Avalaible online at http://journals.ums.ac.id, Permalink/DOI: 10.23917/jep.v23i2.18113

Jurnal Ekonomi Pembangunan: Kajian Masalah Ekonomi dan Pembangunan, 23 (2), 2022, 241-253

Technical Inefficiency in Nine Clusters of Indonesian Manufacturing Firms And its Determinants: Stochastic Frontier Analysis

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Received: 18 April 2022 | Revised: 12 May 2022 | Accepted: 8 December 2022

Abstract

The current study examines the technical inefficiency of Indonesian manufacturing firms and its key determinants. Extending the previous research that mainly focuses on firms in a specific industry, the current study groups firms into nine industrial clusters and estimates them separately to find a variety of results among the clusters. The stochastic frontier analysis (SFA) method is applied to estimate the inefficiency score and the key determinants of 5,848 firms for five years (29,240 total observations). Data period ended in 2014 due to the substantial change in the classification code of the manufacturing industry in the survey by the Indonesian Central Board of Statistics. Five notable findings are recorded. First, the average efficiency score of all observed firms is 0.8815. Second, firm size is found to have a negative effect on inefficiency in the sample of all firms and three out of nine clusters (ISIC 34, ISIC 35, and ISIC 37). Third, foreign ownership generates a negative contribution to firms' technical inefficiency in both the sample of all firms and the sample of each nine industrial clusters. Fourth, export orientation has various effects on firms across nine industrial clusters, with a dominant significant negative impact in paper and paper product industry (ISIC 34) and metal product industry (ISIC 38). Finally, import intensity provides a significant negative impact on firms in most industrial clusters. These findings support the argument on the importance of absorption capacity and unique firm characteristics in analyzing the impact of key determinants of technical inefficiency.

Keywords: Technical Efficiency; Firm Size; Foreign Ownership; Export Orientation; Import Intensity
JEL classification: D22, D24, O12, O14

How to Cite: Astanto T. J., Suyanto S., Santoso H. W., Salim R. (2022). Technical Inefficiency in Nine Clusters of Indonesian Manufacturing Firms And its Determinants: Stochastic Frontier Analysis, 23(2), 241-253. doi:https://doi.org/10.23917/jep.v23i2.18113

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1. Introduction

Manufacturing industry has been the main sector and the backbone that support the Indonesian economy, as its contribution to the nation's Gross Domestic Product (GDP) is the greatest among other sectors (Lestari & Isnina, 2017; Setiawan *et al.,* 2021; Suyanto, Sugiarti, &Tanaya, 2021). The important role of manufacturing industry in the Indonesian economy is reflected not only in its contribution to economic growth but also in its ability in improving the efficiency and productivity of firms within the industry (Priya & Aroulmoji, 2020). In a study of the efficiency and productivity of Indonesian manufacturing firms, Ikhsan (2007) found that although the contribution of manufacturing sector is substantial to economic growth, the efficiency and productivity of firms within the sector have started to experience a decreasing return to scale (DRS). Similarly, more recent research by Suyanto *et al.* (2021) noted a similar finding that firms in the manufacturing industry have experienced a DRS in their production. Moreover, Ikhsan (2007) added that the average technical efficiency score of manufacturing firmsis less than 0.5. The findings are in line with Margono & Sharma (2006), who also found a low-efficiency score of firms in the manufacturing industry. The findings of these previous studies indicate a low average score of efficiency of firms in the manufacturing sector, although the contribution to economic growth is substantial. Whether this evidence remains in a more updated period of data is an interesting point to study. This study utilizes a more recent data period from 2010 to 2014 compared to Ikhsan (2007), which used a data period from 1988 to 2000, and Margono & Sharma (2006), which used a data period from 1993 to 2000. A data period until 2014 was utilized due to a significant change in the industrial code in 2015; the matching of the firm-to-firm data within the industrial classification was hardly done and a concordance table was unavailable.

The present study uses a one-stage method in estimating the production frontier and inefficiency equation simultaneously. The production frontier is used to measure the technical efficiency score of each firm in the nine industrial clusters. Based on the earlier literature, the first null hypothesis (H_1) put forward is that "firms from nine industrial clusters of Indonesian manufacturing have an average efficiency score less than 0.5". Technical efficiency carries a significant role in the context of production. Technical efficiency can be measured from both output and input orientation (Setiawan *et al.,* 2012). Based on the output orientation, firms are considered to achieve full technical efficiency if they can produce maximum output with a certain combination of inputs. On the other hand, input orientation implies that firms have full technical efficiency if they can produce a certain amount of output with less combination of inputs. Furthermore, Farrell (1995) states that the technical efficiency frontier pictures the ability of firms to produce at the frontier isoquant. The two methods commonly used in measuring technical efficiency namely data envelopment analysis (DEA) and stochastic frontier analysis (SFA). The current study applies the SFA method due to the large number of firms used as samples. The SFA method is more beneficial in processing large amounts of data, if compared to DEA (Tsionas, 2020).

The following is the second research question being addressed: "what are the main factors affecting firms' technical inefficiency in nine industrial clusters of Indonesian manufacturing?" This second research question can be answered by examining the inefficiency equation in SFA model. The key factors affecting technical inefficiency in this study are firm size, foreign ownership, export orientation, and import intensity. The earlier studies of these four variables recorded mixed evidence on the impact of each factor on firm-level technical efficiency indicating the importance of further studies. According to previous empirical studies, large firms tend to have higher technical efficiency scores compared to smaller firms (Aggrey, 2010). Firm size is the reason why certain firms have larger access to economic resources compared to other firms (Lafuente *et al.,* 2020). Larger firms have more ability to improve productivity and efficiency due to the economies of scale (Liu, 2018). Hence, the following is the second hypothesis (H_2): "firm size has a negative impact on firm-level technical inefficiency in nine industrial clusters of Indonesian manufacturing."

Firm-level technical efficiency is also influenced by exposure to the international market including access to foreign technology, which is unavailable locally (Lemi& Wright, 2018). Foreign investment generates benefits for local firms through technological spillovers, when the entry of foreign investment with a more advanced knowledge and technology might force local firms to imitate new knowledge and, in turn, increase the local firms' technical efficiency (Suyanto *et al.,* 2021). Based on these previous evidence, foreign ownership plays a significant role in improving firm-level efficiency. Thus, the third hypothesis (H_3) puts forward in this research is "foreign ownership has a negative impact on firm-level technical inefficiency in nine industrial clusters of Indonesian manufacturing industry." Furthermore, participating in export activity can help improve firm-level (Suyanto *et al.,* 2021).

Export is one of the main factors which determine firms' technological innovation and efficiency (Zhu *et al.,* 2018). In accordance with these previous studies, the fourth hypothesis (H_4) put forward in this study is "export orientation has a negative impact on firm-level technical inefficiency in nine industrial clusters of Indonesian manufacturing industry." In addition, import is another factor affecting firm-level technical efficiency. Access to foreign input markets combined with firms' experiences in import activities help improve firms' product quality, which then reduce innovation cost and increase profits (Imbruno & Ketterer, 2018). Firms involved in import activity benefit from technological transfer from other countries, especially those from developed countries (Ai *et al.,* 2019; Suyanto *et al.,* 2020). Therefore, based on the previous research, the last hypothesis put forward in this study is "import intensity has a negative impact on firm-level technical inefficiency from nine industrial clusters of Indonesian manufacturing industry". These four determinants, namely firm size, foreign ownership, export orientation, and import intensity, are examined in this study.

The contribution of the current study is two-fold. First, this study estimates technical efficiency scores for firms in nine industrial clusters of Indonesian manufacturing industry. Complementing prior studies which mainly focus on firms in one particular industry (Setiawan, 2012; Setiawan, 2019b; Suyanto, 2020; Suyanto *et al.,* 2021b), the present study focuses on a more comprehensive scope by taking into account firms in nine industrial clusters. Examining firms in nine industrial clusters is very important due to the varying effects of some pivotal variables on technical efficiency across different industries. Firms are grouped according to their product similarity in the International Standard of Industrial Classification (ISIC). Thus, the current study has an advantage in minimizing the heterogeneity issue by clustering firms into homogenous groups. Second, this study contributes to the empirical debate of technical efficiency's determinants by analyzing the impact of firm size, foreign ownership, export orientation, and import intensity on technical inefficiency.

2. Research Method

2.1 Research Approach and Techniques

The present study is explorative research with a quantitative method. Explanatory research aims to identify and explain the causal relationship of research variables (Strydom, 2013). A quantitative approach is used in this current study to confirm the hypothesis through data analysis and interpretation. This study estimates the technical efficiency scores of each firm in each year of observation. It also analyzes the relationship of four key variables against the technical inefficiency variable. The estimation of the technical efficiency scores and the analysis of the impact of some variables on technical inefficiency scores follow the one-stage parametric model of the Stochastic Production Frontier (SPF) approach.

2.2 Data and Sources

The data source in this study is the annual survey of large and medium enterprises conducted by the Indonesian Central Board of Statistics for 2010-2014. The data is provided under license upon request to the BPS, as the data is not publicly available. The period of data ended in 2014 due to a significant change in the industrial classification code in 2015, which made the firm-to-firm matching between 2014 and 2015 data hardly conducted and the concordance table unavailable. Hence the 2014 is the latest possible year to be used in this study.

The construction of balanced panel data for the analysis in this study follows a five-step procedure. The first step is choosing the relevant firms and grouping them into nine industrial clusters based on the International Standard of Industrial Classification (ISIC). The second step is cleaning noises and typographical errors, including zero or negative values of output or inputs, missing values, and key-punch errors. The third step is back-casting the missing values of capital using the procedure in Suyanto, Salim, & Bloch (2014). The fourth step is matching firms from year to year based on the firm-specific code (PSID). The fifth step is deflating the monetary values of output and materials using a wholesale price index provided by BPS. In contrast, the monetary values of energy are deflated using the energy price index provided by the Indonesian Ministry of Energy and Mineral Resources. After constructing the balanced panel data, the total numbers of firms in the dataset are 5,848 firms. Thus, the total numbers of observations are 29,240. These observations are used to estimate the technical efficiency scores and analyze the determinants of technical inefficiency.

2.3 Variables and the Operational Definitions

The variables used in this study fall into two groups. The first group comprises the production variables, whereas the second group comprises the key variables affecting technical inefficiency. The first group variables are output (Y), labor (L), capital (C), materials (M), and energy (E). The second group variables are technical inefficiency (u), firm size (FS), foreign ownership (FO), export orientation (EX), and import intensity (IM).

The output variable (Y) is measured using the total monetary value of output deflated under the wholesale price index with the base year 2010. The material (M) is calculated from the total monetary value of material used in the production and deflated under the wholesale price index with the base year 2010. Labor (L) is the full-time equivalent number of workers in production. The energy (L) is measured from the total monetary value of fuels and electricity used in the production and deflated under the energy price index with the base year 2010.

The technical inefficiency score (u) is the score of inefficiency calculated from the production frontier (the first equation in the model). Firm size (FS) is the firm's labor ratio to the industry's total labor. Foreign ownership is represented by a binary dummy variable, which takes the value of 1 if firms have foreign ownership and 0 if otherwise. Export orientation (EX) is a binary dummy variable, which takes the value of 1 if firms export their products and 0 if otherwise. Furthermore, import intensity (IM) is calculated from the percentage of material imported. The operational definitions of each variable are presented in Table 1.

Table 1. ***Operational Definitions of Variables***

Variable	Symbol	Definition
Variables for Estimating Technical Efficiency Score		
Output	Y	The total monetary value of output (in rupiah) deflated under the wholesale price index with the base year 2010
Labor	L	Equivalent numbers of full-time labor (in person) in production
Capital	K	The total monetary value of capital (in rupiah) deflated under the wholesale price index with the base year 2010
Material	M	The total monetary value of material (in rupiah) deflated under the wholesale price index with the base year 2010
Energy	E	The total monetary value of energy (in rupiah) calculated from the sum of monetary value of fuels and monetary value of diesel, deflated using the energy index with the base year 2010
Variables for Analyzing Key Determinants of Technical Efficiency		
Technical inefficiency	u	The score of time-varying technical inefficiency of firms calculated from SFA
Firm size	FS	Firm size proxied by the labor ratio of firms to the total labor of the industry
Foreign ownership	FO	Binary dummy variable which takes the value of 1 if firms have foreign ownership and 0 if otherwise
Export orientation	EX	Binary dummy variable which takes the value of 1 if firms are involved in export activity and 0 if otherwise
Import intensity	IM	The percentage of material imported

Source: The definitions consistently follow the survey of large and medium enterprises conducted by Indonesian Central Board of Statistics.

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Jurnal Ekonomi Pembangunan: Kajian Masalah Ekonomi dan Pembangunan, 23 (2), 2022, 241-253

2.4 Methods of Analysis

This study uses the one-stage stochastic frontier analysis (SFA) introduced by Battese & Coelli (1995) to avoid the inconsistency effect found in the two-stage estimation approach (Habiyaremye, 2019; Suyanto *et al.,* 2021a). The one-stage SFA simultaneously estimates the production frontier and inefficiency equation to measure the technical inefficiency scores and variables affecting the inefficiency scores. The one-stage SFA provides accurate estimates for observing random variables (Coelli *et al.,* 2005). SFA model is constructed under maximum likelihood distribution, which needs certain functional model specifications. This study implements the Cobb-Douglas functional model by referring to several previous studies (Hossain & Majumder, 2015; Liu *et al.,* 2018). The SFA model and its inefficiency equation are adopted from Coelli *et al.* (2015) written as follows:

$$Ln(y)= \beta_0+\beta_1 LnL_{it}+\beta_2 LnK_{it}+\beta_3 LnM_{it}+ \beta_4 LnE_{it}+ (v_{it}-u_{it}) \quad (1)$$

$$u_{it}= a_0+a_1 FS_{it}+a_2 FO_{it}+a_3 EX_{it}+a_4 IM_{it}+ \varepsilon_{it} \quad (2)$$

The Coelli *et al.* (2005) model used maximum likelihood method in estimating the parameters (for maximizing the function. Estimation results using the maximum likelihood method are consistent, especially when using a large number of samples (the Monte Carlo simulation for this argument is provided in Battese and Coelli (1995)). In other words, this method allows consistent results, it means the estimated parameters will maximize the exact values and will have low variances (Bogetoft & Otto, 2011).

3. Results and Discussion

3.1 Results of Production Frontier Estimation

Production frontier estimation is based on maximum likelihood distribution calculated by Frontier 4.0 software. Table 2 provides estimates for nine industrial clusters. The upper part of the table pictures the production frontiers, whereas the lower part shows the estimates for inefficiency function. The estimation results of the upper part of Table 2 are discussed in this section, whereas the results of the lower part are discussed in section 3.3 onwards. The upper part of Table 2 shows that all coefficients of input variables in the food and beverage cluster are positive and significant at 1% alpha. The coefficient of Labor is 0.2017, indicating the increase in number of labors by 1% will raise output by 0.2017%. The similar interpretation can be applied to other input coefficients correspondingly. Furthermore, textile and leather firms (ISIC 32) and wood and wood products (ISIC 33) also have a positive coefficient of input variables. They are significant at 1% alpha (except for capital which is significant at 5% alpha). Similarly, the paper and paper products (ISIC 34), chemical and pharmaceutical (ISIC 35), and non-metal minerals (ISIC 36) have a positive and significant input coefficient at 1% alpha. A different result appears in the cluster of basic metal firms (ISIC 37), where the labor variable has a negative coefficient but statistically insignificant, and the capital variable also has a negative insignificant coefficient. Furthermore, in metal products (ISIC 38), capital coefficient is also found to have an insignificant impact on output. Still, the other three input variables, namely labor, materials, and energy, are found to have positive coefficients and are significant at 1% alpha. For firms in other industrial clusters (ISIC 39), all four input variables have a significant positive impact on output.

In addition, Table 2 also indicates that each production factor's coefficient is smaller than 1, which supports the production theory and is in line with the findings of Sari *et al.* (2016), Esquivias and Harianto (2020), and Suyanto *et al.* (2021). Based on the production factor's coefficients, the return to scale (RTS) of manufacturing firms can be calculated by adding-up all production factors' coefficients. It is found that food and beverage firms (ISIC 31) have an average RTS value of 0.9547 for the period of 2010-2014, showing a decreasing return to scale (DRS). The other eight industrial clusters also experienced DRS during the observed period. The elasticity value is less than 1, meaning that an additional double on all inputs increases output for less than double.

Table 2. ***Estimation Results of Maximum Likelihood Stochastic Production Frontier***

	Food and Beverages (ISIC 31)	**Textile and Leather (ISIC 32)**	**Wood and Wood Products (ISIC 33)**	**Paper and Paper Products (ISIC 34)**	**Chemical and Pharmaceutical (ISIC 35)**	**Non-Metal Mineral (ISIC 36)**	**Basic Metals (ISIC 37)**	**Metal Products (ISIC 38)**	**Others (ISIC 39)**	**All Firms**
Production Frontier										
Constant	3,9358***	5,6603***	4,9357***	4,7425***	4,7016*** (21,3448)	4,8348***	3,2051***	4,0683***	5,4260***	4,7641***
	(30,2597)	(29,1918)	(6,2705)	(13,0915)		(14,9409)	(3,2131)	(11,5941)	(7,2554)	(233,8995)
Ln(L)	0,2017***	0,2282***	0,1598***	0,2622***	0,1202*** (3,1876)	0,1872***	-0,1949	0,2123***	0,1795***	0,1841***
	(14,7186)	(12,8777)	(4,1017)	(4,8206)		(10,2911)	(-1,3139)	(5,1769)	(4,3485)	(34,9038)
Ln(K)	0,0371***	0,0206**	0,0741**	0,0666***	0,0588*** (2,7548)	0,0781***	0,1033	0,0286	0,0862**	0,0617***
	(5,6050)	(2,1329)	(2,4709)	(3,0107)		(8,0715)	(1,4263)	(1,6079)	(2,5352)	(16,4536)
Ln(M)	0,6185***	0,5079***	0,5359***	0,4999***	0,5499*** (168,7446)	0,5086***	0,7018***	0,5849***	0,4826***	0,5423***
	(84,4321)	(44,5203)	(15,2166)	(23,0767)		(54,5663)	(10,8802)	(29,0651)	(15,6586)	(514,48007)
Ln(E)	0,0974***	0,1065***	0,0874***	0,1320***	0,1517*** (5,004)	0,1194***	0,1224*	0,1502***	0,1046***	0,1079***
	(14,9279)	(12,1609)	(4,2007)	(5,4843)		(11,3821)	(1,6875)	(7,5768)	(7,4617)	(32,0827)
Inefficiency Function										
Constant	0,0726**	0,0335	0,1218	0,1041 (0,7096)	0,2389	-0,0197	-0,2017	0,0353*	0,0222	0,1387***
	(1,7588)	(0,2029)	(0,6306)		(0,3747)	(-0,0387)	(-0,4178)	(0,1674)	(0,1110)	(4,0116)
Firm Size	0,1446*	0,0059*	0,0161	-0,6291	-0,1227	0,0235	-0,0158	0,3905***	0,0105*	-0,0085***
	(1,2703)	(0,1291)	(0,0973)	(-0,0701)	(-0,1764)	(0,2059)	(-0,3060)	(5,1049)	(0,1513)	(-4,0000)
Foreign Ownership	-0,5637	-0,2464	-0,0719	-0,6291*	-0,1535	-0,0064	-0,5439	-0,0379	-0,0089	-0,3966***
	(-0,5113)	(-0,8349)	(-0,1081)	(-1,5562)	(-0,6709)	(-0,6687)	(-0,7081)	(-0,6282)	(-0,3148)	(-7,8701)
Export Orientation	0,0223	-0,1047	-0,1667	-0,5162*	-0,5042	-0,0176	1,0345**	-0,4838***	0,0943***	-0,0232
	(0,4396)	(-0,9229)	(-0,8325)	(-1,1412)	(-0,9604)	(-0,7088)	(1,8367)	(-3,4294)	(3,0566)	(-0,9811)
Import Intensity	-0,0091*	-0,0097***	-0,1227*	0,0065**	-0,0081	-0,0128**	0,0199***	0,0007	-0,0125***	-0,0011**
	(-1,5428)	(-4,3279)	(1,6571)	(2,0205)	(-0,9076)	(1,9561)	(2,5427)	(0,9664)	(-3,7451)	(-2,3636)
Sigma-squared ()	0,4759***	0,6963***	0,6084***	0,7416***	0,8041*** (6,6340)	0,6106***	0,3272***	0,6189***	0,7632***	0,6853***
	(23,0395)	(181,2275)	(25,4186)	(21,7239)		(46,6596)	(4,5241)	(22,5707)	(76,9955)	(65,1866)
Gamma (γ)	0,0086	0,0353***	0,0366	0,0159 (0,3712)	0,0315 (0,3961)	0,0406***	0,0145	0,0009***	0,0258*	0,0036***
	(0,2802)	(5,4001)	(0,4578)			(6,0241)	(0,1306)	(11,5254)	(1,5183)	(7,1657)
Log Likelihood	-9210	-7528	-1864	-1620	-1375	-6042	-46	-1342	-4894	-34415
Number of Firms	1772	1232	321	256	209	1038	11	229	778	5848
Number of Observations	8860	6160	1605	1280	1045	5190	55	1145	3890	29230

Source: Estimated from Eqs. (1) and (2). Note: Numbers in parentheses are t-statistics. *** represents the significance level at alpha 1%. ** represents the significance level at alpha 5%. * represents the significance level at alpha 10%. Notes: The σ^2 is calculated from $\sigma^2 = \sigma^2_v + \sigma^2_u$, whereas.

3.2 Results of Technical Efficiency Scores

Average technical efficiency score of all manufacturing firms is 0.8815 or 88.15% for the period of 2010-2014. Manufacturing firms are able to achieve 88.15% of their full technical efficiency, with the rest 11.85% is so-called technical inefficiency. During the observed period, food and beverage firms (ISIC 31) have the highest average score of technical efficiency, which is 0.9126, showing that the firms in this industrial cluster produce close to the full efficiency. Hence, the first null hypothesis of "average technical efficiency is less than 0.5" is rejected for the food and beverage industrial cluster. Similarly, technical efficiency scores for eight other industrial clusters are also higher than 0.5 (as provided in Table 3). In short, the null hypotheses is stating that the average technical efficiency is less than 0,5 is rejected for firms in all industrial clusters. The nine observed industrial clusters experience average technical efficiency between 0.8715 and 0.9126.

Table 3. Average Score of Firm Technical Efficiency

Year	Food and Beverages (ISIC 31)	Textile and Leather (ISIC 32)	Wood and Wood Products (ISIC 33)	Paper and Paper Products (ISIC 34)	Chemical and Pharmaceutical (ISIC 35)
2010	0.9554	0.9412	0.9731	0.9351	0.9277
2011	0.9759	0.8577	0.8577	0.9839	0.9490
2012	0.9781	0.9565	0.9386	0.9753	0.8352
2013	0.9744	0.9451	0.9035	0.8857	0.4349
2014	0.7946	0.7225	0.8444	0.9269	0.5809
2010-2014	0.9126	0.8838	0.8715	0.8753	0.8547

Year	Non-Metal Mineral (ISIC 36)	Basic Metals (ISIC 37)	Metal Products (ISIC 38)	Others (ISIC 39)	All Firms
2010	0.9319	0.6332	0.7949	0.9245	0.8834
2011	0.9251	0.7638	0.8746	0.9191	0.9228
2012	0.9667	0.9218	0.9275	0.9166	0.9079
2013	0.8931	0.7896	0.8635	0.7832	0.9091
2014	0.8400	0.1566	0.8088	0.9144	0.8075
2010-2014	0.8939	0.8904	0.8583	0.8849	0.8815

Source: Calculated from results in Table 2

In all industrial clusters, it is found that the values of sigma-squared (σ^2) are greater than 0 and are significant at 1% level. These values indicate that there are technical inefficiency effects in the production function models.

3.3 Results of Firm Size's Effects on Technical Inefficiency

To interpret the impact of firm size on technical inefficiency, we need to go back to Table 2. It can be seen that firm size has a negative impact on technical inefficiency for the total manufacturing firms (the last column of Table 2), and this negative impact is significant at the 1% level. It indicates that an increase in firm size will help reduce firms' inefficiency. The coefficient value of firm size -0.0085 means that an increase in firm size by 1% will reduce inefficiency by 0.0085%. When looking at the nine clusters separately, firm size is also found to have a negative effect on firm inefficiency in paper and paper products (ISIC 34), chemical and pharmaceuticals (ISIC 35), and basic metals (ISIC 37). Hypothesis 2, which states that 'firm size has a negative impact on inefficiency,' is accepted for all firms and the cluster firms in ISIC 34, 35, and 37. This finding corresponds with the organizational theory and supports prior empirical studies either in Indonesia or elsewhere (Parida & Pradhan, 2017; Noor & Siang, 2014; Sahoo & Nauriyah, 2014; Tingum & Ofeh, 2017; AC-Ogbonna, 2018; Setiawan *et al*., 2019; Musau *et al*., 2020; Octarina & Mariam, 2021).

In contrast, firm size is found to have a positive impact on firms' inefficiency in the metal product industry (ISIC 38). When firm size increases, the technical inefficiency score also increases. The same result is found for food and beverage firms (ISIC 31), textile and leathers (ISIC 32), wood and wood products (ISIC 33), non-metal minerals (ISIC 36), and others (ISIC 39). However, the positive impact is significant only for firms in food and beverage (ISIC 31), textile and leather (ISIC 32), metal products (ISIC 38), and others (ISIC 39). The results show that hypothesis 2 is rejected for ISIC 31, ISIC 32, ISIC 38, and ISIC 39. This finding is similar to Aggrey *et al.* (2010), Le & Harvie (2010), Moreno & Carrasco (2015), Sari *et al.* (2016), and Abdulla & Kumar (2021). This finding implies that more prominent firms are not necessarily more efficient than smaller firms. The impact of firm size is varied depending on the unique characteristics of firms and industries.

3.4 Results of Foreign Ownership's Effects on Technical Inefficiency

Foreign ownership is found to have a negative impact on firms' inefficiency for the sample of all firms. The coefficient value of -0.3966 (significant at 1% alpha) means that foreign ownership can help reduce firms' inefficiency by 39.66%. Foreign ownership is also found to have negative coefficients for firms in each industrial cluster, and it has a significant negative impact on firms' inefficiency in the cluster of paper and paper products (ISIC 34). Negative coefficients mean that foreign ownership helps reduce firms' technical inefficiency. Hypothesis 3, which states that "foreign ownership has a negative effect on firms' in efficiency" is accepted for the sample of all nine industrial clusters and the sample of firms in the paper and paper products industry. This finding is consistent with the theory that firms with foreign ownership tend to have more access to foreign technology and managerial expertise, which help them improve efficiency. Furthermore, this finding supports those in Sinani *et al.* (2008), Faruq & Yi (2010), Amornkitvikai *et al.* (2014), Suyanto & Sugiarti (2018), Fukuyama *et al.* (2020), and Suyanto *et al.* (2021) although the period of observation is different.

3.5 Results of Export Orientation's Effects on Technical Inefficiency

Export orientation is found to have a negative insignificant impact on firms' inefficiency in the sample of all firms (the last column of Table 2), but the impact is varied in the sample of each industrial cluster. Firms in the Paper and Paper Products industry (ISIC 34) and in the Metal Products industry (ISIC 38) experience a negative significant effect of export orientation in reducing inefficiency, whereas firms in the Basic Metal industry (ISIC 37) and Others (ISIC 39) receive a positive impact of export orientation on technical inefficiency. Hypothesis 4 which states that "export has a negative impact on inefficiency" is accepted for firms in paper and paper product industry and in the metal products industry, while it is rejected for firms in basic metal industry and others. The finding that shows negative contribution of export to firms' technical inefficiency is similar to prior studies in Indonesia, including Walujadi (2004) and Suyanto, Sugiarti, & Tanaya (2021). It is also in accordance with Turnbull *et al.* (2016) which found that trade liberalization contributes to productivity improvement. This finding is also consistent with other prior studies in other countries, including Granér & Isaksson (2007), Roy & Yasar (2015), Parida & Pradhan (2017), Sharma (2017), Bashir *et al.* (2020), and He & Huang (2021). In contrast, the finding that shows positive relationship between export orientation and inefficiency is in line with Sari *et al.* (2016).

3.6 Results of Import Intensity's Effects on Technical Inefficiency

Import intensity is found to have ambiguous effects on firms' inefficiency. Import intensity negatively impact technical efficiency for firms in Food and Beverage industry (ISIC 31), Textile and Leather industry (ISIC 32), Wood and Wood Products (ISIC 33), Chemical and Pharmaceuticals (ISIC 35), Non-metal Minerals (ISIC 36) and Others (ISIC 39). In contrast, it has a positive impact on inefficiency in Paper and Paper Products industry (ISIC 34) and Metal Products (ISIC 38). Such finding implies that importing materials reduce inefficiency of firms in the six former clusters but increase the inefficiency of firms in the two latter industrial clusters. In addition, the result for the all-firm sample shows that import intensity has a negative significant impact on firms' inefficiency at the 1% level, which is also in line with hypothesis 5.

The negative correlation between import intensity and technical inefficiency is consistent with the theory that states that access to international input markets helps technological transfer which in turn improves firms' efficiency and productivity. A negative relationship between import intensity and technical inefficiency is found in previous studies, including Walujadi (2004), Imbruno & Ketterer (2018) dan Perusic& Zhang (2020). In addition, Bas (2012) found that firms that use imported materials are found to be more efficient compared to firms thatdo not. This finding is also in line with Gutierrez & Teshima (2017) who found import competition helps firms improve efficiency. In contrast, a positive relationship between import intensity and technical inefficiency is also found in Yevhenii (2015), Sari *et al.* (2016), and Liu *et al.* (2021). Thus, the impact of import intensity on technical efficiency is dependent on the unique characteristics of firms and industries as well as on the absorption capability of the firms and industries.

4. Conclusions

The current study analyzes the technical inefficiency of Indonesian manufacturing firms and the effect of several key determinants, namely firm size, foreign ownership, export orientation, and import intensity. Five important findings are recorded. The average score of technical efficiency of all manufacturing firms is 88.15% during the period of 2010-2014; firm size is found to have a negative impact on firms' inefficiency in the all-firm sample and in three out of nine clusters (ISIC 34, ISIC 35, and ISIC 37), whereas it has positive impact in six out of nine industrial clusters (ISIC 31, ISIC 32, ISIC 33, ISIC 36, ISIC 38, and ISIC 39); foreign ownership generates a negative contribution to firms' technical inefficiency in the sample of all firms and the sample of each nine industrial clusters; export orientation has a various impact on firms across nine industrial clusters, with a dominant negative significant impact in paper and paper product industry (ISIC 34) and metal product industry (ISIC 38), and a significant positive impact in basic metal industry (ISIC 37) and others (ISIC 39); import intensity has a negative significant impact on firms in most industrial clusters (ISIC 31, ISIC 32, ISIC 33, ISIC 35, ISIC 36 and ISIC 39), while only three clusters with a positive coefficient of import intensity (ISIC 34, ISIC 37, and ISIC 38). In short, the findings of this study confirm the importance of absorption capacity of each industrial cluster in gaining efficiency impacts from key determinants. Firms in different clusters receive different impacts of key determinants of technical inefficiency, depending on their absorbing capacity. The usefulness of this study is twofold. First, the finding provides evidence that firms within different clusters receive different impact of key determinants of efficiency. For example, firm size is a significant determinant in three clusters of firms (i.e., paper and paper products cluster, chemical and pharmaceutical cluster, and basic metal cluster), whereas foreign ownership is a significant determinant for efficiency score in firms in all nine clusters. Second, the clustering of firms provides evidence that companies should consider the effects of firm size, foreign ownership, export orientation, and import intensity in the decision making regarding technical efficiency, supporting the findings of previous study.

5. Acknowledgement

The authors would like to extend gratitude to the Ministry of Education, Culture, Research and Technology for granting the funding for the basic research on firm productivity, in which this paper is one of the parts. The remaining error and omission are fully the responsibility of the authors.

6. References

Abdulla, & Kumar, S. (2021). Technical Efficiency and Its Determinants in The Indian Textile Garments Industry. *Research Journal of Textile and Apparel, 25*(4), 346-360.

AC-Ogbonna, C. (2018). Determinants of The Technical Efficiency Performance of Privatized Manufaturing Firms in Nigeria: An Econometric Analysis. *International Journal of Development and Economic Sustainability, 6*(1), 19-28.

Amornkitvikai, Y., Harvie, C., & Charoenrat, T. (2014). Estimating a Technical Inefficiency Effects Model for Thai Manufacturing and Exporting Enterprises (SMEs): A Stochastic Frontier (SFA) and Data Envelopment Analysis (DEA) Approach . *Proceedings of Informing Science & IT Education Conference (InSITE)*, 363-390.

Aggrey, N., Eliab, L., & Joseph, S. (2010). The Relationship between Firm Size and Technical Efficiency in East Africa Manufacturing Firms. *Journal of Sustainable Development in Africa, 12*(4), 226-236.

Ai, H., Wu, X., & Li, K. (2019). Differentiated Effects of Diversified Technological Sources on China's Electricity Consumption: Evidence from the Perspective of Rebound Effect. *Energy Policy*, 1-8. DOI: 10.1061/j.enpol.2019.11184

Bas, M. (2012). Input-Trade Liberalization and Firm Export Decisions: Evidence from Argentina. *Journal of Development Economics, 97*, 481-493.

Bogetoft, P., & Otto, L. (2011). Benchmarking with DEA, SFA, and R. *International Series in Operations Research & Management Science*, 10.1007/978-1-4419-7961-2_7.

Battese, G., & Coelli, T. J. (1995). A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. *Empirical Economics, 20*(2), 325-332. DOI: 10.1007/BF01205442

Coelli, T. J., Rao, D. P., & Battese, G. E. (2005). *An Introduction to Efficiency and Productivity Analysis* (2nd ed.). United States: Springer.

Esquivias, M. A., & Harianto, S. K. (2020). Does Competition and Foreign Investment Spur Industrial Efficiency? Firm-Level Evidence from Indonesia. *Heliyon, 6*, 1-10. DOI: 10.1016/j.heliyon.2020.e04494

Faruq, H. A., & Yi, D. T. (2010). The Determinants of Technical Efficiency of Manufacturing Firms in Ghana. *Global Economy Journal, 10*(3), DOI:10.2202/1524-5861.1646.

Farrell, M. J. (1957). The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society*, 253-290.

Fukuyama, H., Matousek, R., & Tzeremes, N. G. (2020). A Nerlovian Cost Inefficiency Two-stage DEA Model for Modeling Banks' Production Process: Evidence from The Turkish Banking. *Omega 95*, 1-13. DOI: https://doi.org/10.1016/j.omega.2020.102198

Granér, M., & Isaksson, A. (2007). Firm Efficiency and the Destination of Exports: Evidence from Kenyan Plant-level Data,. *Economic Research Paper*.

Gutierrez, E., & Teshima, K. (2017). Abatement Expenditures, Technology Choice, and Environmental Performance: Evidence from Firm Responses to Import Competition in Mexico. *Journal of Development Economics*.

Habiyaremye, N., Tabe-Ojong, M. P., Ochieng, J., & Chagomoka, T. (2019). New Insights on Efficiency and Productivity Analysis: Evidence from Vegetable-Poultry Integration in Rural Tanzania. *Scientific African, 6*, 1-11.

He, L.-Y., & Huang, G. (2021). How Can Export Improve Firms' Energy Efficiency? The Role of Innovation Investment. *Structural Change and Economic Dynamics, 59*, 90-97.

Hossain, M. M., & Majumder, K. A. (2015). On Measurement of Efficiency of Cobb-Douglas Production Function with Additive and Multiplicative Errors. *Statistics, Optimization and Information Computing, 3*, 96-104.

Ikhsan, M. (2007). Total Factor Productivity Growth in Indonesian Manufacturing: A Stochastic Frontier Approach. *Global Economic Review, 36*(4), 321-342. DOI: 10.1080/12265080701694488

Imbruno, M., & Ketterer, T. D. (2018). Energy Efficiency Gains from Importing Intermediate Inputs: Firm-Level Evidence from Indonesia. *Journal of Development Economics*, 1-63. DOI: 10.1016/j.jdeveco.2018.06.014

Kumbhakar, S. C. (2013). Specification and Estimation of Multiple Output Technologies: A Primal Approach. *European Journal of Operational Research, 231*, 465-473.

Lafuente, E., Leiva, J. C., Gomez, J. M., & Szerb, L. (2020). A Nonparametric Analysis of Competitiveness Efficiency: The Relevance of Firm Size and the Configuration of Competitive Pillars. *Business Research Quarterly, 23*(3), 203-216. DOI: 10.1177/2340944420941440

Le, V., & Harvie, C. (2010). Firm Performance in Vietnam: Evidence from Manufacturing Small and Medium Enterprises. *WP*, 04-10.

Lemi, A., & Wright, I. (2018). Exports, Foreign Ownership, and Firm-Level Efficiency in Ethiopia and Kenya: An Application of the Stochastic Frontier Model. *Empirical Economics*, 1-30. DOI: 10.1007/s00191-018-1521-9

Lestari, E. P., & Isnina, W.S.U. (2017). Analisis Kinerja Industri Manufaktur di Indonesia. *Journal of Research in Economics and Management, 17*(1), 183-198. DOI: 10.17970/jrem.17.1701013.ID

Liu, Y. (2018). Government Extraction and Firm Size: Local Officials' Responses to Fiscal Distress in China. *Journal of Comparative Economics, 46*(6), 1310-1331. DOI: 10/1016/j/jce.2018.09.002

Margono, H., & Sharma, S. C. (2006). Efficiency and Productivity Analysis of Indonesian Manufacturing Industries. *Journal of Asian Economics, 17*(6), 979-995.

Musau, A., Kumbhakar, S. C., Mydland, O., & Lien, G. (2020). Determinants of Allocative and Technical Inefficiency in Stochastic Frontier Models: An Analysis of Norwegian Electricity Distribution Firms. *European Journal of Operational Research*, 1-30. DOI: https://doi.org/10.1016/j.ejor.2020.06.023

Noor, Z. M., & Siang, L. C. (2014). Technical Efficiency of Malaysian Manufacturing Small and Medium Enterprises. *Prosiding Persidangan Kebangsaan Ekonomi Malaysia*, 676-688.

Octrina, F., & Mariam, A. G. (2021). Islamic Bank Efficiency in Indonesia: Stochastic Frontier Analysis. *Journal of Asian Finance, Economics and Business, 8*(1), 751-758. DOI: 10.13106/jafwb.2021.vol8.no1.751

Parida, P. C., & Pradhan, K. C. (2017). The Determinants of Technical Efficiency of Labor Intensive Manufacturing Firms in India. *Manpower Journal, LI*(4).

Perusic, N. B., & Zhang, J. H. (2019). Import Effect on Technical Efficiency of Cargo Ports: Evidence from Italy, Slovenia, and Croatia. *Journal of Economics and Sustainable Development, 10*(22), 152-159. DOI: 10.7176/JESD/10-22-16

Priya, R. S., & Aroulmoji, V. (2020). A Review on Productivity and its Effect in Industrial Manufacturing. *International Journal of Advanced Science and Engineering, 6*(4), 1490-1499.

Roy, J., & Yasar, M. (2015). Energy Efficiency and Exporting: Evidence from Firm-Level Data. *Energy Economics, 52*, 127-135.

Sahoo, B. K., & Nauriyal, D. K. (2014). Trends in and Determinants of Technical Efficiency of Software Companies in India. *Journal of Policy Modeling*, 1-23. DOI: http://dx.doi.org/10.1016/j.jpolmod.2013.12.001

Sari, D. W., Khalifah, N. A., & Suyanto, S. (2016). The Spillover Effects of Foreign Direct Investment on Productivity Performances. *J Prod Anal*, 199-233. DOI: 10.1007/s11123-016-0484-0

Setiawan, M., Effendi, N., Heliati, R., Syahrin, A., & Waskito, A. (2019b). Technical Efficiency and its Determinants in the Indonesian Micro and Small Enterprises. *Journal of Economic Studies, 46*(6), 1157-1173. DOI: 10.1108/JES-08-2018-0298

Setiawan, M., Emvalomatis, G., & Lansink, A. O. (2012). The Relationship between Technical Efficiency and Industrial Concentration: Evidence from the Indonesian Food and Beverages Industry. *Journal of Asian Economics, 23*, 466-475. DOI: 10.1016/j.asieco.2012.01.002

Setiawan, M., Indiastuti, R., Hidayat, A. K., & Rostiana, E. (2021). R&D and Industrial Concentration in the Indonesian Manufacturing Industry. *Journal of Open Innovation, Technology, Market, and Complexity, 7*(112), 1-12. DOI: 10.3390/joitmc7020112

Strydom, H. (2013). An Evaluation of the Purposes of Research in Social Work. *Social Work, 49*(2), 149-164. DOI: 10.15270/49-2-58

Sharma, C. (2017). Exporting, Access of Foreign Technology, and Firms' Performance: Searching the Link in Indian Manufacturing. *The Quarterly Review of Economics and Finance*. DOI: https://doi.org/10.1016/j.qref.2017.11.015

Sinani, E., Jones, D. C., & Mygind, N. (2008). Determinants of Firm Level Technical Efficiency: A Stochastic Frontier Approach. *Corporate Ownership and Control, 5*(3), DOI: 10.22495/cocv5i3c1p7.

Suyanto, S., Salim, R., & Bloch, H. (2014). Which Firms Benefit from Foreign Direct Investment? Empirical Evidence from Indonesian Manufacturing. Journal of Asian Economics, 33, 16-29

Suyanto, & Sugiarti, Y. (2018). Do Local Suppliers and Local Buyers Benefit from Foreign Direct Investment: Evidence from Indonesia. *Advances in Social Science, Education and Humanities Research (ASSEHR), 186*, 220-223.

Suyanto, S., Sugiarti, Y., & Setyaningrum, I. (2021a). Clustering and Firm Productivity Spillovers in Indonesian Manufacturing. *Heliyon, 7*, 1-10. DOI: https://doi.org/10.1016/j.heliyon.2021.e06504

Suyanto, S., Sugiarti, Y., & Tanaya, O. (2020). Inefficiency of Indonesian Food and Beverages Firms. *ICEBE*, 1-7. DOI: 10.4108/eai.1-10-2020.2304707

Suyanto, S., Sugiarti, Y., & Tanaya, O. (2021b). Technological Progress in Indonesian Food Processing. *Advances in Economics, Business and Management Research, 180*, 92-97.

Tingum, E. N., & Ofeh, M. A. (2017). Technical Efficiency of Manufacturing Firms in Cameroon: Sources and Determinants. *International Journal of Financial Research, 8*(3), 172-186. DOI: 10.5430/ijfr.v8n3p172

Tsionas, M. G. (2020). Quantile Stochastic Frontiers. *European Journal of Operational Research*, 1-16. DOI: 10.1016/j.ejor.2019.10.012

Turnbull, C., Sun, S., & Anwar, S. (2016). Trade Liberalization, Inward FDI and Productivity within Australia's Manufacturing Sector. *Economic Analysis and Policy, 50*, 41-51.

Walujadi, D. (2004). Age, export orientation and technical efficiency: Evidence from garment firms in DKI Jakarta. *Makara, Sosial Humaniora, 8*(3), 97-104.

Yevhenii, S. (2015). Effects of Imports on Technical Efficiency in Russian Food Industry. *Applied Econometrics, Russian*

Presidential Academy of National Economy and Public Administration (RANEPA), 37(1), 27-42.

Zhu, J., Wang, Y., & Wang, C. (2018). A Comparative Study of the Effects of Different Factors and Firm Technological Innovation Performance in Different High-Tech Industries. *Chinese Management Studies*. DOI: 10.1108/SMS-10-2017-0287