Economics Bulletin

Volume 40, Issue 4

Firm's Trade Activities to Promote Technical Efficiency and Total Factor Productivity: The Growth Accounting and The Stochastic Frontier Approach

Mohammad Zeqi Yasin
Department of Economics, University of Essex

Abstract

In this study we attempt to employ two approaches, Growth Accounting (GA) and Stochastic Frontier Analysis (SFA), to estimate the impact of firms' trade activities on technical efficiency and the total factor productivity (TFP) growth of Indonesian manufacturing industry in 2008-2015. We resort to the Translog model that flexibly accommodates the interaction amongst inputs. We reveal significant discrepancy between two approaches by discovering evidence that imported material intensity examined with SFA approach does not affect efficiency, both when it affects alone and when it interacts with export, but it promotes significantly on TFP growth obtained from GA. Conversely, exports significantly increase efficiency, but it is discovered significantly alleviating TFP growth. We also found contradictory results between two approaches in estimating TFP growth: negative TFP growth of SFA and positive TFP growth of GA. We identify that subsectors that have high imported materials tend to experience high TFP of GA, but weak TFP of SFA. However, subsector Products from Coal and Oil Refinery Industry is the most consistent for both GA and SF in leading the TFP growth magnitudes amongst other subsectors.

Citation: Mohammad Zeqi Yasin, (2020) "Firm's Trade Activities to Promote Technical Efficiency and Total Factor Productivity: The Growth Accounting and The Stochastic Frontier Approach", *Economics Bulletin*, Volume 40, Issue 4, pages 3020-3032
Contact: Mohammad Zeqi Yasin - mohammad.zeqi-13@feb.unair.ac.id.
Submitted: July 01, 2020. **Published:** November 18, 2020.

1. Introduction

Since Indonesian economy has dominantly been contributed by the manufacturing sector, measuring the performance of industry is important to highlight evidences about the determinants of that performance. For instance, as an indicator of industry performance, total factor productivity (TFP) was researched by Sari *et al.* (2016) who measured the spill-over effect on the productivity of the manufacturing industry in Indonesia. Sari *et al.* (2016) employed some pivotal variables as efficiency determinants such as the foreign ownership of capital, imported raw material intensity, export, absorptive capacity, market concentration and the spill-over effects. Most studies measured TFP using the Growth Accounting (GA) approach on the macro level (Makiela and Ouattara, 2018). Meanwhile, in terms of micro-level data, many recent studies measuring TFP employed the Stochastic Frontier Analysis (SFA) (see. Suatmi *et al.*, 2017; Sugiharti *et al.*, 2017). To the best of our knowledge, there are no studies that have employed both the GA approach and the SFA approach in a paper to discover TFP at a firm level.

Our study attempts to employ the GA and SFA approaches to address the possible differences in results. It is essential to note that both methods have their own benefits and drawbacks. Employing the GA approach is useful because it helps in accommodating the direct of determinants on the TFP. Fuentes and Morales (2011) argued that the Neoclassical production function represents the maximum output that could be attained from a combination of inputs. However, it might exist some omitted factors that would make it impossible to achieve the production frontier, such as the adjustment costs for intersectoral reallocation of resources and the technology diffusion. The effect of these potential omitted factors must then be captured by the disturbance term in the growth accounting approach. GA approach identifies TFP growth as the value of the production function residual after accounting for the contribution of the growth of inputs to output growth. The residual captures the exogenous factor associated directly with a technological level plus a technological progress.

Meanwhile, SFA is employed to decompose the factors influencing TFP growth, i.e., technical efficiency change (TEC), technological progress/technical change (TC) and scale efficiency change (SEC). Technical efficiency refers to what extent of which producers can efficiently produce different output by utilizing minimal input or optimize input to produce more outputs (Purwono *et al.*, 2018). Technological progress or technical change refers to the condition of the production frontier's shifting. This shifting captures the technological progress, that is embodied in the inputs of capital and labor, to depict the effect of technology in improving factor productivity over time (Fu *et al.*, 2011). Meanwhile, scale efficiency measures how close the production scale relatively to the optimal level (Sari *et al.*, 2016). As these three decompositions might contribute on TFP growth, the conventional approach that does not acknowledge TEC, TC, and SEC might underestimate the real magnitude of TFP growth.

Through using SFA, technical efficiency detects determinants that, in this study, consist export and import and are tested in the GA model. Theory of International trade suggested that countries' productivity can be promoted through the export-import activities channels e.g. intermediate goods and the capital equipment (Amiti and Konings, 2007; De Loecker, 2013; Liu and Nishijima, 2013). Export activities enables country to get involved in the advanced markets so that the export goods are demanded to satisfy the market's high standard. Hence, countries should not only concern on exporting large quantity of goods, but also exporting well-qualified goods. Import activities, such as machinery and intermediate goods, are a part of trade reform to enhance access to imported capital goods and technological advance from leading countries (Suatmi *et al.*, 2017). It is also pertinently essential to promote productivity as countries are forced to meet the stringent technical standards to utilize advanced technology offered by advanced markets (Damijan *et al.*, 2009).

The rest of the paper is organized as follows. In section 2, we discuss the data and model. In section 3, we report our finding that is then followed by section 4 as conclusion.

2. Data and Model Specification

We employ the firm-level data of annual surveys on the level of large and medium manufacturing firms the Central Bureau of Statistics of Indonesia from 2008-2015. A number of firms may change over time due to closing or moving to other subsectors. Selecting unbalanced panel data may create biased in analysis as firms' entry and exit are untraceable. Instead, this study employs balanced panel data that consist 5,822 firms. Hence, we use 46,576 observations in total.

In this study, there are two kinds of variables. The first kind includes production function variables, e.g. total output (in Rupiah), capital (approximated by the fixed asset of a firm, such as land, building, machinery and equipment, in Rupiah), number of laborers, energy (proxied by the consumption of fuel and lubricants in Rupiah), and raw material (in Rupiah). The second kind includes our main variables which are firms' trade variables and determine technical efficiency. Due to limited access and availability to the Indonesian firm-level data, we used imported raw material intensity (that is measured from the ratio of imported raw material and total materials) as a proxy of imports (Amiti and Konings, 2007; Sari *et al.*, 2016). Meanwhile, variable of export is obtained from dummy of whether or not the firm is an exporter[1]. To acknowledge subsector-specific effect, we also consider other variables i.e. firm size (1) and market concentration (2) that are measured as follows (Amiti and Konings, 2007; Sari, 2019; Sari *et al.*, 2016):

$$FSize_{it} = \left(\frac{Y_{it}}{Y_{jt}}\right) \times 100 \quad (1)$$

$$HHI_{jt} = \sum_{i=1}^{n} s_{it}^2 \,, \; i \in j \quad (2)$$

Where $FSize_{it}$ is firm size of firm i in year t and obtained from total outputs of firm i in year t divided by total outputs in the subsector j. HHI is Herfindahl–Hirschman Index to measure market concentration calculated from market share squared, s_{it}^2. The monetary-value variables such as output, capital, energy and material, may be biased if these are directly employed. Therefore, adjusting with price index is required to make the data constant. This study employs the deflating approach with The Wholesale Price Indices of Indonesia and 2010 as the base year.

We employ the Translog model proposed by Christensen *et al.* (1973) that is currently followed by some studies such as Misra (2019) and Nafar (2016) for the case of the GA and Sari (2019) and Suatmi *et al.* (2017) for the case of the SFA. The Translog model in GA uses the Solow residual approach (A) to estimate TFP growth using Ordinary Least Square (OLS) regression. Meanwhile, the Translog model for SFA adheres Battese and Coelli (1995) model that is the time-varying SF production estimated with Maximum Likelihood (ML) to attain the inefficiency effects that are captured by u. We found that most of the GA studies used the rudimentary Cobb-Douglas production function that consists of capital and labor as inputs. Consequently, this function imposes constant elasticity substitution assumption that is ignored if we use another production function i.e. Translog (Kumbhakar and Wang, 2005; Wang and Wong, 2012). Hence, we elaborate the specification by employing the Translog model and by employing four inputs– capital, labor, energy, and raw material. The Translog production functions for the GA approach (1) and the SFA approach (2) are specified below.

---

[1] We do not employ export intensity variable as Sari *et al.* (2016) because the missing value of this variable in 2008-2015 obtains 58,87%, while the missing value of export binary dummy obtains 28.51%.

$$y_{it} = \alpha_k(k_{it}) + \alpha_l(l_{it}) + \alpha_e(e_{it}) + \alpha_r(r_{it}) + \frac{1}{2}\alpha_{kk}(k^2)_{it} + \frac{1}{2}\alpha_{ll}(l^2)_{it} + \frac{1}{2}\alpha_{ee}(e^2)_{it} + \frac{1}{2}\alpha_{rr}(r^2)_{it} + \alpha_{kl}(k_{it} \times l_{it}) + \alpha_{ke}(k_{it} \times e_{it}) + \alpha_{kr}(k_{it} \times r_{it}) + \alpha_{le}(l_{it} \times e_{it}) + \alpha_{lr}(l_{it} \times r_{it}) + \alpha_{er}(e_{it} \times r_{it}) + \alpha_t(t) + \alpha_{kt}(k_{it} \times t) + \alpha_{lt}(l_{it} \times t) + \alpha_{et}(e_{it} \times t) + \alpha_{rt}(r_{it} \times t) + \frac{1}{2}\alpha_{tt}(t^2) + A_{it} \quad (3)$$

$$y_{it} = \beta_k(k_{it}) + \beta_l(l_{it}) + \beta_e(e_{it}) + \beta_r(r_{it}) + \frac{1}{2}\beta_{kk}(k^2)_{it} + \frac{1}{2}\beta_{ll}(l^2)_{it} + \frac{1}{2}\beta_{ee}(e^2)_{it} + \frac{1}{2}\beta_{rr}(r^2)_{it} + \beta_{kl}(k_{it} \times l_{it}) + \beta_{ke}(k_{it} \times e_{it}) + \beta_{kr}(k_{it} \times r_{it}) + \beta_{le}(l_{it} \times e_{it}) + \beta_{lr}(l_{it} \times r_{it}) + \beta_{er}(e_{it} \times r_{it}) + \beta_t(t) + \beta_{kt}(k_{it} \times t) + \beta_{lt}(l_{it} \times t) + \beta_{et}(e_{it} \times t) + \beta_{rt}(r_{it} \times t) + \frac{1}{2}\beta_{tt}(t^2) + v_{it} - u_{it} \quad (4)$$

Where y is the total output, k is capital, l is labor, e is energy, r is raw material. Those variables are expressed in natural logarithmic and deviation from their geometric means. Subscript i and t denote i-th firm and t-th year. A_{it} is the residual that represents TFP where generally $A_{it} = \exp\left(\frac{Y_{it}}{K_{it} \cdot L_{it} \cdot E_{it} \cdot R_{it}}\right)$. t is a time variable. v_{it} is the SF model's random variable assumed as $iid. N(0, \sigma_v^2)$, and u_{it} is a non-negative random variable assumed as the half-truncated normal $(N^+(u_i, \sigma_u^2))$ in distribution and is the inefficiency parameter that captures the inefficiency effects that are specified as follow.

$$u_{it} = \eta_0 + \eta_{\text{imp}} Import_{it} + \eta_{\text{exp}} Export_{it} + \eta_{\text{expimp}}(Export_{it} \times Import_{it}) + \eta_{\text{fsize}} FirmSize_{it} + \eta_{\text{HHI}} HHI_{it} + \omega_{it} \quad (5)$$

While the equation of the determinants of TFP obtained from GA approach is specified as follow.

$$TFP1_{it} = \phi_0 + \phi_{\text{imp}} Import_{it} + \phi_{\text{exp}} Export_{it} + \phi_{\text{expimp}}(Export_{it} \times Import_{it}) + \phi_{\text{fsize}} FirmSize_{it} + \phi_{HHI} HHI_{jt} + \varsigma_{it} \quad (6)$$

Where η is the coefficient of inefficiency effects, ϕ is the coefficient of TFP's determinants of GA approach, and both ω and ς are error terms. To estimate ϕ's parameters, Fixed Effect model is employed. In terms of SFA approach, the generalized log-likelihood test considers alternative production function that in this study is Cobb-Douglas. A null hypothesis (H_0) is Cobb-Douglas model that ignores the coefficients of time squared, interacting inputs, and interacting inputs with time ($\beta_{kk} = \beta_{ll} = \beta_{ee} = \beta_{rr} = \beta_{kl} = \beta_{ke} = \beta_{kr} = \beta_{le} = \beta_{lr} = \beta_{er} = \beta_{kt} = \beta_{lt} = \beta_{et} = \beta_{rt} = \beta_{tt} = 0$). The log-likelihood test is performed by comparing the likelihood ratio statistic from each model. The log-likelihood statistic is obtained from $\lambda = -2[l(H_0) - l(H_1)]$ where $l(H_0)$ is the log-likelihood statistic of Cobb-Douglas model, and $l(H_1)$ is the log-likelihood value of Translog. The null hypothesis is rejected if the λ statistic is less than the χ^2 table with degrees of freedom equal to the number of parameters involved in the restrictions.

To measure TFP growth in the SFA approach, we adhere Sari *et al.* (2016) that decomposed TFP into three indicators: Technical Efficiency Change (TEC), Technological Change or Technological Progress (TC) and Scale Efficiency Change (SEC). The formulas to attain those components are expressed below.

$$TFP2_{it,t-1} = TEC_{it,t-1} + SEC_{it,t-1} + TC_{it,t-1} \quad (7)$$

$$TC_{it,t-1} = 0.5\left[\left(\frac{\partial y_{i,t-1}}{\partial t}\right) + \left(\frac{\partial y_{i,t}}{\partial t}\right)\right] \times 100 \quad (8)$$

$$TEC_{it,t-1} = \ln\left(\frac{TE_{it}}{TE_{i,t-1}}\right) \times 100 \tag{9}$$

$$SEC_{it,t-1} = \frac{1}{2}\sum_{n=1}^{N}[(SF_{it}\epsilon n_{it} + SF_{it-1}\epsilon n_{it-1})(xn_{it} - xn_{it-1})] \times 100 \tag{10}$$

$$SF_{it} = \frac{\epsilon_{Tit}-1}{\epsilon_{Tit}} \tag{11}$$

$$\epsilon_{Tit} = \sum_{n=1}^{N} \epsilon_{nit} \tag{12}$$

$$\epsilon_{nit} = \frac{\partial y_{it}}{\partial xn_{it}} = \beta_n + \frac{1}{2}\sum_{n=1}^{2}\sum_{m=1}^{2}\beta_{nm}xm_{it} + \beta_{nt}t \tag{13}$$

Where $TFP2_{it,t-1}$ refers to the total factor productivity growth estimated from SFA approach. TE_{it} denotes technical efficiency (of i-th firm in t-th year) that is measured as the ratio of the realised output over the potential output in maximum magnitude. The technical efficiency score converges to 1 if firms experience efficiency improvement and converge to 0 if firms' operational production dynamically worsen making such firms technically inefficient. SF denotes scale factors, ϵ_{nit} is the elasticity of each input at each data point and ϵ_{Tit} is the standard return to scale elasticity.

3. Estimation Result

We identify the suitability of production function in our study using the generalized log-likelihood test. The test results λ-statistic at 15,820.45 which is much larger than the critical value of χ^2-table at 1%. Therefore, the use of Translog specification in the analysis is valid.

Table 1 in the Appendix reports the result of specification obtained from (3) using Fixed Effect (FE) model. Meanwhile, (4) should be estimated using maximum likelihood (ML) approach. This estimation is also reported in Table 1. In practice, the GA approach is a two-step approach for estimating the residual with the production function and for estimating the determinants with the residual as a regressand. Whereas, SFA is a one-step approach that we could directly estimate the inefficiency effects in a single step. Notwithstanding, we combine the results of GA and SFA to compare the similarity effect of inputs on output. We estimate residuals (A) to measure the TFP growth with the GA approach. Afterwards, we employ the Fixed Effect to examine the determinants of the TFP growth.

We found that most of our variables in the production function similarly affect outputs and are statistically significant at alpha 10% for both GA and SFA. In terms of inefficiency-effects and the determinants of TFP, import intensity is identified insignificantly promoting technical efficiency, but significantly enlarging TFP. Export shows a negative effect on inefficiency at 7.5%. This means that being exporter is more likely to increase technical efficiency. However, this finding is not supported by the sign of the FE model that shows a high negative direction of export towards TFP. Mok *et al.* (2010) argued that exporters will gain benefit from export activities if only they take up dominant portion of their total sales, otherwise exporters will handle large cost of transaction as well as demanding technical barriers of the trade which in turn sinks their benefits. As our export variable only represents binary dummy, we could not identify the effect of firms' export intensity towards TFP growth. Moreover, our result suggests that being an exporter will immediately boost technical efficiency of the firm, notwithstanding it does not directly promote positively on TFP. As Fuentes and Morales (2011)'s argument, there might be presence omitted factors, such as the adjustment costs for intersectoral reallocation of resources and the technology diffusion, in which technical efficiency does not capture. Exporter firms might be relatively more technically efficient in production, but as TFP in the context of GA approach is a general technological progress index, it does not represent the positive effect of export toward technical efficiency.

An intriguing finding is that the interaction variable, i.e. export-import, reveals significant positive sign that means it negatively affect technical efficiency, but positively significant effect on the TFP, which are the opposite of export effect. This result indicates that imported raw materials are more positively contribute to the non-exporter firms' efficiency more than to the exporter firms' efficiency. In this regard, instead of exporting outputs that employed imported materials, it will be technically efficient to prioritize local demands as the characteristic of Indonesian economy is dominated by the domestic consumption (Negara and Adam, 2012). Otherwise, it can be interpreted that firms supposedly utilize more domestic raw materials if they will export the outputs to promote their technical efficiency.

Meanwhile, in terms of export-import's effect on the TFP, it is related to characteristic of TFP growths obtained from GA representing, one of which, technological progress. It means that importing more raw materials for exporters may tend to shift the frontier up. However, it is not seemingly acknowledged as a convergence to the frontier (or technical efficiency). Providing advanced technology typically makes fast progress of frontier shifting, but it may not be followed by the firms' capabilities to narrow the distance towards the frontier, such as covering the cost of imported technology or transferring knowledge to the next generations. This reason is plausible as we found that technical change (in Table 2 Appendix) of SFA shows positive magnitude at 5.05%, but negative technical efficiency enhancement and scale efficiency growth. It indicates that exporter firms might forcefully cover expensive technology solely to utilize their imported materials, regardless it would affect to their scale efficiency that associates to the economies of scale. In some subsectors, such as Chemical and Pharmaceutical Industry in Indonesia, this argument might be pertinent as those subsectors are allocated high proportion of imported materials (Suatmi *et al.*, 2017).

Firm size significantly reduces technical inefficiency by 1.2%. It means that larger scale of firm leads to the efficiency enhancement. Likewise, it also immensely promotes firms' TFP by 1585.7%. This finding is not surprising as larger firms are more likely to possess advanced technology and capital equipment compared to smaller firms (Sari *et al.*, 2016). Meanwhile, market concentration (HHI) reveals positive sign to the inefficiency. It means that if a sector is more concentrated, it will enlarge firms' inefficiency, coupled to its influence on the TFP. The reason of this finding is related to the market characteristics, for instance oligopoly, that might have less incentive for firm to be more efficient. Hence, the higher market concentration will not force them to be more efficient, at least by the government incentive (Setiawan *et al.*, 2013).

We used the parameters of the stochastic frontier from ML in Table 1 to find the contributor of total factor productivity (TFP2). The decomposition of TFP growth is summarised in Table 2 that also includes the TFP growth of the GA approach. We found contradictory results between two approaches. We found negative TFP growth obtained from SFA by -42.26%. This finding is similar to Sugiharti *et al.* (2017) that examined the year of 2007-2013. Conversely, the GA approach identify positive magnitude of TFP growth at 13.36%. We identify this difference stemming from the decompositions of SFA's TFP growth. We found that scale efficiency change (SEC) contributes to the TFP growth at -46.98% and it is exacerbated by the negative magnitude of technical efficiency change (TEC) at -0.33%. Meanwhile, technical change (TC) is identified positive at 5.05% which is relevant with the context of GA's positive TFP growth that also represents technological progress.

We elaborate the analysis by dividing TFP growth based on 23 subsectors. Table 3 reports the comparation of TFP, Import Intensity, Export Dummy, and Import interacting with Export. According Table 3, subsector Products from Coal and Oil Refinery Industry (code 19) is consistent leading the TFP growth for both GA (TFP1) and SFA (TFP2) approach. This subsector reveals heavy magnitude by 34.42% of TFP1 and 290.22% of TFP2. If we look at the determinants, the proportion of imported materials is moderate at 11.48% with 16% of the firms are exporters. The top 5 subsectors that have highest TFP1 are Products from Coal and Oil Refinery Industry (code 19), Tobacco Industry (code 2), Beverage Industry (code 11), Fabricated Metal Industry (code 4), and Electrical Equipment Industry (5). Meanwhile, the top 5 of TFP2 come from Products from Coal and Oil Refinery Industry (code 19), Metals Industry (code 25), Other Manufacturing Industry (code 32), Apparel Industry (code 14), and Textile Industry (code 13).

Evidently, the Products from Coal and Oil Refinery Industry is the essential sector in Indonesia. The utilization of fossil fuel for electricity system by more than 88% causes the high demand of energy, notably in the domestic markets (IESR, 2019). However, the Domestic Market Obligation (DMO) policy that has been stipulated in 2011 and forced the firms to sell the coal at certain price might affect the firms' decision to export to the global market. It is shown by more than 80% of coal production is exported (IESR, 2019). Consequently, this subsector is typically volatile to the global dynamic pricing of coal and oil. We prove it by overviewing the high deviation of TFP growth the Products from Coal and Oil Refinery Industry across the year (Table 5).

If we look at the rank of import intensity in Table 3, the top 3 largest are Pharmaceutical Industry (code 21), Electrical Equipment Industry (code 27), and Chemical Industry (code 20). All of these subsectors are classified as high-technology (OECD, 2011). Evidently, Indonesian Chemical Industry mainly rely on imported material due to limited capability to generate raw material for production. It then also leads to the high reliance its forward industry, Pharmaceutical Industry. Although Chemical Industry and Pharmaceutical Industry show positive TFP1 (that represents technological progress), but their dependences on the imports may affect their production of scale to be not optimal. Consequently, their TFP2s (that consist scale efficiency change) are largely negative. Coupled to this, the Electrical Equipment Industry experience high TFP1 at 19.27%, but negative magnitude of TFP2 at -27.58%. Kimura & Chen (2018) mentioned that, in 2012-2015 Indonesia tended to enlarge its diversification of importing high-technology based parts and components, while decreasing its import of low-technology based parts and components. This argument relevant with our finding that the technological progress of the Electrical Equipment Industry might be high, but its economies of scale is relatively low (proved by its scale efficiency change that is averagely negative at -31.70%). In this sense, importing raw materials might promote TFP growth through the technological progress channel, but it may worsen the economies of scale or technical efficiency if the costs of material process are expensive.

4. Conclusion

In this study we attempt to employ two approaches, Growth Accounting (GA) and Stochastic Frontier Analysis (SFA), to estimate the impact of firms' trade activities on technical efficiency and the TFP growth of Indonesian manufacturing industry. We resort to the Translog model that flexibly accommodates the interaction amongst inputs. We reveal significant discrepancy between two approaches by discovering evidence that imported material intensity examined with SFA approach does not affect efficiency, but it promotes significantly on TFP growth obtained from GA. Conversely, exports significantly increase efficiency, but it is discovered significantly alleviating TFP growth. We also found contradictory results between two approaches in estimating TFP growth: negative TFP growth of SFA and positive TFP growth of GA. We identify that subsectors that have high imported materials tend to experience high TFP of GA, but weak TFP of SFA. However, subsector Products from Coal and Oil Refinery Industry is the most consistent for both GA and SF in leading the TFP growth magnitudes amongst other subsectors. We justify this difference stemming from the decompositions of SFA's TFP growth, one of which is scale efficiency change that represents economies of scale but not is specifically captured by GA. The policy implications of these findings might not totally promote to a large degree of imported raw materials, although this study's empirical results showed that import intensity variable improves TFP. This is because higher import intensity may entail under-utilized of domestic materials. This study recommends that policy makers should boost imported material proportionally to promote technology transfer since import is one of the channels allowing knowledge transfer from advanced markets. This strategy can be accelerated by firms spending more on human capital development, represented by the absorptive capacity variable, to generate high-skilled labor. Hence, the cost of processing imported materials can be highly reduced along with presence of high-skilled laborers. Moreover, an export-oriented policy might be a suitable strategy to boost the domestic competitiveness of the manufacturing industry in general. Hence, combining these strategies enables policy makers to benefit from trade activities without sacrificing the protection needed for domestic firms.

References

Amiti, M., and Konings, J. (2007) "Trade liberalization, intermediate inputs, and productivity: Evidence from Indonesia" *American Economic Review* **97**(5), 1611–1638.

Battese, G. E., and Coelli, T. J. (1995) "A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data" *Empirical Economics* **20**, 325–332.

Christensen, L. R., Jorgenson, D. W., and Lau, L. J. (1973) "Transcendental Logarithmic Production Frontiers" *The Review of Economics and Statistics* **55**(1), 28–45.

Damijan, J. P., De Sousa, J., and Lamotte, O. (2009) "Does international openness affect the productivity of local firms?: Evidence from south-eastern Europe" *Economics of Transition* **17**(3), 559-586.

De Loecker, J. (2013) "Detecting learning by exporting" *American Economic Journal: Microeconomics* **5**(3), 1–21.

Fu, X., Pietrobelli, C., and Soete, L. (2011) "The Role of Foreign Technology and Indigenous Innovation in the Emerging Economies: Technological Change and Catching-up" *World Development* **39**(7), 1204–1212.

Fuentes, J. R., and Morales, M. (2011) "On the measurement of total factor productivity: A latent variable approach" *Macroeconomic Dynamics* 15(2), 145–159.

Institute For Essential Services Reform (IESR). (2019). *Dinamika Batu Bara Indonesia: Menuju Transisi Energi yang Adil (Indonesian Coal Dynamics: Towards a Just Energy Transition)*, IESR: Jakarta.

Kimura, F., and Chen, L. (2018) "Value Chain Connectivity in Indonesia: The Evolution of Unbundlings" *Bulletin of Indonesian Economic Studies* **54**(2), 165–192.

Kumbhakar, S. C., and Wang, H. J. (2005) "Estimation of growth convergence using a stochastic production frontier approach" *Economics Letters* **88**(3), 300–305.

Liu, W., and Nishijima, S. (2013) "Productivity and openness: Firm level evidence in Brazilian manufacturing industries" *Economic Change and Restructuring* **46**(4), 363–384.

Lucas, R. E. (1988) "On The Mechanics of Economic Development" *Journal of Monetary Economics* **22**, 3–42.

Makiela, K., and Ouattara, B. (2018) "Foreign direct investment and economic growth: Exploring the transmission channels" *Economic Modelling 72*, 296–305.

Misra, B. S. (2019) "Determinants of total factor productivity in Indian states" *Indian Growth and Development Review* **13**(1), 259–282.

Mok, V., Yeung, G., Han, Z., and Li, Z. (2010) "Competition Between Online and Physical Stores: The Implications of Providing Product Information by Pure-Play E-tailer Ryohei" *Managerial and Decision Economics* **31**, 453–463.

Negara, S. D., and Adam, L. (2012) “Foreign Direct Investment and Firms’ Productivity Level Lesson Learned from Indonesia” *Asean Economic Bulletin* **29**(2), 116.

Nafar, N. (2016) “The Sources of Economic Growth in Sub-Saharan African IDB Member Countries” *Management Studies* **5**(1), 17–24.

OECD. (2011) “Classification of manufacturing industries into categories based on R&D intensities” ISIC REV. 3 Technology Intensity Definition, 6.

Purwono, R., Mubin, M. K., and Yasin, M. Z. (2018) “Do infrastructures influence the efficiency convergence of the Indonesian economy? ” *Seoul Journal of Economics* **31**(3).

Romer, P. M. (1986) “Increasing Returns and Long-Run Growth” *Journal of Political Economy* **94**(5), 1002–1037.

Sari, D. W. (2019) “The Potential Horizontal and Vertical Spillovers from Foreign Direct Investment on Indonesian Manufacturing Industries” *Economic Papers* **38**(4), 299–310.

Sari, D. W., Khalifah, N. A., and Suyanto, S. (2016) “The spillover effects of foreign direct investment on the firms’ productivity performances” *Journal of Productivity Analysis* **46**(2–3), 199–233.

Setiawan, M., Emvalomatis, G., and Oude Lansink, A. (2013) “Structure, conduct, and performance: Evidence from the Indonesian food and beverages industry” *Empirical Economics* **45**(3), 1149–1165.

Suatmi, B. D., Bloch, H., and Salim, R. (2017) “Trade liberalization and technical efficiency in the Indonesian chemicals industry” *Applied Economics* **49**(44), 4428–4439.

Sugiharti, L., Purwono, R., Primanthi, M. R., and Padilla, M. A. E. (2017) “Indonesian Productivity Growth: Evidence from the Manufacturing Sector in Indonesia” *Pertanika Journal of Social Science and Humanities* **25**(S), 29–44.

Wang, M., and Wong, M. C. S. (2012) “International R&D Transfer and Technical Efficiency: Evidence from Panel Study Using Stochastic Frontier Analysis” *World Development* **40**(10), 1982–1998.

APPENDIX

Table 1. Estimation Results

	ML of SFA	FE of GA
	Coefficient	Coefficient
Production Function		
$\boldsymbol{k}$	0.253***(0.015)	0.203***(0.010)
$\boldsymbol{l}$	0.751***(0.033)	0.600***(0.026)
$\boldsymbol{e}$	0.134***(0.014)	0.280***(0.010)
$\boldsymbol{r}$	0.193***(0.017)	0.245***(0.012)
$\boldsymbol{k^2}$	0.005***(0.000)	0.001**(0.000)
$\boldsymbol{l^2}$	0.041***(0.002)	0.050***(0.003)
$\boldsymbol{e^2}$	0.018***(0.000)	0.021***(0.000)
$\boldsymbol{r^2}$	0.066***(0.000)	0.059***(0.000)
$\boldsymbol{kl}$	0.030***(0.001)	0.030***(0.001)
$\boldsymbol{ke}$	0.005***(0.000)	-0.001(0.000)
$\boldsymbol{kr}$	-0.036***(0.000)	-0.023***(0.000)
$\boldsymbol{le}$	0.005***(0.001)	0.011***(0.001)
$\boldsymbol{lr}$	-0.101***(0.001)	-0.101***(0.002)
$\boldsymbol{er}$	-0.039***(0.000)	-0.046***(0.001)
$\boldsymbol{t}$	0.123***(0.010)	0.125***(0.005)
$\boldsymbol{kt}$	-0.005***(0.000)	-0.002***(0.000)
$\boldsymbol{lt}$	0.014***(0.001)	0.016***(0.001)
$\boldsymbol{et}$	0.003***(0.000)	0.002***(0.000)
$\boldsymbol{rt}$	-0.007***(0.000)	-0.009***(0.000)
$\boldsymbol{t^2}$	-0.001***(0.000)	-0.001***(0.000)
Inefficiency-Effects		**Determinants of TFP**
$\boldsymbol{Import\ Intensity}$	0.000(0.000)	0.126*(0.066)
$\boldsymbol{Export}$	-0.075***(0.019)	-13.495***(3.026)
$\boldsymbol{Import\ Intensity \times Export}$	0.000***(0.000)	0.155*(0.084)
$\boldsymbol{Firm\ Size}$	-0.012***(0.000)	15.857***(0.506)
$\boldsymbol{Market\ Concentration\ (HHI)}$	0.000***(0.000)	-0.013***(0.000)
$\boldsymbol{Time}$	0.173***(0.012)	-
$\boldsymbol{\sigma^2}$	1.829***(0.015)	-
$\boldsymbol{\gamma}$	0.918***(0.000)	-
Loglikelihood-Ratio	-27,980	-

Note: Significance: ***=1%,**=5%,*=10%. Standard Error is inside parenthesis. Estimates of intercept are not reported on the table to save space.

Table 2. TFP's Decomposition

	SFA		GA	
	Mean	Std. Deviation	Mean	Std. Deviation
TFP	-42.26	5401.10	13.36	102.12
TEC	-0.33	17.20	-	-
TC	5.05	1.53	-	-
SEC	-46.98	5400.97	-	-

Where TFP of Stochastic Frontier is the sum of TEC, TC and SE.

Table 3. TFP, Import Intensity, Export Dummy, and the Interaction of Import and Export from 23 Subsectors

Code	Subsector	TFP1	Rank	TFP2	Rank	Import Intensity	Rank	Export Dummy	Rank	Import*Export	Rank
10	Food Industry	13.16	13	-99.04	18	2.59	20	0.08	19	0.38	23
11	Beverage Industry	22.93	3	-464.61	23	5.15	17	0.08	18	1.65	16
12	Tobacco Industry	25.40	2	4.55	8	1.01	23	0.04	22	0.51	22
13	Textile Industry	6.85	21	34.92	5	9.57	13	0.11	13	2.52	14
14	Apparel Industry	7.79	20	39.68	4	9.29	14	0.15	11	4.24	6
15	Leather and Footwear Industry	9.43	18	10.10	6	7.59	16	0.14	12	2.42	15
16	Wood Industry	16.08	7	3.66	9	2.94	19	0.32	2	1.32	18
17	Paper and Printing Industry	-4.93	22	5.39	7	8.07	15	0.09	15	3.38	10
18	Printing and Recording Media Industry	-6.86	23	-328.22	22	1.79	22	0.04	23	0.65	21
19	Products from Coal and Oil Refinery Industry	34.42	1	290.22	1	11.48	11	0.16	8	1.49	17
20	Chemical Industry	14.05	12	-96.91	17	26.62	3	0.15	10	4.48	5
21	Pharmaceutical Industry	13.10	14	-269.36	21	35.18	1	0.10	14	4.10	7
22	Rubber and Plastic Industry	14.83	9	-44.30	15	10.16	12	0.18	7	2.82	12
23	Fabricated Metal Industry	21.01	4	-51.06	16	3.14	18	0.06	20	1.17	19
24	Metal Base Industry	12.41	15	-99.29	19	22.41	5	0.19	5	3.72	9
25	Metals Industry	18.71	6	141.27	2	16.71	7	0.08	17	2.67	13
26	Computers, Electronics, and Optics Industry	14.22	11	-184.15	20	30.84	2	0.21	4	14.26	1
27	Electrical Equipment Industry	19.27	5	-27.58	12	25.24	4	0.18	6	6.82	2
28	Machinery Industry	8.40	19	-33.06	13	14.27	10	0.15	9	5.06	4
29	Motor and trailers Industry	14.40	10	-16.82	11	19.32	6	0.09	16	4.02	8
30	Other Transport Equipment Industry	11.84	17	-8.18	10	15.64	8	0.06	21	3.20	11
31	Furniture Industry	15.45	8	-43.70	14	2.04	21	0.37	1	0.77	20
32	Other Manufacturing Industry	12.40	16	99.34	3	14.36	9	0.27	3	6.52	3

Note: TFP1 is the Total Factor Productivity obtained from GA approach, while TFP2 is the Total Factor Productivity obtained from SFA approach. Rank is the order from the highest magnitude to the lowest magnitude.

Table 4. The Decompositions of TFP2 from 23 Subsectors

Code	Subsector	TC	Rank	SEC	Rank	TEC	Rank
10	Food Industry	4.91	8	-103.60	18	-0.35	14
11	Beverage Industry	5.73	3	-470.26	23	-0.07	7
12	Tobacco Industry	5.79	2	-1.32	8	0.09	4
13	Textile Industry	4.88	9	30.49	5	-0.45	19
14	Apparel Industry	4.83	10	35.36	4	-0.52	21
15	Leather and Footwear Industry	4.91	7	5.48	6	-0.29	12
16	Wood Industry	5.27	5	-1.61	9	0.00	6
17	Paper and Printing Industry	4.40	18	1.50	7	-0.51	20
18	Printing and Recording Media Industry	4.35	20	-332.22	22	-0.35	15
19	Products from Coal and Oil Refinery Industry	4.65	13	285.33	1	0.23	2
20	Chemical Industry	4.40	17	-101.06	17	-0.26	10
21	Pharmaceutical Industry	4.83	11	-273.99	21	-0.20	9
22	Rubber and Plastic Industry	4.83	12	-48.80	15	-0.32	13
23	Fabricated Metal Industry	6.47	1	-57.01	16	-0.52	22
24	Metal Base Industry	3.85	23	-103.61	19	0.48	1
25	Metals Industry	4.47	15	137.42	2	-0.62	23
26	Computers, Electronics, and Optics Industry	4.26	22	-188.55	20	0.13	3
27	Electrical Equipment Industry	4.49	14	-31.70	12	-0.36	16
28	Machinery Industry	4.45	16	-37.40	13	-0.11	8
29	Motor and trailers Industry	4.35	21	-20.74	11	-0.43	18
30	Other Transport Equipment Industry	4.37	19	-12.12	10	-0.43	17
31	Furniture Industry	5.10	6	-48.51	14	-0.29	11
32	Other Manufacturing Industry	5.28	4	94.00	3	0.05	5

Table 5. TFP Growth (TFP1 and TFP2) in 2009-2015

Code	TFP1								TFP2								Rank of TFP1's Std Deviation	Rank of TFP2's Std Deviation
	2009	2010	2011	2012	2013	2014	2015	**Standard Deviation**	2009	2010	2011	2012	2013	2014	2015	**Standard Deviation**		
10	56.7	-22.2	14.2	11.8	12	-63.0	14.9	**47.2**	-35.1	-17.9	10.9	-274.3	-44.7	-415.5	83.4	**177.9**	**11**	**12**
11	76.1	-40.0	11.9	41.3	1	-61.3	7.5	**64.6**	-142.3	-106.5	5571.6	-8807.8	116.5	56.5	29.1	**4225.5**	**5**	**1**
12	53.5	-42.3	37.2	9.3	23	53.5	21.5	**34.1**	-16.7	55.0	0.3	-20.1	7.3	-7.5	13.5	**25.4**	**18**	**23**
13	7.7	-17.2	9.9	7.6	20	-27.6	14.8	**25.7**	27.0	-0.9	126.0	31.9	141.5	-57.9	-23.2	**74.2**	**21**	**20**
14	2.9	8.0	1.5	9.7	10	-52.2	13.5	**35.9**	-122.6	5.9	210.3	-259.6	427.3	-9.1	22.6	**223.3**	**16**	**10**
15	-1.1	-15.8	23.2	43.6	22	-44.7	31.0	**31.4**	17.0	-53.6	70.8	-6.9	-14.7	58.9	-0.8	**43.2**	**19**	**22**
16	85.3	-24.0	6.2	8.8	21	-61.5	-9.4	**59.9**	-65.6	16.7	45.7	35.0	-65.0	3.5	55.6	**50.2**	**7**	**21**
17	-87.3	-12.9	19.0	1.0	18	-75.0	36.0	**60.7**	94.2	30.5	-31.7	28.7	-134.4	92.4	-42.0	**81.4**	**6**	**18**
18	-75.7	-62.0	49.7	-2.3	2	-6.9	9.0	**47.4**	27.6	-1238.4	341.3	12.6	-1768.3	303.6	17.5	**827.8**	**10**	**2**
19	340.7	-207.2	-5.0	30.4	3	-87.9	76.2	**170.3**	-419.1	506.7	80.7	113.1	1845.4	136.6	-233.2	**746.3**	**1**	**3**
20	31.1	-17.3	9.8	59.0	7	-41.3	3.2	**36.7**	-825.8	-15.9	-14.5	0.9	3.9	-16.7	187.7	**329.6**	**15**	**7**
21	36.6	-23.2	12.1	35.2	4	-47.5	42.6	**35.2**	-38.6	46.5	52.5	-202.8	68.2	-1424.7	-389.3	**536.1**	**17**	**4**
22	38.5	-20.9	22.3	19.4	13	-57.7	34.6	**41.5**	115.3	-271.9	49.7	-143.3	12.0	-0.8	-71.1	**130.2**	**14**	**13**
23	72.5	-11.7	16.3	22.2	14	-43.2	18.6	**41.9**	28.8	47.0	-133.1	8.4	-90.7	-226.7	8.0	**101.8**	**13**	**14**
24	154.1	-55.6	8.8	0.6	5	-55.8	-29.4	**75.2**	-28.5	-887.2	-119.4	115.6	-101.7	114.5	211.0	**368.4**	**4**	**5**
25	122.3	-34.2	0.1	33.8	9	-55.5	9.3	**59.2**	-138.0	46.5	-25.8	29.6	109.4	377.2	583.7	**251.6**	**8**	**9**
26	86.5	-82.6	51.1	-27.1	8	-59.0	1.2	**78.0**	-67.8	-702.6	-238.3	-221.8	-210.3	90.3	61.4	**265.5**	**2**	**8**
27	107.5	-40.8	45.0	29.1	17	55.4	-47.5	**56.3**	-101.8	-14.8	13.5	27.4	58.3	-188.2	12.6	**86.8**	**9**	**17**
28	13.2	14.4	3.8	15.4	16	7.1	-19.5	**13.9**	-24.9	-59.6	-27.5	-19.6	-126.3	140.9	-114.3	**88.1**	**23**	**16**
29	24.6	-17.8	67.1	3.0	15	-13.8	6.6	**29.4**	-33.5	-16.9	-28.4	-143.1	-98.6	140.5	62.3	**94.9**	**20**	**15**
30	144.8	-107.3	29.5	18.1	6	-34.1	13.6	**75.7**	-315.0	249.3	-110.4	-73.3	-456.9	57.4	592.4	**351.5**	**3**	**6**
31	62.8	-37.8	16.2	10.2	19	-39.2	23.6	**43.6**	14.3	-2.0	-31.0	26.7	-133.4	-163.7	-16.7	**74.6**	**12**	**19**
32	-15.4	44.4	6.8	5.8	11	-10.6	16.3	**22.9**	-34.5	-109.6	535.1	144.5	104.2	23.9	31.8	**209.7**	**22**	**11**

Note: Standard Deviation is the standard deviation amongst periods 2009-2015

Table 6. Statistic Descriptive

Variables	Unit		**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Output	Billion Rupiah	Mean	32.32	48.43	39.03	47.94	54.40	101.60	67.77	74.41
		SD	223.20	409.30	358.60	427.90	415.30	778.20	600.70	716.00
Capital	Billion Rupiah	Mean	10.53	56.03	22.75	36.88	18.60	55.38	233.00	55.96
		SD	69.9	2116.0	459.8	1206.0	293.3	1100.0	8466.0	1587.0
Labor	Workers	Mean	183.26	181.82	189.46	187.45	194.17	195.25	190.71	186.28
		SD	752.23	744.95	836.23	728.97	739.98	763.98	730.52	669.69
Energy	Billion Rupiah	Mean	0.71	1.17	0.80	1.07	1.12	2.11	1.36	1.67
		SD	6.29	18.27	11.42	12.33	10.49	21.79	13.73	18.19
Material	Billion Rupiah	Mean	19.77	27.17	22.50	26.93	29.34	53.10	35.06	36.15
		SD	97.32	155.70	200.80	209.40	166.00	354.60	267.60	282.20
Import Material Intensity	Ratio	Mean	7.77	7.59	7.67	7.75	7.49	7.51	7.54	7.49
		SD	22.76	22.62	22.70	22.77	22.39	22.53	22.65	22.42
Export	Binary Dummy	Mean	0.17	0.14	0.13	0.14	0.12	0.13	0.10	0.12
		SD	0.38	0.35	0.34	0.34	0.32	0.33	0.31	0.32
Firm Size	Ratio	Mean	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
		SD	2.17	1.98	2.24	2.22	1.96	2.22	2.27	2.30
HHI	Ratio	Mean	890.37	813.40	848.91	958.67	703.27	827.86	1186.01	1156.60
		SD	1272.85	1145.42	1424.81	1396.28	1058.86	1119.92	1566.25	1425.46

Mean: arithmetic average, SD: standard deviation