Assessing Technical Efficiency of Large and Medium Manufacturing Industry in West Java Province, Indonesia: A data Envelopment Analysis Approach

M. Mujiya Ulkhaq

Department of Industrial Engineering, Diponegoro University, Indonesia

Article Info

Article history:

Received Jun 9, 201xx
Revised Nov 20, 201xx
Accepted Dec 11, 20xx

Keywords:

Data envelopment analysis
Industry
Large and medium manufacturing
Technical efficiency
Indonesia

ABSTRACT

Technical efficiency of Indonesian manufacturing industry has been measured in several studies. However, there is limited study conducted in large and medium manufacturing industries context. This study, therefore, aims to analyze the technical efficiency of the large and medium manufacturing industries in West Java Province, Indonesia. Understanding the technical efficiency is important as firms with full technical efficiency, the less inputs they use, the larger output they achieve. Data envelopment analysis with output-oriented and variable returns-to-scale is used to accomplish the objective of this study. The output is measured by total output value, while the inputs are cost of labor, raw materials, fuel, electricity, and gas, representation and royalty, fixed capital, as well as industrial service. Result shows that among twenty-four decision-making units under-investigated, nine of them are considered as the most efficient.

Corresponding Author:

Name: M. Mujiya Ulkhaq
Institution Address: Department of Industrial Engineering, Diponegoro University, Jl. Prof. Soedarto SH, Tembalang, Semarang 50275, Indonesia
e-mail: ulkhaq@live.undip.ac.id

1. INTRODUCTION

The manufacturing industry contributed the most to Indonesia's 7.07% economic growth in the second quarter of 2021, with a 6.91% growth despite pressure from the COVID-19 pandemic. According to the data from the Ministry of Industry, the manufacturing sector contributed the largest to the national gross domestic product (GDP) in the second quarter of 2021, amounting to 17.34%. In the third quarter of 2021, the manufacturing industry grew 3.68% and contributed 0.75% to the national economy's growth. The proven resiliency indicates that the trajectory of industrial growth is still on track, and the sector is set to become the driver for the national economy, aiming for a GDP contribution of more than 20% by 2024.

Statistics Indonesia classifies manufacturing industry into four classes based on its scale. They are large (number of labors is more than 100), medium (number of labors is between 20 to 99), small (number of labors is between 5 to 19), and micro or domestic industries (number of labors is less than 5). In the first quarter of 2019, the production of large and medium manufacturing industries rose 4.45% compared to the same period last year. This number is also higher than in the average of 2018 which was only 4.07%. The increase in the production was supported by the apparel industry sector, which rose 29.19% due to the abundance of demands, especially from the export market. From the entire manufacturing sectors value-added, more than 40% is contributed by large and medium manufacturing industries. By contrast, small and micro manufacturing industries in the same period contributed less than 10% on average.

Despite the important role of large and medium manufacturing industries in Indonesia's economy, this sector has experienced inconsistent growth in both output growth and labor productivity growth [1]. The output growth fluctuated from minus 10% to 13% during 2000-2015. The instability of output growth can be analyzed by measuring the source of output growth, either due to technological factors or input formation [2]. The objective of this study is then to analyze the technical efficiency of large and medium manufacturing industries in Indonesia. Understanding the technical efficiency, which is simply defined as the ratio of output to input [3], is important because if firms perform consistently with full technical efficiency, the less inputs they use, the larger output they achieve.

Technical efficiency in Indonesian manufacturing industry has been measure in several studies. However, there is limited study in measuring the technical efficiency of large and medium manufacturing industries context (see subsequent section). Therefore, this study seeks to fill the gap in the literature by assessing the technical efficiency of large and medium manufacturing industries in West Java Province, Indonesia.

The rest of the paper is structured as follows. The following section shows literature review we conduct to show the novelty of this study. The next section presents the data used in this study, including inputs and output. The fourth section describes the empirical model of this study, i.e., output-oriented DEA with VRS approach. The five section shows the result of this study while the last section concludes.

2. LITERATURE REVIEW

Technical efficiency is mainly assessed by frontier methods, which can be categorized as parametric and non-parametric approach. The difference lies in the fact that in the parametric approach, one has to define a functional form a priori and estimates the finite set of unknown parameters from the data. On the other hand, the non-parametric approach is considered simple, easy to handle multiple outputs, and it does not require any assumption about the functional form. Among the non-parametric approach, DEA is the most popular tool in assessing technical efficiency.

Literature about assessing technical efficiency of manufacturing industry in Indonesia using DEA is quite limited. We then conduct a search in the Scopus database (www.scopus.com) to verify this claim. The following query is used: TITLE-ABS-KEY (manufactur* AND industry AND efficien* AND Indonesia* AND (dea OR "data envelopment analysis")). It means that the articles which contains this query in the title, abstract, or keywords are extracted. The period of time is not limited. For the sake of quality assurance, the article type is restricted to peer-reviewed research article published in a journal as these sources are the most useful for literature reviews [4]. Therefore, other types of articles such as books or book chapters, conference proceedings, short communications, letters, or editorial materials are excluded. From a pragmatic point of view, only articles published in English are included.

The search yields 6 (six) articles. This low yield indicates that this research area is under-studied—especially among scholars in Indonesia, confirming our previous claim. However, among those six extracted articles, we cannot find the full text of [5] so that this article is excluded for further analysis. These extracted articles are discussed as follows.

[6] used DEA to assess technical efficiency of 130 public manufacturing firms listed in the Indonesian Stock Exchange in 2019. [7] investigated technical efficiency of Indonesian state-owned enterprises manufacturing industry. They used two-stage DEA; as the first stage was intended to calculate the technical efficiency, while at the second stage aimed to investigate the effects of determinants of efficiency. Setiawan et al. [8] assessed technical efficiency of Indonesian micro and small enterprises. They used the data from the micro and small industry survey sourced from Statistics Indonesia for the period 2010–2015. The technical efficiency was estimated using DEA with bootstrapping approach. Van Dijk and Szirmai [9] analyzed the micro- dynamics of catch-up in Indonesian paper manufacturing using a two-country plant-level dataset for the period 1975–1997. They applied DEA to measure to what extent Indonesian paper mills are catching up with Finnish mills in terms of technical efficiency. Finally, Halim [10] evaluated technical efficiency and marketing productivity of Indonesian public manufacturing firms listed at the Indonesia Stock Exchange during the period 2001–2007.

From the literature review, it is apparent that no research has been conducted to—especially—investigate technical efficiency of large and medium manufacturing industries. Therefore, this study seeks to fill the gap in the literature. In addition, this study is expected to provide a portrait of large and medium manufacturing industries in Indonesia, given the role of this industry in Indonesian economy. The manufacturing sector has contributed 27% on average to Indonesia's GDP between 2000 and 2015, with more than 40% of its value-added contributed by large and medium scale [1].

3. DATA AND VARIABLES

This study uses data from the annual survey held by Statistics Indonesia of West Java Province for the period of 2019. The large and medium manufacturing sector is divided into 24 different industrial classifications following the International Standard Industrial Classification of all Economic Activities (ISIC) Revision 4. Statistics Indonesia defines the medium and large industries as the firms with number of labors of 20 to 99 labors and number of labors of more than 100, respectively.

Output in this study is measured by total output value in thousand rupiahs comprises of: (i) value of goods produced from production process, (ii) value of electricity generated by the firm and some of it is sold to other parties, (iii) value of industrial services rendered (meaning that the materials are provided by other parties, while the firm only performs the processing process in exchange for a certain amount of money or goods as compensation), (iv) increase in stock of semi-finished products (it is the difference in the value of the stock of semi-finished products at the end of the year which is reduced by the stock at the beginning of the year), and (v) receipt from non-industrial services rendered. In the literature of efficiency measurement of manufacturing industries, total output value is commonly used, e.g., [11], [12], [13].

I use six inputs in this study. The first is labor cost, representing the total expenditure incurred by employers for the employment of employees, including direct and indirect labor costs. Next are cost of raw materials and other supporting materials, representing costs of materials used to manufacture a product. The next if cost of fuels (e.g., gasoline, diesel, kerosene, and coal), electricity, and gas used during the production process. The next is fixed capital cost, such as building, machinery, and equipment. The last two are representation and royalty cost as well as industrial service cost. Those inputs are also commonly used in the study of efficiency measurement of manufacturing industries. Labor cost was used in [11], [13]; material cost was used in [7], [8], [11], [12], [14]; energy cost was used in [11], [14]; and fixed capital cost was used in [7], [8], [11], [12], [14]. The data is shown in the Appendix.

In DEA, the influence of inputs on output cannot be investigate; thus, the selection of inputs only depends on the literature without knowing whether the selected inputs significantly influence the output. However, [15], [16] argued that inputs must fulfill the requirement of isotonicity (i.e., ceteris paribus, more input implies an equal or higher level of output); hence, the selected inputs should present a significant positive correlation with the output in addition to have theoretical support from previous work. In Table 1, we provide correlation coefficients of all variables used. In Table 1, I provide correlation coefficients of all variables used. Notice that in Table 1, the total output value is positively correlated with inputs.

Table 1. Correlation coefficients between inputs and output

	Output value
Labor cost	0.79617404
Materials cost	0.95682640
Fuel, electricity, and gas cost	0.62362518
Fixed capital cost	0.15504833
Representation and royalty cost	0.01034346
Industrial service cost	0.93274414

4. METHOD

Technical efficiency refers to the ability of a decision-making unit (DMU), in this study, it is the large and medium manufacturing industry in West Java Province, Indonesia, to minimize input used in the production of a given output, or the ability to obtain maximum output from a given inputs. Consequently, a DMU is fully technically efficient if it produces the maximum possible output from a fixed level of inputs (in an output orientation), or if it uses the minimum possible inputs to produce a given level of output (in an input orientation).

This study uses DEA to assess the technical efficiency. It is a non-parametric approach that requires very few assumptions in estimating technical efficiency compared to the parametric approach such as the stochastic frontier analysis (SFA). In SFA, one has to define a functional form a priori and estimate the finite set of unknown parameters from the data. In addition, due to the use of maximum likelihood method, the distribution of inefficiency must be defined a priori. In DEA, we do not consider those issues. DEA has been widely used to assess technical efficiency of industrial sector, e.g., small and medium enterprise [17], [18] and creative industry [19].

Let M be the number of inputs and N be the number of DMUs, (in this study, $M = 6$ and $N = 24$). In order to estimate efficiency of a DMU, the following fractional programming is formulated.

$$
\begin{aligned}
&\text{Min} && \boldsymbol{\theta} \\
&\textit{Subject to} && \boldsymbol{\theta}\boldsymbol{x}_o - \mathbf{X}\boldsymbol{\lambda} \geq \mathbf{0} \\
& && \mathbf{Y}\boldsymbol{\lambda} \geq y_o \\
& && \mathbf{e}\,\mathbf{Y} = \mathbf{1} \\
& && \boldsymbol{\lambda} \geq \mathbf{0}, \qquad (1)
\end{aligned}
$$

where $1 \geq \boldsymbol{\theta} \geq 0$ is the efficiency, $\mathbf{X}$ represents the $M \times N$ input matrix, $\mathbf{Y}$ is the $1 \times N$ output vector, $\boldsymbol{\lambda}$ is $N \times 1$ vector of constants, and e is $1 \times N$ vector of ones, x_o and y_o are inputs and output of DMU under consideration. When efficiency score is 1, the corresponding DMU is considered as efficient; otherwise, when efficiency score is less than 1, the corresponding DMU is considered as inefficient.

The methodology is completely deterministic, in the sense that it attributes all the deviation from the frontier to inefficiency; there is no random error estimated.

The input-oriented model of DEA is used, where it attempts to minimize input while satisfying a given output level. In addition, the assumption of variable returns to scale (VRS) is used, as this assumption is relevant to be applied in the Indonesian economy which is characterized by many distortions.

5. RESULT

The result of this study is shown in Table 2. Note that I use ISIC code as the DMU name, for instance, DMU 10 is the food manufacturing industry, DMU 31 contains firms in the furniture sector, etc. (see the Appendix). The efficiency score is depicted in the second column. According to output-oriented VRS-DEA, the most efficient manufacturing sectors are tobacco products (ISIC code: 12); textiles (13); leather and related products and footwear (15); paper and paper products (17); coke, refined petroleum products (19); basic metals (24); electrical equipment (27); motor vehicles, trailers, and semi-trailers (29); and repair and installation of machinery and equipment (33) as these sectors have efficiency score of one. The other sectors are considered as inefficient since their efficiency scores are less than one.

Table 2 also shows the benchmark (reference set) with its corresponding λ^*. For instance, the λ^*s of DMU 10 are 0.609 and 0.391, showing the proportions contributed by DMU 27 and DMU 29, respectively, to the point used to evaluate DMU 10; hence, DMU 10 is technically inefficient. In fact, based on this reference set and λ^*, we can express the input and output values needed to bring DMU 10 into efficient state as 0.904 × Inputs of DMU 10 = 0.609 × Inputs of DMU 27 + 0.391 Inputs of DMU 29, where 0.904, 0.609, and 0.391 are the efficiency score of DMU 10, λ^* of DMU 10 for DMU 27, and λ^* of DMU 10 for DMU 29, respectively. We can also observe from the magnitude of λ^* that DMU 10 has more similarity to DMU 27 than DMU 29.

Table 2. Result

DMU (ISIC, Rev. 4)	**Efficiency score**	**Benchmark (λ^*)**	**DMU (ISIC, Rev. 4)**	**Efficiency score**	**Benchmark (λ^*)**
10	0.904	27 (0.609); 29 (0.391)	22	0.720	12 (0.024); 24 (0.416); 27 (0.559)
11	0.913	12 (0.799); 15 (3.52×10^{-4}); 17 (0.075); 27 (0.125)	23	0.755	15 (0.005); 27 (0.642); 33 (0.353)
12	1.000	12 (1.000)	24	1.000	24 (1.000)
13	1.000	13 (1.000)	25	0.761	12 (0.353); 24 (0.279); 27 (0.368)
14	0.843	15 (0.030); 27 (0.912); 33 (0.058)	26	0.773	12 (0.347); 27 (0.653)
15	1.000	15 (1.000)	27	1.000	27 (1.000)
16	0.688	12 (0.386); 27 (0.057); 33 (0.557)	28	0.725	12 (0.166); 19 (0.132); 27 (0.703)
17	1.000	17 (1.000)	29	1.000	29 (1.000)
18	0.638	12 (0.753); 24 (0.118); 27 (0.130)	30	0.613	15 (0.001); 27 (0.877); 33 (0.121)
19	1.000	19 (1.000)	31	0.759	12 (0.867);

					24 (0.051); 27 (0.082)
20	0.883	27 (0.789); 29 (0.211)	32	0.772	12 (0.843); 15 (2.50x10^{-4}); 27 (0.114); 33 (0.043)
21	0.853	15 (2.29x10^{-4}); 27 (0.263); 33 (0.737)	33	1.000	33 1.000)

6. CONCLUSION

This study aims to measure the technical efficiency of large and medium manufacturing industries in West Java Province, Indonesia. DEA with output-oriented and variable returns-to-scale approach is used to accomplish the objective of the study. Result shows that among 24 DMUs under-investigated, nine of them are considered as the most efficient, located at the frontier (see Table 2).

This study calls for future research by comparing the finding with the study about measuring technical efficiency of small and micro manufacturing industries as this can give a more holistic portrait of the condition of manufacturing industries in West Java Province. In addition, comparing to other provinces is also worth investigation. Another future research direction is to perform the analysis in a panel data setting. Using panel data, more information of efficiency can be parsed, and in particular, shed light on changes in efficiency; whereas contrarily, in a cross-sectional setting (as in this study), it can only provide a static portrayal of efficiency.

REERENCES

[1] M. R. Primanthi, "Characteristics of Indonesia's large and medium scale manufacturing industries: an exploratory analysis," Ph.D. Dissertation, The Australian National University, Australia, 2021.

[2] C. R. Hulten, "Total factor productivity. A short biography," in *New Developments in Productivity Analysis*, C. R. Hulten, E. R. Dean, and M. J. Harper, Eds., University of Chicago Press, 2001, pp. 1-54.

[3] W. W. Cooper, L. M. Seiford and K. Tone, *Introduction to Data Envelopment Analysis and Its Uses: With DEA- solver Software and References*, Springer, 2006.

[4] M. Saunders, P, Lewis and A. Thornhill, *Research Methods for Business Students,* 6th ed. Pearson, 2012.

[5] P. M. A. Saputra, "Analysis of technical efficiency of Indonesian manufacturing industries: An application of DEA," *International Research Journal of Finance and Economics*, vol. 66, pp. 107-116, 2011.

[6] S. N. Sulistyawati and A. W. Suryani, "Achieving operational efficiency through risk disclosure," *Asian Journal of Business and Accounting*, vol. 15, no. 1, pp. 149-178, 2022.

[7] M. Setiawan and E. T. Sule, "Technical efficiency and its determinants of the state- owned enterprises in the Indonesian manufacturing industry," *International Journal of Economics and Management*, vol. 14, no. 3, pp. 331-342, 2020.

[8] M. Setiawan, N. Effendi, R. Heliati and A. S. A. Waskito, "Technical efficiency and its determinants in the Indonesian micro and small enterprises," *Journal of Economic Studies*, vol. 46, no. 6, pp. 1157-1173, 2019.

[9] M. Van Dijk and A. Szirmai, "The micro-dynamics of catch-up in Indonesian paper manufacturing," *Review of Income and Wealth*, vol. 57, no. 1, pp. 61-83, 2011.

[10] R. E. Halim, "Marketing productivity and profitability of Indonesian public listed manufacturing firms: An application of data envelopment analysis (DEA)," *Benchmarking*, vol. 17, no. 6, pp. 842-857, 2010.

[11] M. A. Esquivias and S. K. Harianto, "Does competition and foreign investment spur industrial efficiency?: firm-level evidence from Indonesia," *Heliyon*, vol. 6, no. 8, p. e04494, 2020.

[12] H. Margono and S. C. Sharma, "Efficiency and productivity analyses of Indonesian manufacturing industries," *Journal of Asian Economics*, vol. 17, no. 6, pp. 979-995, 2006.

[13] L. Sugiharti, R. Purwono, M. R. Primanthi and M. A E. Padilla, "Indonesian productivity growth: evidence from the manufacturing sector in Indonesia," *Pertanika Journal of Social Science and Humanities*, vol. 25, pp. 29-44, 2017.

[14] M. Ikhsan, "Total factor productivity growth in Indonesian manufacturing: a stochastic frontier approach," *Global Economic Review*, vol. 36, no. 4, pp. 321-342, 2007.

[15] J. M. C. Ferrera, E. Crespo-Cebada, and D. S. González, "Factors affecting educational attainment: evidence from Spanish PISA 2006 Results," *Regional and Sectoral Economic Studies*, vol. 10, no. 3, pp. 55-76, 2010.

[16] J. M. C. Ferrera, E. Crespo-Cebada, F. P. Chaparro and D. S. González, "Exploring educational efficiency divergences across Spanish regions in PISA 2006," *Revista de Economía Aplicada*, vol. 19, no. 57, pp. 117-145, 2011.

[17] S. N. W. Pramono, M. M. Ulkhaq, D. Pujotomo, and M. A. Ardhini, "Assessing the efficiency of small and medium industry: an application of data envelopment analysis," *IOP Conference Series: Materials Science and Engineering*, vol. 598, no. 1, p. 012043. 2019.
[18] D. P. Sari, N. U. Handayani, M. M. Ulkhaq, W, Budiawan, D. L. Maharani, and F. Ardi, "A data envelopment analysis approach for assessing the efficiency of small and medium-sized wood-furniture enterprises: a case study," *MATEC Web of Conferences*, vol. 204, p. 01015, 2018.
[19] N. U. Handayani, D. P. Sari, M. M. Ulkhaq, Y. Widharto, and R. C. A. Fitriani, "A data envelopment analysis approach for assessing the efficiency of sub-sectors of creative industry: A case study of batik enterprises from Semarang, Indonesia," *AIP Conference Proceedings*, vol. 2217, no. 1, p. 030038, 2020.