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# Technical Efficiency Chemical Industry in Indonesia: Stochastic Frontier Analysis (SFA) Approach

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## ABSTRACT

This study aims to analyse the technical efficiency of Chemical Industry in Indonesia using Stochastic Frontier Analysis (SFA) approach. A survey explanatory method is adopted with panel type data at 4240 inputs and output level of companies during six years of observation (2010-2015). Determinant technical efficiency is estimated by using multiple regression. Both technical efficiency calculations and regression determinants are done using the TE effect approach in Frontier 4.1 software. The result of research indicates that market share variable significantly and negatively affects technical efficiency. Other variables, such as company age, business ownership, ratio concentration, and capacity utilisation affect the technical efficiency are not significant. This finding implies that to improve the efficiency of the chemical industry, market share needs to be increased through various activities such as promotion.

*Keywords:* Chemical industry, Stochastic frontier analysis, technical efficiency

## INTRODUCTION

Synthetic materials have advantages over natural materials on the ease of obtaining properties of the desired material. Today some of humanity's needs can be met through the chemical industry, from textiles, transportation equipment (tires, carbon composites to vehicle bodies), electronic equipment (most electronics components), communication technology (fibre optic cable), drugs, building materials to household appliances. The development of the chemical industry brings about a huge change in life (Plechkova & Seddon, 2008; Tombs & Whyte, 2003).

The chemical industry is small in Indonesia compared with other industrial subsectors, such as food, beverages, tobacco, agriculture and manufacturing industries.

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European countries, North America and East Asia (Japan, South Korea, and China). When viewed from the development of the chemical industry from year to year, it appears that the chemical industry in Indonesia is not developing properly, although technological developments in the chemical industry has advanced very rapidly in the last two decades (Nandiyanto, Maulana, Ragadhita, & Abdullah, 2018).

The biggest obstacles that must be faced by the industry in chemistry in Indonesia today are: 1) The absence of linkage of micro and small industries with medium and large industries, even the occurrence of competition for market competition and raw materials among small / micro industries with medium-large industries. This inhibits the development of both parties. 2) Weak structure of the upstream-downstream industry. In developed countries, chemical industries are intertwined with each other, so that output from one factory can be used as inputs at other plants. Thus, a long chain of chemical industries will be created which implies an increase in value added to the goods. If seen from the value of the import of chemicals in Indonesia, the chemical industry is still not able to realise the integration between its sub-sectors of the industry. This has resulted in the weakness of industry in Indonesia because it directly creates the dependence of imported raw materials that impact on efficiency issues (Nandiyanto et al., 2018).

Efficiency is an important indicator in measuring the overall performance of a company's activities (Bunse, Vodicka, Schönsleben, Brülhart, & Ernst, 2011). Measurement of efficiency can provide an assessment of the good operation of a company or organisation. An efficient organisation requires minimal use of input resources to produce output. Many commonly used efficiency measurement tools, for example, use the Cobb-Douglas production function with a solution via an econometric model, the Constant Elasticity Of Substitution (CES) model, and in the latest development of efficiency measurements using Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) (Chiona, Kalinda, & Tembo, 2014; Ebrahimnejad, Tavana, Lotfi, Shahverdi, & Yousefpour, 2014; Aggrey, Eliab, & Joseph, 2010; Andersen & Petersen, 1993; Bessent, Bessent, Kennington, & Reagan, 1982; Charnes, Cooper, & Rhodes, 1978). The SFA method was developed by Aigner, Lovell and Schmidt (1977), Andersen & Petersen (1993), and Chiona et al., (2014). Stochastic frontier analysis is one of the methods used in estimating production limits (frontier) and also measuring the level of production efficiency (Chiona et al., 2014). This analysis uses a parametric approach and uses econometric methods in calculating efficiency. An efficiency measurement consists of two components: 1) technical efficiency that reflects the company's ability to get maximum output from a set of available inputs, and 2) allocative efficiency that reflects the ability of the firm to use input in the optimal proportion in accordance with the cost (Coelli, 1996, 2007).

Measurement efficiency in this case assumes that the firm's optimal production function is known. In practice, the production function is unknown, and it is estimated from the sample data using either a non-parametric piece-wise linear technology or parametric function like Cobb Douglas function (Coelli, 1996, 2007).

Based on the phenomenon, it is necessary to study the implementation of Stochastic Frontier Analysis (SFA) to measure the Efficiency of Chemical industry in Indonesia. This study is intended to collect and process data related to chemical industry efficiency in Indonesia so the following can be known 1) general description of input variables (capital, labour, raw materials, fuel and auxiliary materials) and output variables (outputs) 2) Compare whether the performance value characteristics of the DEA model have similarities with traditional model performance results, and 3) Identify the efficiency of food production the DEA model and its causal factors.

This study is expected to contribute to theory and praxis (development of knowledge and practical aspects respectively). From the theoretical aspect (science development), this research is expected to increase knowledge insight, especially related to micro economy and efficiency measurement using Stochastic Frontier Analysis approach. For practical aspects, this research provides recommendations for policy makers (government) and the chemical industry to improve efficiency.

## LITERATURE REVIEW

The definition of efficiency was first introduced by Debreu (1951) and Koopmans (1951) and has been widely used in the production and production efficiency literature t. Efficiency is input use in producing the most optimal output. It is a condition where people get the most goods / services that can be obtained from scarce resources (Farrell, 1957). In macroeconomics, the general equilibrium approach is a good tool used to calculate efficiency (Mankiw, 2014; Nicholson & Snyder, 2008). The efficiency of a company can be measured from its technical and allocative aspects. Technical efficiency is the company's ability to produce the maximum output from an existing set of inputs. Allocative efficiency is the company's ability to use inputs in optimal proportions, at existing prices. Both types of efficiency are then combined to produce total economic efficiency (Mankiw, 2014; Coelli, 1996).

Technical efficiency is the company's ability to produce maximum output from an existing set of inputs. Allocative efficiency is the company's ability to use inputs in optimal proportions, at existing prices. Both types of efficiency are then combined to produce total economic efficiency (Debreu, 1951; Koopmnas, 1951). Two approaches in the calculation of efficiency are output oriented and input oriented. The output is to maximise the output produced with a fixed set of inputs while the input is to minimise input which is used to produce a fixed output.

Figure 1 shows the differences in technical and allocative efficiency of the input and output approaches. This analysis assumes that the firm produces two inputs (x1 and x2), yielding one y output at full efficient condition at the firm. In the left image, the SS line represents the firm's production isoquant, while the AA line represents the price-input ratio. The 0P line represents the input used in the production process. Then QP represents the number of inputs that can be reduced without reducing output. Thus, what is meant by technical efficiency in the input approach is a comparison between 0Q and 0P.

While the RQ line represents a reduction in production costs that will occur if the company operates efficiently in terms of allocation at the point Q. Therefore, the allocative efficiency can be formulated with 0R versus 0Q. The combination of both types of efficiency is total efficiency. Total efficiency can be formulated with 0R / 0P. The output-based efficiency is shown in the right figure. ZZ line is a possibility of production. The point AB represents technical inefficiency, because with fixed inputs it can produce output at a higher level. Then the measurement of technical inefficiency is 0A / 0B. If the price is known, then the DD line can represent it. Then it can be written that 0B / 0C is a measure of the allocative efficiency. Thus, the overall economic efficiency can be calculated by multiplication between TE and AE. Some studies have focused on the calculation of technical efficiency and determinant factors.

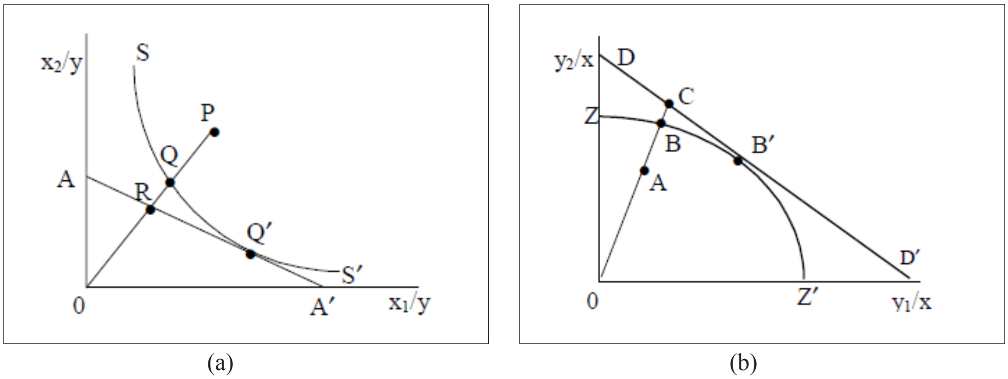


*Figure 1.* Technical and allocative efficiency, a) input oriented efficiency, b) output oriented efficiency. Adapted from *The measurement of productive efficiency and productivity growth* (pp. 24-25), by H. O. Fried, C. K. Lovell and S. S. Schmidt, 2008, New York, NY: Oxford University Press. Copyright 2008 by Oxford University Press.

An earlier study focused on the food, textile, chemical and metal manufacturing industries in Indonesia (Margono & Sharma, 2006). It uses variable determinants of ownership, company location, size, and age of company. In the food sector, significant ownership factors affect technical inefficiency; in the textile sector, location and size of the company; in the chemical and metals sectors, size of ownership, and age.

A study had looked at the determinants of technical efficiency in the manufacturing sector in Germany. The variables used are industrial effects, ownership, age, legality, ownership structure, size, location, and outsourcing. The industry effect variable is the major determinant of technical efficiency, followed by the size and location variables. Other variables have a very small determining role.

Earlier research also focused on factors affecting technical efficiency in the electronics and optical manufacturing industries in Ireland (Uğur, 2003). This research used data panels with SFA approach. The variables used are investment intensity, worker quality, export intensity. The results of the research show intensity of investment and the quality of the workers affect significantly the overall technical inefficiency. The intensity of exports only signifies.

## METHODS

The present study used a survey explanatory method with panel type data of 4240 inputs and output level of companies during six years of observation (2010-2015). Determinants of technical efficiency (TE) are estimated using multiple regression. This research will combine the use of determinant variables that have been used (Aggrey et al., 2010; Uğur, 2003).

Market share variables, company age, capacity utilisation, company ownership, and concentration ratio are variables used in this study.

This study uses the main analysis tool of Stochastic Frontier Analysis (SFA) which calculates technical efficiency (TE) and the factors that affect it. Technical efficiency and the determinant variable are then estimated using Maximum Likelihood Estimation (MLE). The data used are panel data consisting of 4240 inputs and output level companies (DMU) within 6 years of observation (2010-2015). Technical efficiency is calculated using four input variables, namely labour (L), capital (K), raw material resources (M), fuel resources (E). The four variables are then used in the frontier production function by using the trans log variable specification. The model used is:

$$
\begin{aligned}
LnY = \; & \beta_0 + \beta_1 LnK_{ij} + \beta_2 LnL_{ij} + \beta LnM_{ij} + \beta_4 LnE_{ij} + \beta_5 LnT_{ij} \\
& + \beta_6 LnL_{ij}{}^2 + \beta_7 LnK_{ij}{}^2 + \beta_8 LnM_{ij}{}^2 + \beta_9 LnE_{ij}{}^2 \\
& + \beta_{10} LnT_{ij}{}^2 + \beta_{11} LnT^2{}_{ij} + \beta_{12} LnT_{ij} LnL_{ij} \\
& + \beta_{13} LnT_{ij} LnK_{ij} + \beta_{14} LnT_{ij} LnM_{ij} + \beta_{15} LnT_{ij} LnM_{ij} \\
& + \beta_{16} LnT_{ij} LnE_{ij} + \beta_{17} LnL_{ij} LnK_{ij} + \beta_{18} LnL_{ij} LnM_{ij} \\
& + \beta_{19} LnL_{ij} LnE_{ij} + \beta_{20} LnM_{ij} LnE_{ij}
\end{aligned}
$$

where Ln is natural logarithm, T is time (period), is variable parameter. While the inefficiency model used is

$$TE_{ij} = \delta_0 + \delta_1 MS_{ij} + \delta_2 AGE_{ij} + \delta_3 CU_{ij} + \delta_4 DLOC_{ij} + \delta_5 CR4_{ij}$$

where TE is technical efficiency, MS is market share, AGE is firm age, DLOC is dummy local ownership (0 = local, 1 = foreign), CR4 is company ratio concentration. Both technical efficiency calculations and regression determinants are done by using the TE effect approach in Frontier 4.1 software.

## RESULTS

Calculations using stochastic Frontier Analysis are shown in Table 1, Table 2 and Table 3.

Table 1
*Summary of descriptive statistics estimated technical efficiency*

| Year | Mean | Std. Dev. | Min. | Max. |
|---|---|---|---|---|
| 2010 | 0.9521 | 0.0170 | 0.6596 | 1 |
| 2011 | 0.9515 | 0.0167 | 0.6603 | 1 |
| 2012 | 0.9500 | 0.0239 | 0.5401 | 1 |
| 2013 | 0.9499 | 0.0188 | 0.5414 | 1 |
| 2014 | 0.9506 | 0.0183 | 0.5409 | 1 |
| 2015 | 0.9497 | 0.0175 | 0.5403 | 1 |

Table 2
*Average technical efficiency based on determinant variables*

| Variable | 2010 | | 2011 | | 2012 | | 2013 | | 2014 | | 2015 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Total | Mean | Total | Mean | Total | Mean | Total | Mean | Total | Mean | Total |
| AGE (Year) | | | | | | | | | | | | |
| 1-20 | 0.956 | 2860 | 0.956 | 2752 | 0.954 | 2588 | 0.955 | 2453 | 0.956 | 2331 | 0.96 | 2220 |
| 21-40 | 0.946 | 1167 | 0.946 | 1267 | 0.946 | 1417 | 0.946 | 1541 | 0.947 | 1651 | 0.95 | 1739 |
| 41-60 | 0.933 | 162 | 0.934 | 170 | 0.933 | 180 | 0.932 | 188 | 0.933 | 196 | 0.93 | 212 |
| 61-80 | 0.919 | 33 | 0.918 | 33 | 0.920 | 37 | 0.918 | 38 | 0.918 | 40 | 0.92 | 46 |
| >81 | 0.910 | 18 | 0.915 | 18 | 0.912 | 18 | 0.910 | 20 | 0.912 | 22 | 0.91 | 23 |
| LOC | | | | | | | | | | | | |
| 0 (local) | 0.949 | 3862 | 0.949 | 3862 | 0.947 | 3862 | 0.947 | 3862 | 0.948 | 3862 | 0.95 | 3862 |
| 1 (foreign) | 0.982 | 378 | 0.982 | 378 | 0.981 | 378 | 0.981 | 378 | 0.982 | 378 | 0.98 | 378 |
| CR4 (%) | | | | | | | | | | | | |
| 0-10 | 0 | 0 | 0.945 | 175 | 0.0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 |
| 10.1-25 | 0.951 | 3070 | 0.950 | 2541 | 0.949 | 2806 | 0.948 | 3070 | 0.948 | 2145 | 0.95 | 2287 |
| 25.1s-50 | 0.955 | 936 | 0.953 | 1282 | 0.951 | 1093 | 0.953 | 928 | 0.952 | 1497 | 0.95 | 1355 |
| 50.1-65 | 0.978 | 58 | 0.981 | 16 | 0.957 | 132 | 0.958 | 202 | 0.957 | 558 | 0.96 | 558 |
| >65.1 | 0.958 | 176 | 0.962 | 226 | 0.958 | 209 | 0.971 | 40 | 0.968 | 40 | 0.97 | 40 |
| CU | | | | | | | | | | | | |
| 1-20 | 0.989 | 41 | 0.987 | 21 | 0.987 | 36 | 0.987 | 31 | 0.986 | 36 | 0.99 | 34 |
| 21-40 | 0.979 | 116 | 0.978 | 116 | 0.977 | 116 | 0.975 | 105 | 0.976 | 111 | 0.98 | 122 |
| 41-60 | 0.965 | 473 | 0.965 | 432 | 0.963 | 526 | 0.962 | 430 | 0.964 | 418 | 0.96 | 409 |
| 61-80 | 0.953 | 2038 | 0.953 | 2093 | 0.952 | 1951 | 0.952 | 2087 | 0.952 | 2160 | 0.95 | 2127 |
| >81 | 0.944 | 1572 | 0.944 | 1578 | 0.940 | 1611 | 0.942 | 1587 | 0.943 | 1515 | 0.94 | 1548 |

Table 3
*Estimation parameters of stochastic production frontier and technical inefficiency model*

| Variable | Parameters | Coefficient | Standard Error | t-ratio |
|---|---|---|---|---|
| Stochastic Production | | | | |
| Intercept | β0 | 4.000391 | 0.995273 | 4.019391 |
| LnL | β1 | 0.873324 | 0.967823 | 0.902359 |
| LnK | β2 | 0.056982 | 0.726318 | 0.078454 |
| LnM | β3 | 0.090938 | 0.780713 | 0.116480 |
| LnE | β4 | 0.261519 | 0.815973 | 0.320500 |
| T | β5 | 0.024975 | 0.969357 | 0.025765 |
| $LnL^2$ | β6 | 0.033911 | 0.449802 | 0.075390 |
| $LnK^2$ | β7 | 0.010278 | 0.022934 | 0.448170 |
| $LnM^2$ | β8 | 0.071200 | 0.129237 | 0.550924 |
| $LnE^2$ | β9 | 0.035602 | 0.162339 | 0.219306 |

Table 3 *(continue)*

| Variable | Parameters | Coefficient | Standard Error | t-ratio |
|---|---|---|---|---|
| $T^2$ | β10 | -0.005953 | 0.051172 | -0.116334 |
| T*LnL | β11 | 0.003010 | 0.030288 | 0.099369 |
| T*LnK | β12 | -0.001187 | 0.079861 | -0.014859 |
| T*LnM | β13 | -0.002868 | 0.102757 | -0.027906 |
| T*LnE | β14 | 0.004884 | 0.085168 | 0.057341 |
| LnL*LnK | β15 | 0.011596 | 0.390880 | 0.029667 |
| LnL*LnM | β16 | -0.087875 | 0.561817 | -0.156412 |
| LnL*LnE | β17 | 0.010884 | 0.215669 | 0.050467 |
| LnK*LnM | β18 | -0.019793 | 0.428080 | -0.046237 |
| LnK*LnE | β19 | -0.003460 | 0.409366 | -0.008452 |
| LnM*LnE | β20 | -0.067827 | 0.194989 | -0.347849 |
| Technical Inefficiency Model | | | | |
| Intercept | δ0 | -0.002159 | 0.486978 | -0.004433 |
| MS | δ1 | -0.001784 | 0.000309 | -5.777606 |
| AGE | δ2 | 0.000687 | 0.006107 | 0.112544 |
| CU | δ3 | 0.000632 | 0.002158 | 0.292972 |
| DLOC | δ4 | -0.032479 | 0.189350 | -0.171530 |
| CR4 | δ5 | -0.000195 | 0.002645 | -0.073604 |
| Other parameters | | | | |
| Sigma-squared | | 0.148197 | 0.058142 | 2.548885 |
| Gamma | | 0.000008 | 0.000109 | 0.076986 |
| Log likelihood function | | -11970.72 | | |
| Mean technical efficiency | | 0.95065 | | |

## DISCUSSION

Table 1 is an overview of the technical efficiency of the manufacturing industry in Indonesia. The smallest TE in the observational study is 0.54. This means that for every single input used, it will produce an output of 0.54. The largest number is 1, not least for all years. This means that in every year there are always companies that achieve full technical efficiency. The average indicates that there is no year with a TE of less than 0.94. This figure is supported by a small standard deviation (0.01-0.02). A small standard deviation indicates the resulting slope / fault of the resulting average is relatively small. Of the 100 estimated data that has an average of between 0.94-0.95 only 1-2 data that is not the number. Therefore, it can be said that the average number represents the population, i.e. the average TE of 0.94-0.95 for all years of observation.

Table 2 provides an overview of the association. Judging by its relation to the year variable, technical efficiency for all firms in all years has a downward trend for firms with longer standing ages. Companies aged 1-20 years have an average TE of 0.95-0.96. Companies with more than 81 years of age have an average TE of about 0.91. Therefore, it can be assumed the older the company is, the lower its TE. Additionally, the company with foreign ownership has a larger

TE value than the company with local ownership. In all years of observation, local companies have TE values ranging from 0.94-0.95. Companies with foreign holdings have a TE value of 0.98. Hence, it can be concluded foreign companies are working at a higher level of efficiency than local companies. In terms of concentration ratios, in the first three years of observation all firms have an average TE that varied between 0.95-0.98. The last three years of observation have certain TE value patterns. Companies with higher concentration ratio values have higher TE values. The value varies between 0.94 and 0.97. Thus, the higher the CR4, the higher TE is expected to only be valid for the last three years of observation.

In terms of capacity utilisation, during the observation period, firms showed a higher CU pattern, a lower TE. The average value of TE varies between 0.94-0.99. The higher CU signifies the company is operating at a higher capacity. Therefore, it can be concluded that high production capacity of the company leads to reduced TE. The estimated parameters of TE with selected input sets are shown in Table 3. The approach used is MLE with transcendental logarithmic model. Table 3 provides an overview of the stochastic production estimation coefficients for the samples in this study. The dependent variable used in this estimate is TE. Therefore, a significant positive relationship between dependent and independent variables has a higher independent variable meaning will cause higher TE numbers. This means the company is efficient. This result is in line with that of previous studies (Aggrey et al., 2010; Margono & Sharma, 2006; Uğur, 2003).

MS is suspected to have a positive relationship with TE; the former is calculated based on the ratio between company's sales to the overall sales of the industry. Increased sales means that the company operates on a larger scale. Few competitors means companies with high MS will lead to an oligopoly market. Thus, the company will increasingly compete to improve the efficiency of its production. The estimation results show a significant negative relationship between MS and TE at the 95% probability level. Therefore, the initial hypothesis is rejected. The higher the MS value of the company, the lower its TE value. In other words, it will lead to inefficiency. This result is in line with previous studies (Aggrey et al., 2010; Margono & Sharma, 2006; Uğur, 2003).

Age of the company is suspected to have a positive relationship with TE. The longer the company operates, it will become more specialised. It will improve the technical efficiency of the company. The estimation results show a positive and insignificant relationship between AGE and TE at the 95% probability level. Therefore, it can be said the company's age does not significantly affect its technical efficiency. Production Capacity or CU is suspected to have a positive relationship with TE. This result is in line with previous researches (Aggrey et al., 2010; Margono & Sharma, 2006; Uğur, 2003).

Higher CU means the companies are more productive and achieving full capacity. The debate over the measurement of CU is due to the absence of a definite measure of full capacity in production, the subject matter of full production capacity assessment, and the valuation policy used to measure output. Regardless of the situation, the more companies operate at full capacity, the higher the company's TE. The estimation results show a positive and insignificant relationship between CU and TE at 95% probability level. This means high-low production capacity achieved by the company does not significantly affect technical efficiency of the company. This result is in line with previous research (Aggrey et al., 2010; Margono & Sharma, 2006; Uğur, 2003).

The DLOC is a dummy variable of company ownership. Domestic-owned companies are assigned a value of 0 and foreign-owned companies are assigned a value of 1. There is no firm hypothesis regarding the relationship between ownership of a company and TE based on citizenship. The results show the coefficient is not significant and therefore, there is no strong evidence to suggest that both local and foreign companies have a higher level of technical efficiency. This result is in line with previous researches (Aggrey et al., 2010; Margono & Sharma, 2006; Uğur, 2003).

The CR4 is the ratio of unbalanced concentration of firms in an industry. It is based on the output share (or sales) of the four largest companies in the industry. It is said not weighted because there is no weighting for large and small companies. The CR4 is suspected to have a positive relationship with TE. A bigger CR4 means the company is producing at a higher level. Thus, the company seems to operate on the oligopoly market. With such a market model the company tries its utmost to improve production efficiency in order to win the competition. This result is in line with previous researches (Aggrey et al., 2010; Margono & Sharma, 2006; Uğur, 2003).

The results show a negative and insignificant relationship between CR4 and TE at 95% probability level. This means that it can be said that CR4 affects TE insignificantly in the sample of this study. Technical inefficiency and other random factors may have influenced the variation in errors. The value of gamma coefficients close to 1 indicates that the variation of the errors is influenced by technical inefficiency. The value of the gamma coefficient away from 1 indicates the variation of error is more influenced by other random factors. The results show the gamma coefficient has a value relatively far from 1. This means random factors other than independent variables and technical inefficiency dominate the variation of error.

## CONCLUSION

This research focuses on technical efficiency in chemical industry in Indonesia and its determinant variables. Technical efficiency is calculated using the stochastic frontier analysis (SFA) approach. Determinants of technical efficiency are estimated by using multiple regression. Both technical efficiency calculations and regression determinants are done by one step using the TE effect approach in Frontier 4.1 software. The result of research indicates that market share variable significantly and negatively affects technical efficiency. Other variables such as company age, business ownership, ratio concentration, and capacity utilisation are not significant. This finding implies that to improve the efficiency, the chemical industry needs to increase its market share.

The following are findings of the present study to enhance the growth of chemical industry in Indonesia:

1) Achieve synergy between medium / large industry with small / micro scale industry. The growth of Small / micro industry is vital to boost the growth of medium / large industries. Big industry players and the government can take on this role so that small / micro

industries have direction and production standards that meet the needs of large industries. The medium / large industry can support the development of small / micro industries.

2) Creating a road map for the chemical industry in Indonesia. Thus, will form a chain from upstream to downstream which reduces the amount of imported raw materials. In the implementation, the establishment of new factories can be pursued for industries that process raw materials . Providing incentives to the raw material processing industry can encourage investors to follow the scenario. Additionally, the import duties on raw materials can be increased so that importers will be more keen to source local raw materials.
3) Unnecessary cost cuts, especially licensing fees so investors can reallocate their budget to drive technology development. The latest technology will boost efficiency which will bring down selling prices. In addition, the availability of local raw materials at lower prices will further boost product competitiveness.

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## REFERENCES

Aggrey, N., Eliab, L., & Joseph, S. (2010). Firm size and technical efficiency in East African manufacturing firms. *Current Research Journal of Economic Theory, 2*(2), 69-75.

Aigner, D., Lovell, C. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics, 6*(1), 21-37.

Andersen, P., & Petersen, N. C. (1993). A procedure for ranking efficient units in data envelopment analysis. *Management Science, 39*(10), 1261-1264.

Bessent, A., Bessent, W., Kennington, J., & Reagan, B. (1982). An application of mathematical programming to assess productivity in the Houston independent school district. *Management Science, 28*(12), 1355-1367.

Bunse, K., Vodicka, M., Schönsleben, P., Brülhart, M., & Ernst, F. O. (2011). Integrating energy efficiency performance in production management–gap analysis between industrial needs and scientific literature. *Journal of Cleaner Production, 19*(6-7), 667-679.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research, 2*(6), 429-444.

Chiona, S., Kalinda, T., & Tembo, G. (2014). Stochastic frontier analysis of the technical efficiency of smallholder maize farmers in Central Province, Zambia. *Journal of Agricultural Science, 6*(10), 108.

Coelli, T. J. (1996). *Centre for Efficiency and Productivity Analysis (CEPA)*. Working Papers, Armidale: University of New England.

Coelli, T. J. (2007). *A guide to frontier version 4.1: A computer program for stochastic frontier production and cost function estimation.* Working Paper, Armidale: University of New England.

Debreu, G. (1951). The coefficient of resource utilization. *Econometrica, 19*, 273– 292.

Ebrahimnejad, A., Tavana, M., Lotfi, F. H., Shahverdi, R., & Yousefpour, M. (2014). A three-stage data envelopment analysis model with application to banking industry. *Measurement, 49*, 308-319.

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society, 120*(3), 253-290.

Fried, H. O., Lovell, C. K., & Schmidt, S. S. (2008). *The measurement of productive efficiency and productivity growth.* New York, NY: Oxford University Press.

Koopmans, T. C. (1951), *Activity analysis of production and allocation.* New York, NY: Cowles Commission Monographs, John Willey & Sons.

Mankiw, N. G. (2014). *Principles of economics* ($7^{th}$ ed.). Stamford, USA: Cengage Learning.

Margono, H., & Sharma, S. C. (2006). Efficiency and productivity analyses of Indonesian manufacturing industries. *Journal of Asian Economics, 17*(6), 979-995.

Nandiyanto, A. B. D., Maulana, A. C., Ragadhita, R., & Abdullah, A. G. (2018). Economic evaluation of the production ethanol from cassava roots. *IOP Conference Series: Materials Science and Engineering, 288*(1), 012023-1 – 0123023-6.

Nicholson, W., & Snyder, C. (2008). *Microeconomic theory: Basic principles and extensions* ($10^{th}$ ed.). Mason, Ohio: Nelson Education.

Plechkova, N. V., & Seddon, K. R. (2008). Applications of ionic liquids in the chemical industry. *Chemical Society Reviews, 37*(1), 123-150.

Tombs, S., & Whyte, D. (2003). Unmasking the crimes of the powerful. *Critical Criminology, 11*(3), 217-236.

Uğur, A. (2003). *Technical efficiency in Irish manufacturing industry, 1991-1999.* Working Paper, Dublin: Trinity College Dublin.