Total Factor Productivity: How Productive is the Palm Oil Milling Sector in Malaysia?

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ABSTRACT

This study investigates the total factor productivity (TFP) growth for Malaysian palm oil mills over the period 2010 – 2014, using the stochastic frontier analysis (SFA) model. TFP focuses on three components, namely, technical efficiency (TE), technical progress (TP), and scale components (SC). The first step in estimating TFP comprises specification and estimation of SFA, followed by tests for specification of the stochastic production functions. Secondly, it involves the selected specification of a regression model used to predict the TE effects. The empirical results show that productivity growth was driven mainly by TE, followed by TP. However, the change in SC had a small effect on productivity growth. Overall, results of the study suggest that there is an opportunity to improve productivity growth in the palm oil milling sector in Malaysia, for instance, by improving working conditions, upgrading the capacity of the mills, and providing incentives and rewards to the workers.

Keywords: total factor productivity, Malaysian palm oil mills, technical progress, technical efficiency, scale components.

INTRODUCTION

The Malaysian oil palm industry has been developing rapidly for the past few decades in line with the development of the oil palm plantation sector. The planted area increased by more than double to 5.64 million hectares in 2015 from 2.03 million hectares in 1990 (*Table 1*). The same trend also occurred in the palm oil milling sector as there is a parallel development between these two sectors. There were only 261 palm oil mills in operation with a total processing capacity of 42.9 million tonnes of fresh fruit bunches (FFB) per year, which then increased to 445 mills with a total capacity of 108.4 million tonnes (*Table 2*) in 2015. Out of these 445 mills, 243 (54.7%) were located in Peninsular Malaysia, 129 (29.0%) mills in Sabah and the balance of 73 (16.4%) in Sarawak (*Table 3*).

In Peninsular Malaysia, most of the palm oil mills were located in Pahang (71 mills) and Johor (61

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TABLE 1. OIL PALM PLANTED AREA BY CATEGORY: 1990, 2010 - 2015

Year	Area			Total area (million hectares)	CAGR (%)
	Private estates	Government schemes	Smallholdings		
1990	0.912	0.934	0.184	2.029	-
2010	2.935	1.268	0.651	4.854	4.46
2011	3.037	1.265	0.697	5.000	3.02
2012	3.127	1.258	0.692	5.077	1.54
2013	3.219	1.263	0.748	5.230	3.01
2014	3.317	1.268	0.807	5.392	3.11
2015	3.447	1.313	0.883	5.643	4.65

Note: CAGR – Compound Annual Growth Rate.
Source: MPOB (1990; 2010; 2012; 2013; 2014; 2015).

TABLE 2. NUMBER OF OPERATING PALM OIL MILLS AND THEIR TOTAL CAPACITY IN MALAYSIA: 1990, 2010-2015

Year	Number of mills	Capacity (million tonnes FFB per year)	CAGR (%)
1990	261	42.874	
2010	421	97.381	4.19
2011	426	99.852	2.52
2012	432	102.342	2.49
2013	434	104.090	1.71
2014	443	106.708	2.52
2015	445	108.396	1.58

Note: FFB - fresh fruit bunches.
CAGR - Compound Annual Growth Rate.
Source: MPOB (1990; 2010; 2012; 2013; 2014; 2015).

TABLE 3. NUMBER OF MILLS IN OPERATION ACCORDING TO STATE, MALAYSIA: 2015

State	Number of mills	Capacity (million tonnes)
Johor	61	15.885
Kedah	6	1.564
Kelantan	10	1.679
Negeri Sembilan	15	3.509
Pahang	71	15.692
Perak	45	10.303
Selangor	17	3.330
Terengganu	13	3.318
Other states	5	1.056
Peninsular Malaysia	243	56.336
Sabah	129	33.763
Sarawak	73	18.297
Sabah/Sarawak	202	52.060
Malaysia	445	108.396

Source: MPOB (2015).

mills), having a combined capacity to process about 32 million tonnes of FFB per year. It is also noted that these two states accounted for the largest oil palm planted areas in Peninsular Malaysia. In 2015, the oil palm planted areas in Johor and Pahang were 739 583 and 725 239 ha, respectively.

According to Azman (2014), palm oil mills processing their own crop normally produced better quality of crude palm oil (CPO) as well as achieved a higher oil extraction rate (OER) compared with mills processing crops from other estates. This is because less time is needed to transport FFB from the estates to the mills. Therefore, on site FFB can be processed immediately, taking less processing time than for mills processing crops transported from elsewhere. This is a very important consideration because to achieve better quality of CPO, FFB should be processed as soon as possible after harvest. However, some palm oil mills which process their own crops still needed to buy FFB from other estates or smallholders in order to fully exploit their capacity.

The only study done on productivity growth of the palm oil downstream sector, especially palm oil milling, was conducted by Norhidayu *et al*. (2014). The study focussed on total factor productivity (TFP) for the three palm oil sectors, namely, palm oil milling, palm kernel crushing and palm oil refining. Among these three sectors, palm oil milling showed the lowest TFP at 0.3994.

The above study, however, has its limitations as it was unable to explain the low TFP for the palm oil milling sector. The main reasons could be that only a small number of mills (71) out of 443 palm oil mills in operation were involved, and that the study used only three variables from the Manufacturing Industries Annual Survey conducted by the Malaysian Department of Statistics to explain productivity. The period of the study is also quite obsolete, *i.e*. from 2005-2010. Thus, there is a need to analyse further the productivity of palm oil mills to explain their low TFP.

LITERATURE REVIEW

There are a few studies done on TFP in Malaysia for different industries. Among them is a study carried out on 32 Malaysian food manufacturing sub-industries for the period 2002 to 2007. The findings indicate that TFP only grew at a slow rate of 0.3% per annum despite an encouraging frontier shift or innovative improvement of 3.4% per annum. Only three sub-industries were found to be operating effectively, while 29 exhibited variable returns to scale, indicating the need for operation adjustment. The findings suggest that 18 of these sub-industries should scale down, while 11 should expand their scale of operation if they were to operate on the efficient frontier (Mohamad and Said, 2010).

Another study investigated productivity growth and efficiency of large-scale enterprises (LSE) in the Malaysian food processing industry for the period from 2000-2006. The findings suggest that average technical efficiency (TE) of LSE was 0.683 during the period of observation, which indicates that the firms were able to expand their output by as much as 31.7% using the same level of inputs. TFP growth was positive at 7.3%, which was contributed by a TE change of 4.3% and a technological change of 3.0% (Yodfiatfinda *et al*., 2012).

Another interesting study was done on balanced panel data consisting of annual time-series observations for 5112 Malaysian manufacturing firms during the period 2000 to 2004. The sample covered all the companies within the five main manufacturing industries from the Annual Survey of Manufacturing Industries for the year 2000–2004 by the Malaysian Department of Statistics. The results show that total TFP was driven mainly by technical progress (TP), but was adversely affected by deteriorating TE. A change in scale components (SC) and allocative efficiency, also exerted significant influences on TFP. The skill and quality of the workers were the most important determinants for TE, whereas foreign ownership, imports and employee quality underpinned TP (Kim and Mazlina, 2009).

While some studies on palm oil TE were revealed by the literature review conducted, a study on TFP in the context of Malaysia has yet to be found, except for the work by Norhidayu (2014). TFP growth was calculated as the sum of the changes in TE and TP, and the change in SEC. In the Malaysian palm oil milling sector, TE had been a key contributor to TFP growth at 0.3994. The lowest TFP values recorded were 0.1016, 0.1395 and 0.1672. All of these were for mills which were registered as private limited companies, located in Perak and Sabah. The low TFP recorded was due mainly to low TE and SEC obtained for the period 2005-2010. It was highly recommended for these mills to enhance the efficient use of existing technology to catch up with frontier technology, and at the same time improve the quality of their workers such as by job training and optimum working hours.

METHODOLOGY

This study used primary data which were collected through the sampling technique using a questionnaire. The questionnaire was designed and sent to palm oil mills via e-mail and fax. Realising the fact that self-administered e-mailed and faxed questionnaires usually have a relatively low response rate, and may have a relatively high number of incomplete responses (Keller, 2008), this study also conducted telephone interviews on respondents who did not return the completed questionnaire.

The minimum sample size for this study was determined using the standard sample size determination formula for a finite population (Keller, 2008; Berenson *et al*., 2014):

$$n = \frac{n_0 N}{n_0 + (N-1)}\ ;\ n_0 = \left(\frac{Z_{\alpha/2}}{ME}\right) p(1-p)$$

where:

n = required sample size;
n_0 = sample size for infinite population;
N = population size;
$Z_{\alpha/2}$ = Z critical value at chosen confidence level;
P = proportion of population; and
ME = margin of error.

According to the *Malaysian Oil Palm Statistics 2015* compiled by the Malaysian Palm Oil Board (MPOB), there were 443 palm oil mills in Malaysia in 2014. Based on the sampling technique, the minimum number of respondents to be interviewed in this study was 95. For the study, a total of 115 respondents were surveyed via fax, e-mail or by telephone.

A structured questionnaire was carefully designed with the aid of officers from the Engineering and Processing Research Division and the Economics & Industry Development Division of MPOB. The completed questionnaire was then tested on selected palm oil mills in Negeri Sembilan, Pahang and Johor in Malaysia, for further comments and to gauge the reliability of the questionnaire. The completed questionnaire was then circulated to all palm oil mills in Malaysia via fax.

The questionnaire was divided into four parts. The first part covered questions on the profile of the palm oil mills [*i.e.* type of steriliser, planted area (as source of own crop), fixed assets and number of employees]. The second part elicited information on productivity measurements (*e.g.* technology changes, factors effecting productivity and incentives given). Meanwhile, the third part covered the millers' perceptions on processing efficiency (*e.g.* factors contributing to mill efficiency).

RESULTS AND DISCUSSION

Frontier Model

In this study, the Stochastic Frontier Production Model was used, which was modified from the earlier version by Battese and Coelli (1996). They proposed a time-varying model for the TE effects in the Stochastic Frontier Production for panel data. In this study, the maximum-likelihood estimates of the parameters of the model and the predictors of TE were calculated using Stochastic Frontier Production and Cost Function Estimation. Details of the programme are found in Coelli (1996) and the method can be outlined as follows:

$$\ln V_i - = X_i - \beta t\ (v_i; - X_i)$$

where:

$\ln V_i$ = log of scalar output for i-th firm;
X_i = row of logs of *K* inputs by i-th firm;
β = column vector of *K* unknown coefficients;
$(v_i - u_i)$ = capture measurement error, random factors and other noise.

There were two production processes that can be utilised in this study which were represented by $Q = f(K, L, M)$ and $V = f(K, L)$. They are represented by the following respective translog production functions:

$$\ln Q_{it} = \alpha_0 + \alpha_t T + \alpha_K \ln K_{it} + \alpha_L \ln L_{it} + \alpha_M \ln M_{it} + 0.5\beta_{KK} (\ln K_{it})^2 + 0.5\beta_{LL} (\ln L_{it})^2 + 0.5\beta_{MM} (\ln M_{it})^2 + \beta_{KL} \ln K_{it} \ln L_{it} + \beta_{KM} \ln K_{it} \ln M_{it} + \beta_{LM} \ln L_{it} \ln M_{it} + \beta_{Kt} \ln K_{it} T + \beta_{Lt} \ln L_{it} T + \beta_{Mt} \ln M_{it} T + 0.5\beta_{tt} T^2 + \varepsilon_{it}$$

or

$$\ln V_{it} = \alpha_0 + \alpha_t T + \alpha_K \ln K_{it} + \alpha_L \ln L_{it} + 0.5\beta_{KK} (\ln K_{it})^2 + 0.5\beta_{LL} (\ln L_{it})^2 + \beta_{KL} \ln K_{it} \ln L_{it} + \beta_{Kt} \ln K_{it} T + \beta_{Lt} \ln L_{it} T + 0.5\beta_{tt} T^2 + \varepsilon_{it}$$

where:

Q_{it} = gross value of output for the sector, *i* at time, *t*;
V_{it} = value-added for the sector, *i* at time, *t*;
α_x, β_x = coefficients of the production function;
K_{it} = total capital input for the sector, *i* at time, *t*;
L_{it} = total labour input for the sector, *i* at time, *t*;
M_{it} = total material input for the sector, *i* at time, *t*;
T = time; and
ε_{it} = error term.

There were basically two common functional forms of production used in studying TE using Stochastic Production Functions, namely, the Cobb-Douglas and general translog functional forms. They are represented by the following translog:

$$\ln V_{it} = \beta_0 + \sum_j \beta_j \ln X_{jit} + \beta_t T + 0.5\sum_j\sum_k \beta_{tk} \ln X_{jit} \ln X_{kit} + 0.5\,\beta_{tt} T^2 + \sum_j \beta_{jt} T \ln X_{jit} + v_{jit} - u_{it}$$

where the subscripts *i* and *t* indicate firm and time; *V* is the output; X_j is a vector of inputs, and subscripts *j* and *k* index inputs. The efficiency error, *u*, represents production loss due to firm-specific technical inefficiency. Thus, it is always greater than or equal to zero ($u \geq 0$), and it is assumed to be independent of the statistical error, *v*, that is assumed to be independently and identically distributed.

The stochastic frontier model allows for non-neutral TP. TP is input *j*-using (saving) if βTj is positive (negative): and TP is neutral if all βTjs ($j = L, K$) are equal to zero. If all βs are equal to zero (βLL = βKK = βLK = βTT = βTL = βTK = 0), the production function reduces to the Cobb-Douglas function with neutral TP (Kim and Han, 2001). Significance of the neutral and non-neutral technical changes in the model can be tested by using the generalised likelihood test.

Model Estimation

The data consisted of annual time series for 115 palm oil mills, which operated from years 2010 to 2014. The required data for the studies were crude palm oil (CPO) production (*V*), value of assets (K), total number of workers (*L*) and utilisation rate (*U*).

Maximum likelihood estimation was used to estimate the parameters of the Stochastic Frontier Function as proposed by Battese and Coelli (1995). TE of the palm oil milling sector in Malaysia was estimated by using a translog production frontier as follows:

$$\ln V = \beta_0 + \beta_1 \ln K + \beta_2 \ln L + \beta_3 \ln U + \beta_4 t + 0.5 (\beta_5 \ln K \ln K + \beta_6 \ln L \ln L + \beta_7 \ln U \, Ln \, U + \beta_8 t\, t) + \beta_9 \ln K \ln L + \beta_{10} \ln K \ln U + \beta_{11} \ln K t + \beta_{12} \ln L \ln U + \beta_{13} \ln L t + \beta_{14} \ln U t + (v_{it} - u_{it})$$

where the subscripts *i* and *t* indicate firm and time; *V* is production of CPO; *K* is capital; *L* is labour; *U* is utilisation rate, and $(v_{it} - u_{it})$ is the error term.

The software program, FRONTIER 4.1C, was used for estimation of the Stochastic Frontier Production Function. The software was made available by Professor Tim Coelli from the Centre for Efficiency and Productivity Analysis (CEPA).

Specification Testing

Tables 4 and *5* present the likelihood ratio test of various null hypotheses on the total sample of palm oil mills in Malaysia. The likelihood-ratio test statistic is $\lambda = -2[L (H0) - L (H1)]$, where L (H0) and L (H1) are the values of the log-likelihood function under specifications of the null and alternative hypotheses, H0 and H1, respectively. If the null hypothesis is true, then λ has approximately a Chi-square (or a mixed Chi-square) distribution with degrees of freedom equal to the number of restrictions. If the null hypothesis includes Y = 0, then the asymptotic distribution is a mixed Chi-square distribution (Coelli and Battese, 1996).

In *Table 4*, the first null hypothesis that represented no technical inefficiency effects (H_0: $\gamma = \mu = \eta = 0$) was rejected at the 1% significance level for the total sample. The result suggests that the average production function or ordinary least square (OLS) was an inadequate representation of the Malaysian palm oil milling sector, and underestimated the actual frontier because of the technical inefficiency effects.

The second null hypothesis was time-invariant and was obtained by imposing the restrictions of H_0: $\eta = 0$. This hypothesis was not rejected at the 1% significance level which indicated technical inefficiency in the Malaysian palm oil milling sector is time-invariant.

The third and fourth null hypotheses, that there was no technical change of H_0: $\alpha_t = \beta_{tt} = \beta_{tl} = \beta_{tk} = 0$ and where TP was neutral of H_0: $\beta_t = \beta_{tl} = \beta_{tk} = 0$, were not rejected at $p = 1\%$. This implied the existence of non-neutral technical progress in the Malaysian palm oil milling sector.

The last null hypothesis, that the technology in Malaysian palm oil mills was not a Cobb-Douglas production function (H_0: $\beta_{ll} = \beta_{kk} = \beta_{lk} = \beta_{tt} = 0$), was rejected at the 1% significance level.

Thus, the specification of a full translog model with time-invariant technical inefficiency is appropriate to represent the Malaysian palm oil milling sector. The model is as follows:

$$\ln V = \beta_0 + \beta_k \ln K + \beta_l \ln L + \beta_u \ln U + \beta_t t + 0.5 (\beta_{kk} \ln K \ln K + \beta_{ll} \ln L \ln L + \beta_{uu} \ln U \, Ln \, U + \beta_8 t\, t) + \beta_{kl} \ln K \ln L + \beta_{ku} \ln K \ln U + \beta_{kt} \ln K t + \beta_{lu} \ln L \ln U + \beta_{lt} \ln L t + \beta_{ut} \ln U t + (v_{it} - u_{it})$$

The parameter estimates for the palm oil milling sector are presented in *Table 5*.

Components of Total Factor Productivity (TFP) Growth

In this study, TFP growth focused on three components, *i.e.* rate of TP, change of SC, and change in TE.

TE change can be estimated using the following equation:

$$TE = \frac{\partial u_{it}}{\partial T} = \eta \exp[-\eta(t - T)]$$

where TE can be interpreted as the rate at which firms move from the production frontier.

The rate of technological progress can be estimated as follows:

$$TP = \frac{\partial \ln V_{it}}{\partial T} = \beta_t + \beta_{tt} + \beta_{kt} \ln K_{it} + \beta_{it} \ln L_{it} + \beta_{ut} \ln U_{it}$$

Meanwhile, the change in SC is the elasticity of inputs contributing to TFP growth as follows:

$$SC = (e-1)\left(\frac{ek}{e}\Delta K + \frac{el}{e}\Delta L + \frac{eu}{e}\Delta U\right)$$

where *ek*, *el* and *eu* are elasticities of output with respect to capital, labour and utilisation rate.

Therefore, by using this method, TFP growth can be equated as follows:

$$\Delta TFP = \Delta TE + TP + SC = \eta \exp[-\eta(t-T)] + (\beta_i + \beta_{tt} t + \beta_{kt} \ln K_{it} + \beta_{it} \ln L_{it} + \beta_{it} \ln U_{it}) + \left[(e-1)\left(\frac{ek}{e}\Delta K + \frac{el}{e}\Delta L + \frac{el}{e}\Delta U\right)\right] + (v_{it} - u_{it})$$

Technical Efficiency (TE)

The estimated average TE for the palm oil milling sector in Malaysia for the period 2010 - 2014 stood at 0.4595 for the total sample of

TABLE 4. STATISTICS FOR TEST OF HYPOTHESES: STOCHASTIC PRODUCTION FUNCTION FOR MALAYSIAN PALM OIL MILLS

Null hypothesis	Log-likelihood function	Test statistics (λ)	Critical value	Decision
1. No technical inefficiency $H_0: \gamma = \mu = \eta = 0$ $H_1: \beta k = \beta l = \beta u = \beta t = \beta kk$ $= \beta ll = \beta uu = \beta tt = \beta kl = \beta ku$ $= \beta kt = \beta lu = \beta lt = \beta ut$	-197.1102	736.4906	10.5	Reject H_0
2. Time-invariant $H_0: \eta = 0$ $H_1: \beta k = \beta l = \beta u = \beta t = \beta kk$ $= \beta ll = \beta uu = \beta tt = \beta kl = \beta ku$ $= \beta kt = \beta lu = \beta lt = \beta ut$	168.2169	5.8364	6.64	Do not reject H_0
3. No technical change $H_0: \alpha t = \beta tt = \beta tl = \beta tk = \beta tu = 0$ $H_1: \beta k = \beta l = \beta u = \beta kk = \beta ll$ $= \beta uu = \beta kl = \beta ku = \beta lu$	163.6380	14.9942	16.81	Do not reject H_0
4. Technically neutral $H_0: \beta tl = \beta tk = \beta tu = 0$ $H_1: \beta k = \beta l = \beta u = \beta t = \beta kl$ $= \beta ll = \beta uu = \beta tt = \beta ku = \beta lu = \beta lt$	166.3013	9.6676	13.28	Do not reject H_0
5. Cobb Douglas $H_0: \beta ll = \beta kk = \beta tt = \beta uu$ $= \beta kl = \beta ku = \beta kt = \beta lu$ $= \beta lt = \beta ut = 0$ $H_1: \beta k = \beta l = \beta u = \beta t$	84.8443	172.5816	30.58	Reject H_0

Note: Rejection of the null hypothesis was at the 1% significance level.

115 palm oil mills. The top five highest estimates for the palm oil mills were 0.9253, 0.9177, 0.8573, 0.8402 and 0.8175 for the mills located in Johor, Sabah, Sabah, Sarawak and Sabah, respectively. The least efficient palm oil mill was a private limited mill in Negeri Sembilan with TE of 0.1160.

Technical Progress (TP)

The full translog production function is the appropriate model for the Malaysian palm oil milling sector, as defined in the equation below. Thus, TP for the sector is defined as follows:

$$TP = \partial V/\partial T$$
$$= \beta_t + \beta_{tt}\, t + \beta_{Kt} \ln K_{it} + \beta_{lt} \ln L_{it} + \beta_{ut} \ln U_{it}$$

The average TP for palm oil mills was 0.0089 for the period 2010 - 2014. TP was related to effective and efficient utilisation of technology, capital, work attitudes and management. Based on the experiences gained in developed countries, TP should eventually be the main source of TFP growth, given the limits of economic restructuring and improvement of the educational profile of the workforce. However, based on the data collected, most of the mills were still using the conventional batch steriliser, which requires more unskilled workers to operate it. In contrast, the other types of sterilisers require fewer

TABLE 5. PARAMETER ESTIMATES OF THE PRODUCTION FUNCTION FOR MALAYSIAN PALM OIL MILLS

Variable	Parameter	Coefficient	Standard error	t-ratio
Intercept	β_0	-5.2131	1.0240	-5.0909
ln K	β_k	0.0087	0.0852	0.1024
ln L	β_l	2.0058	0.2803	7.1573*
ln U	β_u	1.3158	0.2807	4.6873*
t	β_t	-0.0387	0.0399	-0.9713
0.5(ln K)^2	β_{kk}	0.0240	0.0082	2.9376*
0.5(ln L)^2	β_{ll}	-0.1879	0.0531	-3.5365*
0.5(ln U)^2	β_{uu}	0.2295	0.0510	4.4998*
0.5(ln t)^2	β_{tt}	0.0093	0.0049	1.8919
(ln K) (ln L)	β_{kl}	-0.0127	0.0163	-0.7796
(ln K) (ln U)	β_{ku}	-0.0478	0.0153	-3.1299*
(ln K) (t)	β_{kt}	0.0025	0.0022	1.1497
(ln L) (ln U)	β_{lu}	-0.1962	0.0438	-4.4764*
(ln L) (t)	β_{lt}	0.0012	0.0060	0.2043
(ln U) (t)	β_{ut}	-0.0035	0.0081	-0.4366
	σ^2	0.1613	0.0257	6.2835
	Υ	0.9647	0.0038	257.1017
	μ	0.7888	0.0639	12.3372
η is restricted to be zero				
Log likelihood function = 168.2169				

Note: *Significant at 5% level.

workers and produce more output efficiently.

Scale Components (SC)

For the period 2010 – 2014, the estimated average growth rate of SC for palm oil mills stood at 0.0005. The small value of the estimated SC implies that the mills in this study had already reached a certain size where scale economies no longer exist.

Total Factor Productivity (TFP)

TFP growth is calculated as the sum of changes in TE, TP and the change in SC. In the Malaysian palm oil milling sector, TE has been a key contributor to its growth.

The average TFP for the palm oil milling sector over the years 2010 - 2014 was 0.4689. The top three highest TFP stood at 0.9376, 0.9286 and 0.8694, which were for mills located in Johor, Sabah and Sabah, respectively. Generally, all of these mills had their own plantation area, a large processing capacity of more than 90 t/hr and achieved an average OER above 20%.

Meanwhile, the three lowest TFP were 0.1227, 0.1591 and 0.1674. The mills concerned were located in Negeri Sembilan, Perak and Perak, respectively. Generally, all of these mills had a small processing capacity, *i.e.* less than 20 t/hr, with the age of mill being more than 20 years, except for one mill in Negeri Sembilan which was previously a training centre, and recorded an average OER of 20% or below.

CONCLUSION

The empirical results of this study show that productivity growth of the Malaysian palm oil milling sector was driven mainly by change in TE and slightly by TP. However, change in SC had a negative effect on productivity growth. Thus, the results suggest that there are opportunities to improve productivity growth in the palm oil milling sector. The mills should improve their productivity by introducing policies to induce technological innovation in order to move up the production frontier, and it is highly recommended that they apply known technologies, which includes improvement in learning-by-doing processes and improvement in managerial practices.

As a result of the follow-up interview with the palm oil mills which attained high TFP, it is recommended that the less productive mills (which achieved 0.50 TFP and below) emulate the management practices of the more productive mills. It is also highly recommended for the mills to inject more capital into upgrading their processing capacity and machinery.

It is highly recommended that the palm oil mills processing their own crops conduct regular meetings with their estate managers in order to deliver their requirements and expectations on the FFB quality received. By doing so, the quality of FFB and, subsequently, that of the throughput can be monitored. For palm oil mills processing crops from outside their estates, an agreement can be made between these mills and the FFB dealers to ensure the quality of FFB received.

Incentives can be one of the motivational factors to boost employee productivity. These can be in terms of monetary or non-monetary incentives, for instance, monthly cash incentive, yearly bonus, company's family day trip and vouchers/coupons when certain key performance index (KPI) are achieved. KPI can be set up based on production of monthly throughput, less usage of power/electricity, zero recorded working accidents, or no recorded absence from work, and favourable audits from internal or external auditors.

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