Economics Bulletin

Volume 41, Issue 4

Does Firm Size Matter? Evidence from Indonesian Manufacturing Firms

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Abstract

We examine the impact of firm size and international exposure i.e., foreign direct investment (FDI) and imports on firms' technical efficiency in five manufacturing sub-sectors in Indonesia from 2001 to 2015. Firm-level data is used to estimate a stochastic production frontier with the time-variant model. Three indicators proxy the firm size based on the sales (market share), capital, and labour to test whether firm size matters for both domestic and foreign firms, as well as for importer-non-importer firms. Generally, foreign owned firms and companies with higher access to foreign inputs report larger efficiency. Firm size as indicated by market share and the number of labour positively affects efficiency. However, the positive effect of firm size (market share) are mitigated by FDI and import intensity. On the other hand, the effect of firm size as indicated by capital intensity has a positive impact on technical inefficiency. However, the adverse effect from high intensity of capital is lessened when large firms have access to imported materials. The impact of size (capital) on technical efficiency is larger for high technology subsectors e.g., pharmaceutical, as they have high fixed cost, hence larger minimum efficient scale. Among the three size indicators, the proxy related to labour has the largest correlation with technical efficiency, suggesting that it is the most appropriate one. Firms' technical efficiency is divergent over time, driven primarily by capital inputs

This research was supported by the Research Grant Hibah Penelitian Mandat Universitas Airlangga 2022
Citation: Mohammad Zeqi Yasin and Miguel Angel Esquivias and Suyanto Suyanto, (2021) "Does Firm Size Matter? Evidence from Indonesian Manufacturing Firms", *Economics Bulletin*, Vol. 41 No. 4 pp. 2401-2417.
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Submitted: July 19, 2021. **Published:** December 29, 2021.

1. Introduction

The nexus between firm size and productivity remains an intriguing issue in the field of industrial organisation as it still reveals ambiguous findings amongst studies. Some scholars stated that large firms are associated with higher productivity benefiting from economies of scale. Large enterprises can employ more sophisticated technology and often have larger access to capital, helping them to press down production costs (Charoenrat et al., 2013; Ciani et al., 2020; Sari et al., 2016; Toma, 2020). Lucas (1978) believed that large firms also benefit from managerial expertise that allows for optimum production, namely more output produced from the available ratio of inputs. They may also enjoy wider access to credit for investment and hire highly-skilled professionals, giving a competitive edge in achieving greater diversification (Toma, 2020). In addition, large firms also benefit from foreign direct investment (FDI) as they have more international exposure and are linked to a network of foreign affiliates. All of this increases the bargaining power of large foreign affiliated firms in a domestic market where they operate (Fu & Gong, 2011; Suyanto et al., 2012).

However, some other studies have revealed the opposite findings. Large size does not necessarily support higher firm performance. Other factors, e.g., the firm's age, the managerial ability, the capital ownership, the country's economic development level, and the government regulation, are also important determinants in promoting higher firm performance (Ciani et al., 2020). Diaz and Sanchez (2008) argued that small and medium enterprises (SMEs) may be more efficient than large firms because they do not have the complexity and barriers faced by large firms in in terms of organisational and managerial control. Meanwhile, smaller firms have more flexibility and the ability to develop and adopt new capabilities (Drbevich & Kriauciunas, 2011; Hernández-linares et al., 2018). The least efficient SMEs may exit the market more easily under economic downfall, while the most efficient ones remain (Toma, 2020). The self-selection mechanism is common in SMEs as they faced lower exit barriers. This may explain why SMEs appear to be more efficient than large firms, which often have higher exit barriers.

The mixed findings on whether firm size favours enterprise performance may stem from the methodology issues or the a priori assumptions in the models. Using a single indicator to proxy a firm's size may be the source of the disagreement. For instance, Sari (2019) and Sari et al. (2016) only employed the share of output from the total sub-industrial output to measure a firm's size. Other studies (Sugiharti et al., 2019; Esquivias & Hariyanto, 2020) classify Indonesian firms as medium or large according to the number of workers, finding that larger firms experienced lower technical inefficiency. Nevertheless, a single indicator of firm size may not capture the entire picture of how size affects a firm's efficiency, missing the role of capital, labor, or output—three aspects essential in determining economies of scale.

Several other studies capture the role of firm size and foreign-owned structure individually but did not look into the interacting effect of firm size and ownership (Mohan & Mohan, 2020; Orlic et al., 2018; Yasin, 2020). Ciani et al. (2020) noted that combining the effects of firm size and ownership may influence the economic performance, allowing firms to achieve different levels of productivity.

Therefore, in this paper, we examine the impact of enterprise size on a firm's performance, which we captured via technical efficiency (TE). We propose three indicators to capture the impact of size on firm's technical efficiency. We measure TE in five Indonesian manufacturing subsectors: pharmaceutical, chemical, rubber, plastic, and foods and beverages. These five industries are aggregated according to the OECD classification of technology intensity (2011).

This study contributes to the literature on firm performance in several ways. First, we employ three indicators to capture the impact of size on firm's technical efficiency: 1) share of firm's sales in total sub-sector sales (market share); 2) share of firm's capital in total sub-sector capital;

3) the number of employees. Second, we use interaction variables between international exposure (imported raw material intensity and foreign capital) and firm size to capture the combined effect of size and foreign exposure in promoting technical efficiency. The result will disclose to what extent firm size matters for domestic-owned firms, foreign firms, and importer firms. Third, we use 15 years (2001-2015) of firm level data, while most Indonesian cases employ no more than ten years or use less recent data.

The investigation of the technical efficiency determinants is of great importance in evaluating firm-level performance. Instead of merely scrutinizing the productivity growth based on the standard theory of production, technical efficiency will capture the variation of firms' economic achievements. Classical theory on production growth assumes that firms operate at full efficiency. This is an ill-suited postulation for the real world. Variation in efficiency derives from firm-specific managerial expertise, diverse operating environment, and differences in regulatory restrictions across sectors and regions (Page, 1984; Parmeter & Kumbhakar, 2014).

Earlier studies in Indonesia have identified that foreign-owned firms achieve higher technical efficiency than domestic firms in the pharmaceutical sector (Suyanto & Salim, 2011), although missing the effects of firm size. Suatmi et al. (2017) analysed the role of rate of effective protection, import penetration, and foreign investment in the chemical sector, finding that a larger share of imports and FDI is associated with more efficient operations. Nevertheless, firm size was not analysed. Setiawan & Lansink (2018) look into the food and beverage sector, finding that sub-sectors, where large firms operate (output), are associated with lower efficiency levels. In none of the abovementioned studies, more than one measurement of size is employed (if ever). Similarly, no interaction between foreign-owned firms or international exposure (trade) variables with the firm size is tested, opening a research gap for our paper.

2. Data and Model Specification

This study employs Indonesian firm-level data of the large and medium manufacturing industry (IBS) annually surveyed by Statistics Indonesia from 2001 to 2015. Five subsectors are taken from the Indonesian Standard Classification of Business Fields or *Klasifikasi Baku Lapangan Usaha Indonesia* (KBLI): foods Industry (KBLI 10), beverages (KBLI 11), chemical (KBLI 20), pharmaceutical (KBLI 21), and rubber and plastic (KBLI 22). The number of firms may change over time because of exit-entry behaviour. However, selecting balanced panel data limits the number of firms to be examined[1]. In this regard, this study uses unbalanced-panel data with 70,206 observations with the minimum number of 2,259 manufacturing establishments in 2006 and the maximum number of 5,322 firms in 2013.

There are two groups of variables in this study. The first group includes the variables related to a conventional production function, e.g. total output, capital (approximated by fixed assets such as land, building, machinery, equipment, and vehicles), number of workers, energy (approximated by fuel and lubricants utilization), and raw material. The monetary variables are in Indonesian Rupiah. The second group contains variables that may affect technical efficiency: firm size, imported material intensity, and foreign-owned capital ownership.

There are three indicators of firm size in this study. The first indicator is FS^S, calculated from the share of sales of firm i in the subsector j at year t. The variable of sales is obtained from the total production plus beginning inventory substracted by ending inventory[2]. The

[1] The number of firms would be reduced by 97.92% if balanced panel data is employed. Efficiency estimates vary if firms that enter and exit the market are omitted from the sample; they are an important in the theory of selection.
[2] We do not use share of total output as some prior studies did (see: Esquivias & Harianto, 2020; Sari, 2019; Sari et al., 2016) to avoid possible endogeneity issue.

second is FS^K is calculated from the ratio between the capital of firm i in the subsector j and the total capital of subsector j. The third indicator is FS^L, calculated from the number of workers classified by Statistics Indonesia: if a firm has 100 workers or more, it is classified as a large, while medium-firm empowers workers between 20-99 (Wiboonchutikula et al., 2016; Widodo et al., 2015)[3].

Other variables taken into account are imported material intensity (*IMP*) calculated from the ratio of imported raw material and total materials (Sari et al., 2016; Yahmed & Dougherty, 2016; Yasin, 2020) and foreign-owned capital ownership (*FOR*). The *FOR* variable is in dummy where a firm is categorized as foreign if the percentage of foreign-capital ownership share exceeds a certain threshold (Sari, 2019). Although the rate of foreign share ownership in a firm consists of several thresholds, this study refers to the 5 per cent (Haddad & Harrison, 1993). Table 1 reports the descriptive statistics of all variables that are employed in this study.

In this study, the time-varying stochastic production function (SF) of Battese and Coelli (1995) is taken into account to capture the effect of firm size on the firms' technical efficiency. The Transcendental Logarithmic (Translog) is used as the primary stochastic production frontier model as it is more flexible for recognizing non-fixed substitution elasticity. Similarly, the Translog function imposes fewer constraints than those in a general logarithm linear model, e.g., Cobb-Douglas (Christensen et al. 1973). Moreover, the Translog function does not inflict constant elasticity of substitution, as the Cobb-Douglas model does (Kumbhakar & Wang 2005; Wang & Wong, 2012). The Translog specification is expressed in the following form:

$$y_{it} = \beta_0 + \sum_{n=1}^{N} \beta_n xn_{it} + \frac{1}{2}\sum_{n=1}^{N}\sum_{m=1}^{N} \beta_{nm}\, xn_{it} xm_{it} + \beta_t t + \frac{1}{2}\beta_{tt} t^2 + \sum_{m=1}^{N} \beta_{nt}\, xn_{it} t_{it} + v_{it} - u_{it} \quad (1)$$

where y is the total output, xn represents inputs consisting of capital (k), labour (l), energy (e), and raw materials (r). All output and inputs are expressed in the natural logarithm (ln) and as a deviation from their geometric means. Subscripts i and t denote i-th firm and t-th year. v_{it} is the SF model's random variable assumed as $iid.\, N(0, \sigma_v^2)$, and u_{it} is a non-negative random variable assumed as half-truncated following a normal distribution $N(\mu, \sigma^2)$ and the exponential specification of time-varying firm effects following Battese & Coelli (1992). The u_{it} represents the inefficiency parameter that captures inefficiency effects, specified as below:

$$u_{it} = \delta_0 + \sum_{k=1}^{K} \delta_k Zk_{it} + \omega_{it} \quad (2)$$

Where δ_k is the coefficient of the inefficiency effects Zk, ω_{it} is defined by the truncation of the normal distribution with zero mean and variance, σ^2 or $\omega_{it} \sim N^+(0, \sigma_\omega^2)$ subject to the point of truncation is -$z_{it}\delta$. This assumption implies that the random variable ω_{it} could be negative if $z_{it}\delta > 0, i.e.\, \omega_{it} \geq -z_{it}\delta$. As shown by Battese and Coelli (1995), this assumption is consistent with the assumption of u_{it} (the technical inefficiency term). Equation (2) can be specified as follows (three models):

$$u_{it}{}^S = \zeta_0 + \zeta_1 FS_{it}^S + \zeta_2 FDI_{it} + \zeta_3\, Imports_{it} + \zeta_4 (FS_{it}^S \times FDI_{it}) + \zeta_5 (FS_{it}^S \times Imports_{it}) + \omega_{it}^S \quad (3)$$

$$u_{it}{}^K = \vartheta_0 + \vartheta_1 FS_{it}^K + \delta_2 FDI_{it} + \vartheta_3\, Imports_{it} + \vartheta_4 (FS_{it}^K \times FDI_{it}) + \vartheta_5 (FS_{it}^K \times Imports_{it}) + \omega_{it}^K \quad (4)$$

$$u_{it}{}^L = \varphi_0 + \varphi_1 FS_{it}^L + \varphi_2 FDI_{it} + \varphi_3\, Imports_{it} + \varphi_4 (FS_{it}^L \times FDI_{it}) + \varphi_5 (FS_{it}^L \times Imports_{it}) + \omega_{it}^L \quad (5)$$

where $\zeta_0, \vartheta_0, \varphi_0$ are the constant, $\zeta_1 - \zeta_5$, $\vartheta_1 - \vartheta_5$, $\varphi_1 - \varphi_5$ represent the coefficients of inefficiency effects. FS_{it}^S is the firm size based on market share, FS_{it}^K is the firm size based on

[3] We do not use log of number of workers as in (Aggrey et al., 2010; Schiersch, 2013) as a two-step approach to identify the impact of firm size on the technical efficiency is used. Aggrey et al. (2010) use Data Envelopment Analysis to calculate TE and estimate the impact of firm size (number of workers) on TE using Generalized Least Square (GLS).

capital, FS_{it}^{L} is the firm size based on labour, FDI_{it} is the dummy for foreign owned firms, $Imports_{it}$ is the raw material intensity, ω_{it} is the error term. Three models are proposed where different measures of firm size are tested. Model 1 (Equation 3) uses only sales or market share (FS^{S}) to estimate inefficiency effects; Model 2 (Equation 4) uses capital as a proxy for firm size (FS^{K}); and Model 3 (Equation 5) employs labour (FS^{L}).

Table 1: Descriptive Statistics

Variable (Unit)		Foods		Beverages		Chemical		Pharmaceutical		Rubber and Plastic	
		Local	FDI	Local	FDI	Local	FDI	Local	FDI	Local	FDI
Y (Billion Rupiah)	Mean	28.85	326.02	16.14	115.60	95.88	254.23	52.98	374.50	43.81	286.75
	SD	232.94	1,300.48	64.53	185.39	746.43	1,016.86	187.12	4,341.00	210.93	2,505.33
K (Billion Rupiah	Mean	78.03	1,862.47	75.19	116.11	237.11	1,666.45	351.04	56.00	69.37	197.92
	SD	3,726.92	45,735.71	2,867.40	637.69	10,550.24	28,731.85	9,026.24	93.75	1,975.48	2,164.30
L (Workers)	Mean	109.63	460.97	101.76	341.54	170.17	312.79	267.73	314.98	221.07	454.08
	SD	395.65	1,142.82	174.55	369.41	508.62	999.81	440.23	284.13	641.65	699.77
E (Billion Rupiah)	Mean	0.55	5.10	0.50	2.05	3.32	6.93	0.53	0.98	1.21	2.68
	SD	6.24	25.49	2.31	4.32	37.34	62.01	2.45	2.15	37.84	7.48
R (Billion Rupiah)	Mean	19.05	208.74	4.61	44.42	48.31	123.56	19.00	161.10	30.10	228.58
	SD	152.62	932.36	23.07	85.20	384.07	360.14	87.92	1,990.08	132.07	2,394.07
Import (Ratio)	Mean	0.02	0.13	0.02	0.17	0.18	0.47	0.32	0.65	0.08	0.38
	SD	0.12	0.28	0.11	0.29	0.31	0.37	0.40	0.38	0.22	0.41
FS^{S} (Ratio)	Mean	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00
	SD	0.00	0.00	0.01	0.03	0.01	0.01	0.02	0.05	0.00	0.02
FS^{K} (Ratio)	Mean	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.01	0.00	0.01
	SD	0.01	0.02	0.03	0.06	0.02	0.05	0.05	0.02	0.01	0.04
FS^{L} (Ratio)	Mean	0.18	0.75	0.26	0.81	0.34	0.58	0.51	0.83	0.42	0.76
	SD	0.39	0.43	0.44	0.39	0.47	0.49	0.50	0.38	0.49	0.42
Observation		46,871	1,971	2,086	232	4,556	1,329	1,582	243	10,178	1,158

Source. the large and medium manufacturing industry (IBS) annually surveyed by Statistics Indonesia

The stochastic production frontier requires precise and stringent specification forms and may cause instability of numerical and statistical samples in infinite samples (Sari, 2019). To maintain the numerical and statistical samples' stability, an additional test, e.g., the generalized log-likelihood test (Kumbhakar, Wang & Horncastle 2015) is taken into account to select the proper specification form. The baseline model is Translog (TL). Meanwhile, the other two models are Hick-Neutral technological progress (HN) and Cobb-Douglas (CB). A null hypothesis (H_0) is the CD model that omits the coefficients of time, time-squared and excludes coefficients related to time in the equation (1) ($\beta_{nm} = \beta_{nt} = \beta_{tt} = \beta_t = 0$). In contrast, the HN model omits the coefficients of interacting input with time ($\beta_{nt} = 0$).

Among these three specifications, the log-likelihood ratio (LLR) test will select the most appropriate production function by comparing the log-likelihood statistic generated from the estimates using SFA and the χ^2 table. The decision of the LLR test is determined from the value of $\lambda = -2[l(H_0) - l(H_1)]$ where $l(H_0)$ is the log-likelihood statistic of the CD and HN specification. $l(H_1)$ is the log-likelihood value of the TL. The null hypothesis is rejected if the λ statistic is more than the χ^2 table with degrees of freedom equal to the number of parameters involved in the restrictions.

3. Results and Discussion

A maximum-likelihood approach was employed to estimate the Stochastic Production Frontier (Equation 1), considering the specification set for the inefficiency function (Equation

2). The LLR test is applied to analyse the results. Table 2 reports the decision taken for each of the four proposed models. By referring to α =1% in χ^2, Table 2 reveals that $\lambda > \chi^2$ for all models, suggesting that the Translog specification is the most suitable for further analysis.

Table 2: Loglikelihood Ratio Test

	HN (df=4)	CD (df=16)	No Inefficiency of CD (df=17)	Decision
Model 1	1190.7	29988.7	33584.6	TL
Model 2	476.2	30665.7	32764.4	TL
Model 3	280.4	30243.8	32755.7	TL
χ^2	13.2	31.9	6.4	

Note: Model 1 uses firm size based on output or market share (FS^S), Model 2 uses capital (FS^K), Model 3 uses labor (FS^L). TL is Translog, HN is Hicks-Neutral, CD is Cobb-Douglas, No Inefficiency of CD is the utilization of Ordinary Least Square (OLS) estimate. LLR (TL as baseline)

Table 3 shows the estimated coefficients of the production function and the inefficiency effects of the exogenous variables. Only results based on the preferred specification for each model are displayed. For robustness test purposes, in the appendix (Table 5), the results using the Cobb-Douglas approach are displayed. The result shows that the production functions for all models are robust by showing relatively similar magnitude.

3.1 Analysis of Efficiency of Indonesian manufacturing firms

The degree of international exposure measured by imported material intensity (*IMP*) and foreign ownership (*FOR*) are both negative and significant, suggesting that the larger the global exposure, the lower the technical inefficiency. The results prove our hypotheses that international exposure promotes technical efficiency in firms, in line with the theoretical model of the pro-competitive influence of trade on the productivity of Melitz and Ottaviano (2008). The findings on *IMP* and *FOR* support prior studies that revealed a positive impact of imported material intensity and foreign-owned capital ownership towards technical efficiency (Andersson & Stone, 2017; Suyanto et al., 2014; Yahmed & Dougherty, 2016). One possible reason for the positive links between *IMP* and technical efficiency is that importing firms meet stringent technical standards needed to employ more advanced technology and management practices that are offered via imported goods (Andersson & Stone, 2017; Damijan et al., 2009). Another reason is that larger import penetration results in a higher quality of raw materials that allow higher efficiency on production, as noted in Javorcik et al. (2012). Wider availability of input goods also helps firms make better input choices (Yahmed & Dougherty, 2016).

Similarly, foreign-owned firms affiliated with a parent company get the opportunity to access foreign technology, likely helping to achieve higher technical efficiency (Dachs & Peters, 2014). Access to foreign markets, more efficient managerial practices, mature know-how, and other technical aspects are likely to be sources of higher efficiency for foreign-owned firms, as noted in Esquivias and Harianto (2020).

The impact of firm size on efficiency is mixed when different proxies for size are applied. The market share indicator (FS^S) and the labour indicator (FS^L) (Model 1 and Model 3) reveal that the larger the market share and the labour force, the higher the firm efficiency. By contrast, the indicator of size based on capital (FS^K) decreases firm efficiency. The positive effect of firm size (FS^S) on firm efficiency supports the study by Esquivias and Harianto (2020) and Sari (2019) in Indonesia, which noted that firms with a larger market share are more efficient. The results are also in line with the study by Diaz and Sanchez (2008) in the Spanish context, stating that a larger market share (equivalent to FS^S) and a larger number of workers (FS^L) lower the inefficiency, while a larger capital by workers (comparable to our FS^K) increases inefficiency.

A positive effect of market share (FS^S) on efficiency may be related to the gains in the market power. Referring to the Efficient Structure hypothesis, fiercer competition prompts efficiency as firms are forced to innovate and managers are urged to use production factors more efficiently. Similarly, larger firms based on labour force (FS^L) may realise cost competitive advantages by scaling size, which lower inefficiency. By contrast, a negative impact from employing large capital (FS^K) may relate to large sunk costs and less flexibility to adapt to technological changes (Green & Mayes, 1991). The negative sign in capital share (FS^K) may be associated with the firm selection model of Jovanovic (1982), which notes that firms differ in efficiency not only because of 'fixity' of capital but because of their capacity to find their advantage and sources of efficiency and act consequently.

Table 3: The Estimate Using Stochastic Frontier Analysis

Production Frontier	Model 1		Model 2		Model 3	
	Coeff	SE	Coeff	SE	Coeff	SE
$Constant$	0.007***	0.006	-0.095***	0.006	-0.138***	0.003
k	0.065***	0.001	0.067***	0.001	0.072***	0.001
l	0.234***	0.003	0.235***	0.003	0.233***	0.004
e	0.115***	0.001	0.115***	0.001	0.115***	0.001
r	0.682***	0.001	0.685***	0.001	0.688***	0.000
k^2	0.013***	0.001	0.012***	0.001	0.011***	0.001
l^2	0.030***	0.004	0.031***	0.003	0.037***	0.002
e^2	0.049***	0.001	0.050***	0.000	0.049***	0.001
r^2	0.148***	0.001	0.148***	0.001	0.150***	0.001
$k \times l$	0.024***	0.001	0.023***	0.001	0.022***	0.001
$k \times e$	0.004***	0.001	0.003***	0.001	0.004***	0.001
$k \times r$	-0.034***	0.001	-0.033***	0.000	-0.032***	0.001
$l \times e$	0.011***	0.002	0.012***	0.001	0.013***	0.001
$l \times r$	-0.081***	0.001	-0.081***	0.000	-0.085***	0.001
$e \times r$	-0.060***	0.001	-0.060***	0.001	-0.062***	0.000
t	0.016***	0.001	0.030***	0.001	0.018***	0.001
t^2	0.001***	0.000	0.000	0.000	0.000	0.000
$t \times k$	0.003***	0.000	0.003***	0.000	0.002***	0.000
$t \times l$	0.005***	0.001	0.004***	0.000	0.005***	0.001
$t \times e$	0.003***	0.000	0.003***	0.000	0.003***	0.000
$t \times r$	-0.007***	0.000	-0.007***	0.000	-0.007***	0.000
Inefficiency Effects						
$Constant$	0.234***	0.006	0.036***	0.006	0.066***	0.009
$time$	0.000	0.000	0.013***	0.001	0.002***	0.000
$Imported\ Materials\ (IMP)$	-0.009***	0.000	-0.148***	0.004	-0.223***	0.039
$Foreign\ Company\ (FOR)$	-0.098***	0.008	-0.263***	0.005	-0.239***	0.052
$Firm\ Size\ 1\ (FS^S)$	-0.060***	0.001				
$FS^S \times IMP$	0.001***	0.000				
$FS^S \times FOR$	0.020***	0.001				
$Firm\ Size\ 2\ (FS^K)$			0.920***	0.117		
$FS^K \times IMP$			-1.279***	0.306		
$FS^K \times FOR$			0.226	0.186		
$Firm\ Size\ 3 (FS^L)$					-0.024***	0.008
$FS^L \times IMP$					-0.083	0.07
$FS^L \times FOR$					0.084	0.069
σ^2	0.228***	0.001	0.228***	0.001	0.234***	0.001
γ	0.040***	0.001	0.004***	0.000	0.008***	0.001

Source: The Author.

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% level. Model 1 refers to the estimate using FS^S as proxy for firm size (market share Equation 3); Model 2 uses FS^K (capital, Eq. 4); and Model 3 refers to estimate using FS^L (labor, Eq. 5). Coeff is coefficient. SE is standard errors.

Furthermore, the market share indicator connects to the issue of market competition between foreign and domestic firms. Foreign firms may indeed have access to the more advanced technologies, shown by a much larger share of capital. Still, they may compete in different markets (higher standards and different profit levels). In all sub-sectors but pharmaceuticals, the average capital of foreign firms is visibly larger than domestic firms (Table 1). Still, domestic firms may have superior knowledge of the local market dynamics (Griffith et al., 2004), particularly in the food sector. Hence, having a larger share of the market for domestic firms is more important to improve technical efficiency, while having a larger share of fixed capital promotes technical efficiency in importers and foreign-owned firms.

When the effect from firm size is combined with the indicators of international exposure, i.e., imported raw material and foreign-affiliated firm, the results are mixed up. Referring to market share (FS^S), the interaction terms $FS^S \times IMP$ and $FS^S \times FOR$ decrease the firm's efficiency, suggesting that a larger market share will promote the firm's technical inefficiency only when the firm increases import intensity or is owned by foreigners. A possible explanation for such effects can be attributed to large foreign owned firms competing in markets for higher quality goods, where product differentiation matters and profits are larger. Another possibility is connected to the findings of Yahmed and Dougherty (2016), where the impact of imports on firm performance depends on the firm's distance to the production frontier (PF). Firms further away from the PF benefit less than those closer to it.

A contrast effect is found on the interaction effects related to capital (FS^K) and international exposure variables (Model 2). Firms with a larger share of capital and positive import penetration ($FS^K \times IMP$) are more efficient than firms with high capital and low imported material intensity. This finding implies that the utilization of imported material should be incorporated with advanced capital, such as technology and machinery, to achieve higher firm performance. This finding is the opposite with the result in Model 1 where the interaction of FS^S and *IMP* reveal positive association towards inefficiency. This result suggests that capital intensive firms may require good access to imported materials to obtain better efficiency. The coefficient of the interaction between capital and materials in the production function suggest that capital and materials are complementary inputs, supporting the findings. When the size is indicated by the number of workers (FS^L), there is a positive relation between firm size and technical efficiency. This result implies that large firms (employing more than 99 workers) tend to be less inefficient than medium size firms (less than 100 workers). This finding is in line to Andersson and Stone (2017), Wang and Wong (2016), Widodo et al. (2015) that used the number of workers as the firm size indicator and found that large firms are more efficient than the medium firm. Nevertheless, those earlier studies did not capture the interaction between firm size and international exposure (e.g., FDI and imports). The interaction effects can reinforce or lessen the impact of size on firm efficiency.

To illustrate the impact of each size indicator (FS^S, FS^K, and the number of workers[4]) on technical efficiency, Figure 4 in the appendix provides the scatter plots. As our dataset has high density, we classified the technical efficiency score from each model based on percentiles. Most subsectors reveal a positive association between firm size and technical efficiency. The finding for FS^K may be in contrast with the results in Model 2. The relation between efficiency and firm size generally follows a monotonically non-decreasing function, but the trends are not straight lines. Most sectors experienced a high slope in the initial stages and eventually slowed down. Such effect may be in line with the finding by Jovanovic (1982), noting that smaller firms may grow faster and more dynamically than larger ones, although only the efficient ones will survive.

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[4] We do not use FS^L as it is dummy variable. Instead, we may classify the number of labour into percentile.

To determine which indicator of firm size is appropriate, Table 6 to 8 reports the correlation matrixes. The largest correlation for all subsectors stems from the firm size based on labour (FS^L)[5]. Using labour as a proxy for size may be closer to reality than market share or capital base. Our findings on size (labour) are somewhat in line with earlier studies (Diaz & Sanchez, 2008; Schiersch, 2013), which all found positive relations between firm size (labour based) and efficiency. A plausible explanation on why proxies of size based on market share and capital are less accurate relates to the research by Jovanovic (1982). Rates of return vary between more or less concentrated sectors, and higher market share is associated with higher profits for larger firms but not for smaller ones.

Table 4 reports the calculation of technical efficiency classified by firm size and subsector in two different categories: importer vs non-importer and foreign vs local firms. To distinguish firms whose values are in ratio (i.e. FS^S and FS^K), we split the sizes into four quartiles averages: Q1-Q4. In each column, we sorted the magnitude of technical efficiency and divided it into four clusters: upper, middle-upper, lower-middle, and lower.

As shown in Table 4, we found different patterns in technical efficiency according to sectors and firm characteristics depending on the firm size proxy. When using market share for size (FS^S in Model 1), the average efficiency across quartiles is smaller than when using capital (FS^K in Model 2). Furthermore, the FS^K shows larger consistency in all sectors and categories, namely efficiency increases from Q1 (lowest quartile) to Q4 (highest). By contrast, in Model 1, most efficient firms are in non-Q4-quartile (except for pharmaceutical). Meanwhile, when using FS^K, the differences in average efficiency across quartiles are more substantial than when using FS^S (market share). As an example, for the chemical sector, most estimates suggest an average of 0.809 efficiencies across groups in Model 1. By contrast, in Model 2, the lowest efficiency is within local firms in Q1 (0.85), and the highest is in local firms in Q4 (0.92).

Table 4: Technical Efficiency Based on Quartile and Groups

Subsector	Quartile of Firm Size	Model 1 (Market Share based) Category				Model 2 (Capital based) Category			
		Local Firms	Non-Importer Firms	Foreign Firms	Importer Firms	Local Firms	Non-Importer Firms	Foreign Firms	Importer Firms
10 Foods Industry	Q1	0.818†††	0.818††††	0.838††††	0.818†††	0.859†	0.859†	0.865†	0.875†
	Q2	0.817†††	0.817†††	0.812††	0.816††	0.877†	0.876††	0.865†	0.889††
	Q3	0.818††††	0.818††††	0.817†††	0.820†††	0.885††	0.885†††	0.879††	0.892††
	Q4	0.817†††	0.817†††	0.817†††	0.817††	0.894†††	0.892†††	0.883††	0.901††††
11 Beverages Industry	Q1	0.817†††	0.817†††	0.812††	0.840††††	0.862†	0.863†	0.914††††	0.866†
	Q2	0.818††††	0.818†††	0.831††††	0.838††††	0.870†	0.871†	0.896††††	0.861†
	Q3	0.817†††	0.817†††	0.831††††	0.832††††	0.876†	0.878†††	0.889†††	0.865†
	Q4	0.811†	0.811†	0.807†	0.807†	0.879††	0.880†††	0.893†††	0.894††
20 Chemical Industry	Q1	0.814†	0.812†	0.804†	0.818†††	0.880††	0.873†	0.876†	0.898†††
	Q2	0.813†	0.812†	0.811††	0.816††	0.886†††	0.877††	0.882††	0.900†††
	Q3	0.816††	0.813†	0.806†	0.813†	0.895†††	0.888†††	0.891†††	0.901†††
	Q4	0.813†	0.812†	0.807†	0.809†	0.904††††	0.894†††	0.894††††	0.902††††
21 Pharmaceutical Industry	Q1	0.814††	0.815††	0.791†	0.813†	0.883††	0.876†	0.876†	0.899†††
	Q2	0.819††††	0.818††††	0.822††††	0.820†††	0.901††††	0.894††††	0.886†††	0.909††††
	Q3	0.819††††	0.823††††	0.818†††	0.816††	0.907††††	0.900††††	0.899††††	0.910††††
	Q4	0.828††††	0.822††††	0.816††	0.825††††	0.920††††	0.917††††	0.917††††	0.919††††
22 Rubber and Plastic Industry	Q1	0.814†	0.814†††	0.824††††	0.824††††	0.885††	0.884†	0.882††	0.892††
	Q2	0.814††	0.814†††	0.812†	0.812†	0.891†††	0.891†††	0.872†	0.884†
	Q3	0.817††	0.817†††	0.816†††	0.816††	0.899†††	0.899††††	0.882††	0.892††
	Q4	0.814††	0.814†††	0.821†††	0.821†††	0.905††††	0.906††††	0.894†††	0.898†††

Note: † : Lower Class, ††: Lower-Middle Class, †††: Middle-Upper Class, ††††: Lower Class. Q1 is the first quartile average of firm size, Q2 is the second quartile average of firm size, Q3 is the third quartile average of firm size, and Q4 is the fourth quartile average of firm size.

[5] The number of labour has the second largest correlation with TE, concluding FS^L and labour are alike.

At the sectoral level, foreign-owned firms within the food sector are the most efficient when using a market share (FS^S). Nevertheless, when using capital (FS^K), foreign-owned firms show the lowest efficiency level. We conclude that the choice of proxy for firm size to test the impact of size on technical efficiency matters.

An intriguing finding is shown by Model 2 (FS^K, firm size based on capital). The result reveals that most of the technical efficiency scores are high for firms in Q4. The scores are especially larger for the pharmaceutical sector. This result supports our econometric estimates in Model 2 that capital size and imported intensity matter for high technology subsectors to obtain high efficiency. The finding supports the theory of minimum efficient scale, defined as the minimum size at which a firm can sustain operation without making losses (Ciani et al., 2020). Pharmaceutical firms may have a larger minimum efficient scale because faced higher fixed cost to produce efficiently, in line with findings by Toma (2020) for pharmaceutical firms in Italy. Once the minimum efficient threshold is not satisfied, they might gain inefficiency.

Figure 1-3 illustrate the technical efficiency dispersion over time. The figure depicts the heterogeneity and convergence process of technical efficiency estimated from each of the three firm size indicators. It is evident that the technical efficiency score in each subsector shows a divergent trend over time. FS^K has the fastest divergent process as it has the most elongated box among all diagrams. This illustration is consistent with our econometric estimates in Table 3, revealing that the time trend variable shows a positive direction towards inefficiency. Firms' technical efficiency shows a decreasing trend over time by 1.3 percent annually, in the presence of a larger share of the firm's capital. A possible reason is that the increases in capital need to be accompanied by more efficient sourcing of materials (as noted in the interaction of capital and raw materials in the production function).

Figure 1: Technical Efficiency of Foods (left) and Beverages (right) Sectors Over Time

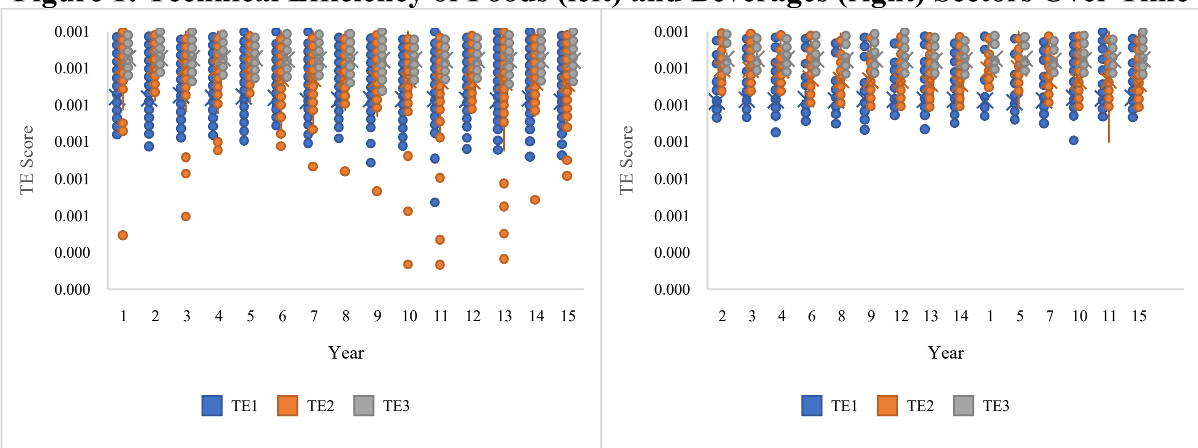


Figure 2: Technical Efficiency of Chemical (left) and Pharmaceutical (right) Sectors

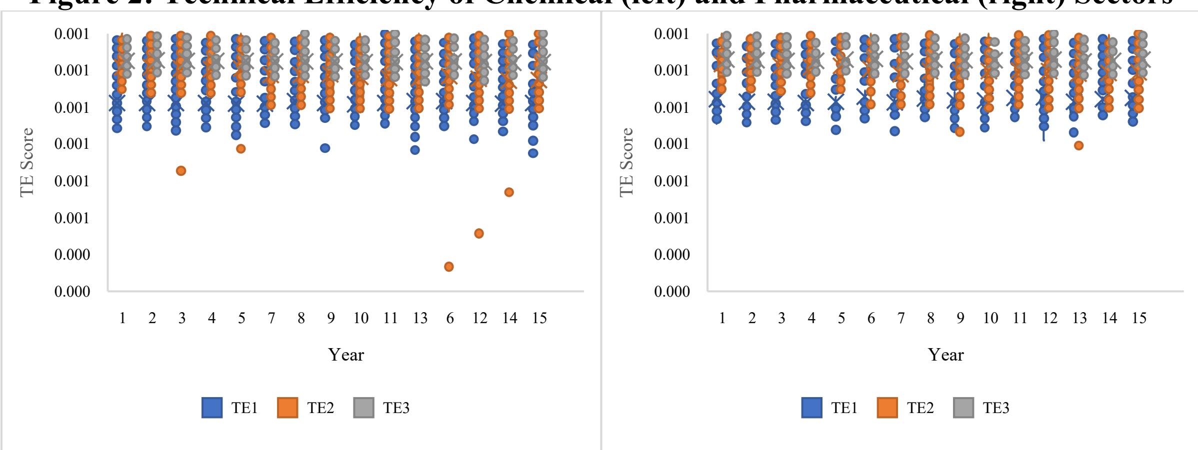
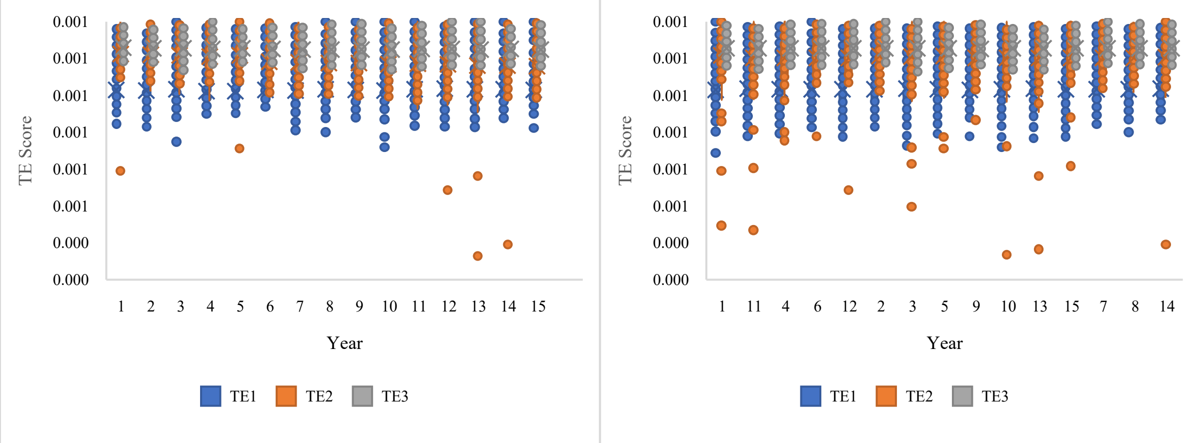


Figure 3: Technical Efficiency of Rubber & Plastics (left) and All (right) Sectors



Source: Own calculations based on Large and medium manufacturing industry (IBS) survey.

4. Conclusion

We have demonstrated the impact of firm size on technical efficiency (firm performance). Import penetration and foreign investment have negative effects on a firm's inefficiency. However, some intriguing findings are identified when interaction terms between firm size and international exposure (import penetration or FDI) are employed.

The first is that the firm size proxied by the firm's market share (sales) in the industry positively affects firm efficiency. However, the effect of market share is detrimental to firms' efficiency with international exposure, such as importer and foreign-owned establishments. A second finding relates to the link between firm size based on the capital measurement towards technical efficiency. It illustrates that firm size based on capital is positively related to technical efficiency only as import ratio increases. This finding strengthens prior studies that capital intensive firms performs better when having better access to international raw or intermediate inputs. Furthermore, the positive impact of firm size (capital-based) on technical efficiency is more robust for high technology subsectors (pharmaceutical) than low-tech sectors (beverages as well as rubber and plastics). The minimum efficient scale is a plausible reason for this result, as high tech sectors may have a higher minimum efficient scale (output) as they faced higher fixed cost. Another possibility is that foreign-owned firms attract the most efficient inputs (capital and labour), crowding out the domestic actors. Third, the econometric estimates reveal that firms' technical efficiency is divergent over time, with larger capital share as the primary contributor in accelerating this process.

Our study delivers the following implications. First, the choice of indicator to measure firm size matters. Helping firms to grow market share (sales) and size of labour will have positive effects on efficiency. In capital intensive sectors, large firms need good access to foreign inputs to benefit from large size. Government policies may need to support local firms' performance by facilitating the developments of skills, technological absorption capability, better infrastructure, market intelligence, and access to finance. Attracting foreign investment may accelerate this strategy as positive efficiency externalities might occur for the local firms. Second, large firms may enjoy large efficiency since they were established (born big). Nevertheless, most of the firms are SMEs and have to strive to grow bigger. In these two different conditions, the government's treatment should be distinguished as one might have initially achieved better performance, have higher barriers to exit, and being more resourceful. In contrast, SMEs are more exposed to exit the market when competitive pressures intensify.

Finally, we provide evidence that employing the number of labour as a proxy for firm size offers a more appropriate estimates compare to proxies based on market share or capital, which are common in earlier studies.

Data availability

The data that support this study are available from Statistics Indonesia; Large and medium manufacturing industry (IBS) survey. https://www.bps.go.id/subject/9/industri-besar-dan-sedang.html

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APPENDIX

Figure 4: Scatter Plots of Technical Efficiency and firm size (FS^S, FS^K, and Number of workers)

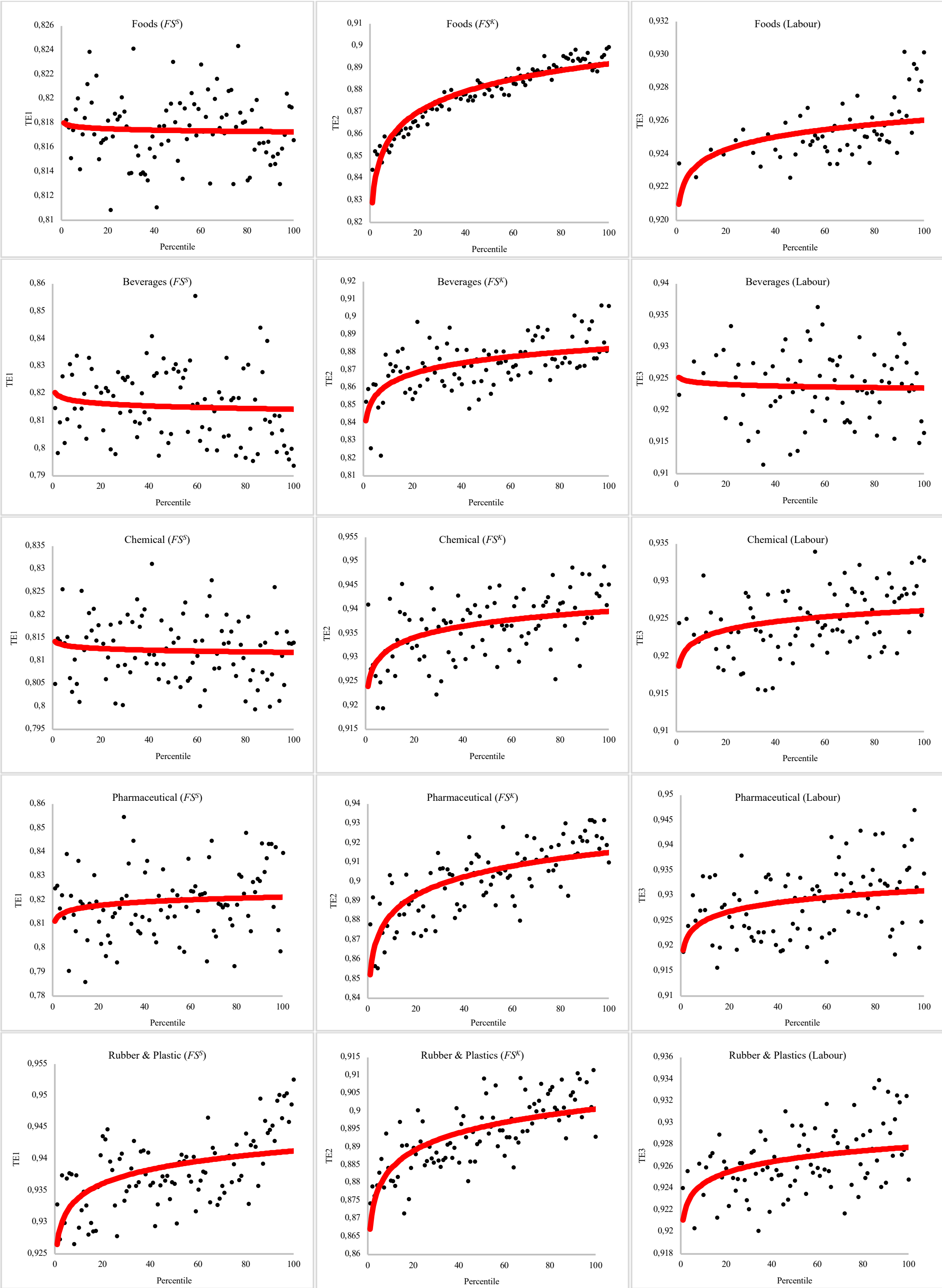

Table 5: Robustness Test - Estimates of Translog and Cobb-Douglas Specifications

Production Frontier	Model 1		Model 2		Model 3	
	TL	CD	TL	CD	TL	CD
$Constant$	0.007	0.094***	-0.095***	0.091***	-0.138***	0.294***
	(0.006)	(0.002)	(0.006)	(0.002)	(0.003)	(0.009)
k	0.065***	0.096***	0.067***	0.098***	0.072***	0.096***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
l	0.234***	0.274***	0.235***	0.280***	0.233***	0.243***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
e	0.115***	0.133***	0.115***	0.134***	0.115***	0.134***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
r	0.682***	0.607***	0.685***	0.611***	0.688***	0.610***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.002)
k^2	0.013***		0.012***		0.011***	
	(0.001)		(0.001)		(0.001)	
l^2	0.030***		0.031***		0.037***	
	(0.004)		(0.003)		(0.002)	
e^2	0.049***		0.050***		0.049***	
	(0.001)		(0.000)		(0.001)	
r^2	0.148***		0.148***		0.150***	
	(0.001)		(0.001)		(0.001)	
$k \times l$	0.024***		0.023***		0.022***	
	(0.001)		(0.001)		(0.001)	
$k \times e$	0.004***		0.003***		0.004***	
	(0.001)		(0.001)		(0.001)	
$k \times r$	-0.034***		-0.033***		-0.032***	
	(0.001)		(0.000)		(0.001)	
$l \times e$	0.011***		0.012***		0.013***	
	(0.002)		(0.001)		(0.001)	
$l \times r$	-0.081***		-0.081***		-0.085***	
	(0.001)		(0.000)		(0.001)	
$e \times r$	-0.060***		-0.060***		-0.062***	
	(0.001)		(0.001)		(0.000)	
t	0.016***		0.030***		0.018***	
	(0.001)		(0.001)		(0.001)	
t^2	0.001***		0.000		0.000	
	(0.000)		(0.000)		(0.000)	
$t \times k$	0.003***		0.003***		0.002***	
	(0.000)		(0.000)		(0.000)	
$t \times l$	0.005***		0.004***		0.005***	
	(0.001)		(0.000)		(0.001)	
$t \times e$	0.003***		0.003***		0.003***	
	(0.000)		(0.000)		(0.000)	
$t \times r$	-0.007***		-0.007***		-0.007***	
	(0.000)		(0.000)		(0.000)	
Inefficiency Effects						
$Constant$	0.234***	0.334***	0.036***	0.312***	0.066***	0.556***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.009)	(0.012)
$time$	0.000	-0.024***	0.013***	-0.024***	0.002***	-0.024***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)
$Imported\ Materials\ (IMP)$	-0.009***	-0.001***	-0.148***	-0.124***	-0.223***	-0.202***
	(0.000)	(0.000)	(0.004)	(0.004)	(0.039)	(0.012)
$Foreign\ Company\ (FOR)$	-0.098***	-0.237***	-0.263***	-0.244***	-0.239***	-0.311***
	(0.008)	(0.004)	(0.005)	(0.005)	(0.052)	(0.008)
$Firm\ Size\ 1\ (FS^S)$	-0.060***	-0.123***				
	(0.001)	(0.004)				
$FS^S \times IMP$	0.001***	0.001***				
	(0.000)	(0.000)				
$FS^S \times FOR$	0.020***	0.025***				
	(0.001)	(0.006)				
$Firm\ Size\ 2\ (FS^K)$			0.920***	0.017		
			(0.117)	(0.194)		
$FS^K \times IMP$			-1.279***	-0.739***		
			(0.306)	(0.197)		
$FS^K \times FOR$			0.226	1.374***		
			(0.186)	(0.241)		
$Firm\ Size\ 3 (FS^L)$					0.024***	-0.139***
					(0.008)	(0.008)
$FS^L \times IMP$					-0.083	0.115***
					(0.070)	(0.008)
$FS^L \times FOR$					0.084	0.116***
					(0.069)	(0.007)
σ^2	0.228***	0.349***	0.228***	0.354***	0.234***	0.353***
	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
γ	0.040***	0.000***	0.004***	0.000	0.008***	0.000
	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)

Note. . *, **, and *** indicate significance at the 10%, 5%, and 1% level.

Table 6: Matrix of Correlation between TE_1 and FS^S, FS^K, FS^L, Labour

Subsector	FS^S	FS^K	FS^L	Labour
Foods Industry	-0.001	-0.006	-0.001	0.004
Beverages Industry	-0.068	-0.030	-0.058	-0.054
Chemical Industry	0.008	0.019	0.014	0.008
Pharmaceutical Industry	0.017	0.045	0.063	0.051
Rubber and Plastics Industry	-0.001	-0.004	0.012	-0.003
All	**-0.005**	**0.001**	**-0.001**	**0.002**

Table 7: Matrix of Correlation between TE_2 and FS^S, FS^K, FS^L, Labour

Subsector	FS^S	FS^K	FS^L	Labour
Foods Industry	0.032	0.016	0.118	0.079
Beverages Industry	0.055	0.070	0.102	0.032
Chemical Industry	0.073	0.016	0.222	0.128
Pharmaceutical Industry	0.100	0.074	0.250	0.209
Rubber and Plastics Industry	0.051	-0.002	0.135	0.050
All	**0.045**	**0.022**	**0.155**	**0.089**

Table 8: Matrix of Correlation between TE_3 and FS^S, FS^K, FS^L, Labour

Subsector	FS^S	FS^K	FS^L	Labour
Foods Industry	0.006	0.001	0.036	0.022
Beverages Industry	-0.033	0.004	-0.022	-0.039
Chemical Industry	0.031	0.013	0.066	0.038
Pharmaceutical Industry	0.044	0.058	0.100	0.083
Rubber and Plastics Industry	0.018	-0.012	0.048	0.007
All	**0.011**	**0.005**	**0.045**	**0.023**

Figure 5: Scatter Plot of Technical Efficiency (TE) from Translog (TL), Cobb-Douglas (CD), and Hicks-Neutral (HN).