43.78%) revealed that the overall efficiency of the smallholders was more affected by the technical efficiency rather than the scale. More specifically, 44% of the overall inefficiency could be explained by the sub-optimal scale of the smallholders' operation and the remaining 66% could be attributed to the non-rational use of inputs as deduced from Tables 4 and 5. Moreover, 85.26% of the 95 smallholders scored higher for SE than PTE, which meant that there was inefficiency in resource utilization, primary inefficiency that was due to managerial inefficiency rather than scale.

3.4 Area of Efficiency Improvement: Slacks and Targets Settings

DEA also projected target inputs level for each inefficient smallholder to give suggestions on the input quantity that should be used and the quantity of output that the smallholders should produce. The target inputs level were projected using the dual weights from the smallholders reference set, while the dual weights for each efficient DMU are derived from the CRS model. The reference set consists of efficient DMUs and acts as the basis for calculating the target input level. Target inputs and outputs projected by DEA in the study showed that slacks for inefficient smallholders delineated among the input variables; 5 smallholders (5%) had non-zero slacks for tree age, 40 smallholders (42%) had non-zero slacks for total lot area (ha.), 57 smallholders (60%) had non-zero slacks for rubber tapping area (ha.), 21 smallholders (22%) had non-zero slacks for number of trees per hectare, and 35 smallholders (37%) had non-zero slacks for number of trees tapped per year. These suggest that, overall, most of the inefficient smallholders need to reduce rubber tapping area, total lot area (ha.), and the number of trees per hectare in order to project themselves onto the efficient frontier.

The outcome of this study is consistent with the previous study conducted by [3], which discovered a positive coefficient for capital-land ratio as represented by the number of trees cultivated per hectare that denoted intensity of trees reduced latex production per hectare. The study also found a negative coefficient value for the yield-tapping ratio, which indicated that yield attainment per tree tapped elevated latex production with every additional increase of projected yield. As for tree age, although it is quite obvious that there is no way for the smallholders to reduce the age of trees, the information could be important for the smallholders as well as RISDA in planning for the replanting of rubber trees.

4.0 CONCLUSION

The empirical analysis results for the efficiency of Pahang rubber smallholders have been presented in the previous section. The study found that the average Overall Technical Efficiency (OTE) and Pure Technical Efficiency (PTE) scores of the smallholders were 43.47% and 43.78%, respectively. Thus, the majority of the smallholders were not technically efficient in producing rubber. Furthermore, based on the return to scale estimated, 41% of the smallholders were operating under the Increase Return to Scale (IRS), which implied that the smallholders had a sub-optimal scale size.

This study offered better understanding of the technical efficiency as well as the scale efficiency measurement among rubber smallholders in the state of Pahang, Malaysia. The DEA approach was employed to measure the efficiency. From the analysis that had been carried out, it can be suggested that the DEA model is indeed an appropriate efficiency measurement approach for rubber smallholders because it allows one to expand the output while simultaneously contracting the input. This study is especially useful in the Malaysian context, as the application of DEA for efficiency measurement in rubber smallholders is still in its infancy. Therefore, this study provides a new dimension concerning efficiency measurement in the Malaysian context, particularly among rubber smallholders wherein both inputs and outputs were considered in the analysis.

The findings from the study will provide some implications to the rubber smallholders or even the government, i.e. RISDA as well as agricultural planners, to devise a strategy in order to increase the productivity of the rubber smallholders in Malaysia. The findings are anticipated to give some light and direction in formulating policies, laws, regulations, and strategies pertaining to any performance issues so that the productivity is in balance with the performance of rubber smallholders. Properly designed environmental regulations will encourage the rubber smallholders to operate in an efficient manner.

Despite the relevance and importance of this study, like any other study, it has limitations. Data availability is limited in this study. A possibility for future studies with regards to empirical research is that the studies should also take into account labour; pesticides and fertilizer costs; fixed assets; and equipment value in the analysis. It might be useful to take all these elements into consideration so that the results can be used to make a generalization on the production process of the rubber smallholders.

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