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ECONOMIC PAPERS

ECONOMIC PAPERS, VOL. 38, NO. 4, DECEMBER 2019, 299–310

Special Section:Understanding Indonesia's Economic and Financial Systems.

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This study investigates the potential horizontal and vertical spillovers from FDI towards firms' efficiency level on Indonesian manufacturing industries, using firm-level panel data. The result suggests that positive evidence of horizontal spillovers arise instantaneously, but the impacts of vertical spillovers appear a year later. These indicate that foreign competitors cause local firms more efficient in the same industry. Furthermore, after one period of time MNCs running their business in Indonesia, they bring positive impacts on downstream markets but deteriorate manufacturing industries in the upstream markets. Therefore, the Indonesian government must ensure that overall benefits from promoting FDI must overweight their negative impacts.

Keywords: horizontal spillovers, forward spillovers, backward spillovers, technical efficiency, Indonesian manufacturing industry.

1. Introduction

Incoming foreign direct investment (FDI) can bring direct and indirect advantages to the economy of recipient countries. The direct advantages of foreign investment can be increasing the absorption of indigenous labour and increasing production capacity as well as demand for local intermediate goods or raw materials. Hence, the existence of FDI can encourage increased gross domestic product or economic growth and tax revenues (Takii, 2005). In the literature, indirect benefits from FDI are known as externalities or spillovers, which are generated through non-market mechanisms into the economy of the recipient countries (Takii, 2011 as well as Lu, Tao, & Zhu, 2017).

The existence of FDI may spill over to the manufacturing firms within or across industries. If the presence of multinational companies (MNCs) makes local companies to be more efficient within industries, these phenomena are regarded as horizontal spillovers. The channels of horizontal

*This work was partially supported by Kementerian Riset, Teknologi, dan Pendidikan Tinggi (Kemenristek Dikti). We would like to thank Chun-ping Chang and other participants at BI Institute and APAEA Joint International Conference for useful comments and suggestions on an earlier version. We appreciate to two anonymous referees for posing several questions and valuable comments that led us to sharpen the analysis.

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JEL classifications: D24, F23

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Accepted date: July 6, 2019

doi: 10.1111/1759-3441.12264

spillovers can be divided into the demonstration effect, labour mobility and competition. However, if the presence of MNCs upsurges efficiency of domestic firms across industries, these phenomena are considered as vertical spillovers. The transmission mechanisms of vertical spillovers can take place through both backward and forward linkages (Javorcik & Spatareanu, 2011; as well as Orlic, Hashi, & Hisarciklilar, 2018).

These spillovers from FDI may bring important contributions through knowledge transfer to local firms. Most of MNCs have advanced technology, new production knowledge and better managerial expertise that can be transmitted to the local firms. Local firms may adopt their technology or have incentive to use existing resources more efficient. These will contribute to the impressive efficiency gains and smooth the process of fast technological progress, leading the industry to become an engine of economic growth. For this reason, incoming FDI has considered as the most significant channel not only for technology transfer but also for efficiency improvement (Kokko & Kravtsova, 2008; Smeets, 2008).

On the other hand, the values of incoming FDI to Indonesia tend to increase. According to data from Investment Coordinating Board (BKPM), the FDI realization stayed at US$ 1875 million in 2003 and US$ 3620 million in 2007. Moreover, the FDI reached to US$ 19,474 million in 2011 and US$ 29,276 million in 2015. It continued to increase in 2017 to be US$ 32,240 million. This has been broad-based, spread across industries ranging from mining and manufacturing to services sectors such as wholesale and retail trade and transport and communication.

The presence of FDI has played a significant role in generating technology transfer and efficiency improvement, especially for the Indonesian manufacturing industry. The entering FDI has introduced proprietary technology, innovative management and better scale production knowledge that can spill over to the Indonesian manufacturing firms, resulting in efficiency enhancements. Most of the Indonesian FDI spillover empirical studies focus on the within industries or horizontal spillovers (Todo & Miyamoto, 2006; Salim & Bloch, 2009; Taki, 2011 as well as Suyanto & Salim, 2013); conversely, there is a lack study of FDI spillovers across industries or vertical spillovers. To address these gaps, this study goes beyond the existing study in Indonesia, which considers FDI spillover within and across industries. Hence, it is important to examine not only the impacts of horizontal spillovers but also the impacts of vertical spillovers from FDI on the firms' efficiency level. Furthermore, most of the studies when calculating vertical (backward and forward) spillovers are only considering direct linkages; however, this study is allowing total linkages to compute vertical spillovers.

The rest of the paper is organized as follows: Section 22 reviews the potential channels of FDI spillovers. Section 33 presents data and estimation technique is presented in Section 33. Section 44 focuses on empirical results. Finally, Section 55 provides final remarks.

2. The Potential Channels of FDI Spillovers on the Firms' Efficiency

The potential spillovers from FDI are defined as externalities, which are beneficial for indigenous firms through enlargement of their efficiency. These spillovers can work through two broad channels (Girma, Görg, & Pisu, 2008; Lin, Liu, & Zhang, 2009; Keller, 2010; Takii, 2011). Firstly, incoming MNCs may generate efficiency gains to domestic competitors in the same industries, leading to horizontal spillovers. The horizontal spillovers can be passing on three channels of transmission mechanisms, namely demonstration effects, labour mobility and competition. Secondly, the existence of foreign companies may increase efficiency of local establishments in different industries, leading to vertical spillovers. Vertical technology transfers could take place from foreign buyers to domestic suppliers that are acknowledged as backward spillovers and from foreign suppliers to domestic buyers that are recognized as forward spillovers. Furthermore, the spillover effect may not arise instantaneously, and it may propagate through certain lag mechanism. Therefore, this study does not only consider contemporaneous variables but also one lagged value of spillover variables.

The first channel of horizontal spillovers is known as demonstration effects. Foreign companies generally apply their superior technology to their affiliates in host country, causing them to be more competitive compare to domestic competitors. This causes disequilibrium in the existing market and creates native companies to learn simply by duplicating and observing the behaviour of foreign companies in order to protect their market shares and profits. Local companies can advance their technology, managerial skills and scale of production, and may experience an increase in the level of efficiency of the company, thereby creating a demonstration effect (Takii, 2005; Haskel, Pereira, & Slaughter, 2007 as well as Khalifah & Adam, 2009).

Second channel for horizontal spillovers is related to the movement of workers within industries. The foreign firms that engage indigenous workers conduct more dynamic roles. They educate and train their workers more superior than local firms. Through these activities, and subsequent work experiences, indigenous workers turn out to be aware of the advance technology and production skills. Hence, domestic firms have chance to employ labour who formerly worked for MNCs or the trained workers create their own business. They recognize advance knowledge and technology and ready to implement it in the local firms, and result in efficiency enlargement (Fosfuri, Motta, & Rønde, 2001 as well as Balsvik, 2011).

Furthermore, a competition pressure from foreign affiliates is a third feature of horizontal spillovers. Since foreign companies assist host country markets and their products substitute each other, their existence will push local firms to turn out to be more efficient. The local establishments are motivated to use their input proficiently or even to apply better managerial skills and sophisticated technology. Local firms are then pushed to compete with their foreign rivals by improving their performances through increasing their efficiency (Vives, 2008; as well as Yeung & Coe, 2015).

On the other hand, FDI spillovers can occur across industry through vertical linkages. These linkages will take place when foreign firms are connected to upstream (backward spillovers) and to downstream (forward spillovers) in host countries. These channels generate opportunities for local suppliers or buyers to obtain productivity gains (Blalock & Gertler, 2008; Javorcik, 2008; Lin *et al.*, 2009; Javorcik, & Spatareanu, 2011; Iršová & Havránek, 2013 as well as Fujimori & Sato, 2015).

Backward spillovers occur in the upstream markets when foreign firms use intermediate inputs from local producers. It may be profitable for foreign affiliates to generate local provider networks. They request intermediary inputs with particular standard, which is usually higher quality than the local quality. To maintain these relationships, they offer technical assistance and information regarding advance technology to domestic producers. Besides that, they also give technical and managerial training to guarantee the material inputs encounter their standard or provide some other services. These demands push local producers to produce intermediary goods with high-quality standard, leading to efficiency and productivity enhancement.

In addition, foreign affiliates might provide high-quality standard of inputs for local manufacturers in the downstream markets. Local firms may have advantages when they use intermediate inputs produced by foreign firms. These inputs may be offered to local producers with complementary services that may not be available when they are imported. Using higher quality of inputs is expected to improve firms' efficiency in downstream industries. This advantage that come from foreign companies and enjoyed by domestic manufacturers is mostly recognized as forward spillovers.

3. Data and Estimation Technique

The data are drawn from the Indonesian Central Board of Statistics (BPS), such as annual medium and large manufacturing establishments survey (Statistik Industri/SI), wholesale price index (WPI) and input–output (I-O) table. The annual survey for manufacturing establishments is design for employing at least twenty workers, which medium manufacturers are hiring twenty to ninety-nine workers, while large manufacturers are concerning more than ninety-nine workers. The data set covered the period of 2009–2014. The number of firm observation per annual is differed. The lowest is 23,345 establishments in 2010, and the highest is 24,529 establishments in 2014.

Some establishments are excluded annually when constructing consistency between international standard industrial classifications (ISIC) with industrial codes. The material input is also controlled from an unreasonable sense using ratio of material input over output. When ratio is almost zero or one, this looks implausible. Therefore, when the ratio <10 per cent or higher than 90 per cent, they will be omitted from the observations. The data set also minimizes from noise such as misreporting or key-punch error. Finally, balanced panel data are constructed with the number of individual firms and series, which are, respectively, 18,084 firms and six years. Hence, the total observation will be 108,504 firms. The WPI at a constant price of 2010 is implemented to deflate all monetary variables into real terms. The I-O table of years 2005 and 2010 is also applied for computing vertical spillover variables (backward and forward spillovers). The I-O table consists of ninety manufacturing sectors and will then be adjusted to the ISIC code.

Moreover, firms' technical efficiency level can be measured by estimating a production function using stochastic frontier analysis (SFA). A conventional production function is different from the stochastic production function. A production frontier is a function that represents the maximum output that can be produced using certain input combinations. The conventional production function assumes that firms produce their output with particular amount of inputs at full efficiency level. In contrast, the stochastic production function assumes that firm's product below a maximum output is characterized as inefficiency. Therefore, the objective of the stochastic production function is not only estimating the parameters of production function but also estimating inefficiency by splitting the two components of errors.

Furthermore, the stochastic production function for panel data with inefficiency effect, u_{it}, is specified in a common form as follows:

$$Y_{it} = f(\boldsymbol{X_{it}}; \alpha, \boldsymbol{\beta}).exp(v_{it} - u_{it}) \tag{1a}$$

$$u_{it} = \boldsymbol{Z}_{it}\boldsymbol{\delta} + \omega_{it} \tag{1b}$$

where Y implies output, $\boldsymbol{X}$ represents inputs input that utilized in the production process, α and $\boldsymbol{\beta}$ are parameters to be estimated. Subscript i and t stand for firm i and year t. v is the stochastic error term, and μ is the technical inefficiency. $\boldsymbol{Z}$ denotes exogenous variables, which influence technical inefficiency. $\boldsymbol{\delta}$ denotes parameters of the inefficiency effect and to be estimated. ω is an error term of inefficiency function.

Equation 1a expresses the stochastic production function, while Equation 1b expresses inefficiency function. Equation 1a corresponds with Equation 2a, which is a translog production function. Furthermore, the econometric version of a translog stochastic production function and the inefficiency function with exogenous variables can be represented by:

$$y_{it} = \alpha_0 + \sum_{k=1}^{K} \beta_k x_{kit} + \frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{L} \beta_{kl} x_{kit} x_{lit} + \sum\nolimits_{k=1}^{K} \beta_{kt} x_{kit} t + \beta_t t + \frac{1}{2}\beta_{tt} t^2 + v_{it} - u_{it} \tag{2a}$$

$$u_{it} = \delta_0 + \sum\nolimits_{m=1}^{M} \delta_m \boldsymbol{Z}_{mit} + \omega_{it_{it}} \tag{2b}$$

where y and x are output and inputs in logarithm natural forms and t is a time trend.

The coefficients of Equations 2a and 2b will be estimated simultaneously using maximum-likelihood method that proposed earlier study by Battese and Coelli (1995), and currently, studies still apply the same approach, such as Katuwal *et al.* (2016), Sari *et al.* (2016) and Silva *et al.* (2017). The maximum-likelihood function can be written in term of variance parameters: $\sigma_s^2 \equiv \sigma_v^2 + \sigma^2$ and $\gamma \equiv \sigma^2/\sigma_s^2$, where $0 < \gamma < 1$. The conventional production function will be realized when $\gamma = 0$, and $\boldsymbol{Z}$ variables can be directly included into the production function. This indicates that the standard panel data regression for estimating production function is suitable with the data. However, the SFA model will be fulfilled when γ is closer to 1.

The SFA model is hard to estimate even in a full parametric model, because of numerical and statistical instability in the infinite samples. It requests precise parametric functional forms. Hence, the generalized log-likelihood test will be realized to select a proper stochastic production function. The translog production function will be used as a base model and tested against subvarious production functions, such as Hicks-neutral technological progress, no technology progress, Cobb–Douglas and no-inefficiency effect production functions.

The Hicks-neutral technological progress production function exists when the interacting input coefficients with time equivalent to zero ($\beta_{kt} = 0$). No technology progress production function occurs when the time coefficients equal to zero ($\beta_t = \beta_{tt} = \beta_{kt} = 0$). Cobb–Douglas production function arises when the input coefficients equal to zero ($\beta_{kl} = \beta_{kt} = \beta_t = \beta_{tt} = 0$). Furthermore, no-inefficiency effect function takes place when the coefficients of inefficiency functions equal to zero ($\gamma = \delta_0 = \delta_m = 0$), where γ is variance of inefficiency function. If $\gamma = 0$, then a conventional production function with the exogenous variables directly included into the model will be executed.

Furthermore, an equation of the generalized likelihood ratio statistic, which will be performed to select the suitable production function, can be formulated as follows:

$$\lambda = -2[l(H_O) - l(H_1)] \tag{3}$$

where $l(H_O)$ stands for the log-likelihood statistic of the subvarious production functions, while $l(H_1)$ represents the log-likelihood statistic of a translog production function. When the value of statistic is around a χ^2 distribution with degrees of freedom equal to the amount of coefficients restricted in the subvarious production functions, then the null hypothesis (H_O) is not rejected. However, the statistic test for no-inefficiency effect production function is using a mixed χ^2 distribution.

The output (y), which is used in the equation 2a, is total value of gross output. The inputs that used in the production function consist of capital, labour, material inputs and energy. Capital stock (k) is the value of fixed assets, which cover three types of asset: lands and buildings; machinery and other capital goods; and vehicles. Since the data of man hours are not available, the labour (l) is using the number of workers. Material inputs (m) are equal to the total cost of domestic and imported materials inputs, while energy (e) is measured by the sum of total spending on electricity, diesel fuel, gasoline, public gas, lubricant and kerosene. The output and all inputs will be in the form of logarithm natural.

Furthermore, the explanatory variables (**Z**) in the Equation 2b contain variables of FDI spillovers and other regressors. The variables of FDI spillovers involve foreign firm (*FOR*), horizontal spillovers (*HorSpill*), forward spillovers (*ForSpill*), lagged forward spillovers (*L.ForSpill*), backward spillovers (*BackSpill*) and lagged backward spillovers (*L.BackSpill*), while the other explanatory variables are the degree of market competition (*HHI*) and firm size (*FSize*). All manufacturing industries are categorized based on the five digit of ISIC, this is shown by subscript j, and all calculations of their values for explanatory variables are built from unbalance panel data.

Variable of *FOR* depicts foreign ownership, and all joint-venture companies with ten percentages of foreign assets or more are included as foreign firms. This is in line with OECD (2009) definitions. Variable *FOR* is a dummy variable. It has a score 1 if the equity share of foreign ownership is bigger than or equal to 10 per cent and has a score 0 if otherwise.

The horizontal and vertical spillover variables are measured such as in Blalock and Gertler (2008) and Javorcik (2008). However, there is a little bit modification, especially when calculating across industries for vertical linkages. Most of the earlier studies concern direct linkages, but this study includes not only direct but also indirect linkages as well. Sum of direct and indirect linkages are recognized as total linkages. Furthermore, this study also considers the lagged value of horizontal and vertical spillover variables.

The horizontal spillover (*HorSpill*) is the FDI spillover effects in the same industries. The *HorSpill* variable can be formulated as follows:

$$HorSpill_{jt} = \frac{\sum_{i \in j} ForShare_{it} * Y_{it}}{\sum_{i \in j} Y_{it}} \tag{5}$$

ForShare is the total equity share which possessed by foreign investors. Subscript j describes the j-th industry, and $i \in j$ indicates a firm i in the industry j.

The vertical spillover is the FDI spillover in the different industries. When foreign firms are connected to upstream market, it is acknowledged as backward spillovers (*BackSpill*). On the other hand, when foreign firms related to downstream market, it is admitted as forward spillovers (*ForSpill*). The vertical spillover variables here are constructed according to input–output framework, particularly the Leontief inverse matrix which covers both direct and indirect (total) linkages.

To do so, across industry linkage is generated based on Leontief inverse matrix which constructed from the input–output table as follows:

$$Y = AY + FD + X, \quad A = [a_{mn}] \text{ and } a_{mn} = \frac{Y_{mn}}{Y_n} \tag{6a}$$

Solving for Y, it gives:

$$Y = [I - A]^{-1}[Y + X], \quad [I - A]^{-1} = [b_{mn}] \tag{6b}$$

where Y symbolizes matrix of domestic gross output in the input–output table, A represents matrix of domestic input–output coefficient, a_{mn} is element of matrix A that considers as direct linkage, FD denotes column vector of final demand, X stands for column vector of export, $[I - A]^{-1}$ implies Leontief inverse matric, and b_{mn} is element of matrix $[I - A]^{-1}$ that reveals as total linkage.

The variable of *BackSpill* that captures the spillovers from existing foreign company is defined as follows:

$$BackSpill_{jt} = \sum\nolimits_m b_{mn} * HorSpill_{jt} \tag{7}$$

where, b_{mn} captures direct and indirect (inter-sectoral) linkages, which is constructed from the Leontief inverse matrix in Equations 6a,b. It denotes amount of output, which produced by industry m that demanded by industry n for producing one additional unit of output.

Furthermore, *ForSpill* variable is computed in a similar way with backward spillover. However, output that is exported by foreign firms is neglected $(Y_{it} - Ex_{it})$. The forward spillover can be specified as:

$$ForSpill_{jt} = \sum\nolimits_n b_{mn} * \frac{\sum_{i \in j} ForShare_{it} * (Y_{it} - Ex_{it})}{\sum_{i \in j} (Y_{it} - Ex_{it})} \tag{8}$$

where b_{mn} shows amount of output from industry m that is demanded and utilized as inputs for producing one unit of output of industry n.

The Herfindahl–Hirschman Index (*HHI*) describes the degree of market competition (Owen, Ryan, & Weatherston, 2007; Gu, 2016). Bigger values of *HHI* show greater output sales concentration within industry and the market will be less competitive, while less values of *HHI* describe less output sales concentration within industry and the market will be higher competitive. The *HHI* is formulated as follows:

$$HHI_{jt} = \sum\nolimits_{i \in j} s_{ijt}^2 \tag{9}$$

where s_{ijt} is the output share of firm i in industry j at period t, and HHI_{jt} is the Herfindahl–Hirschman index of industry j in year t.

The variable of firm size (*FSize*) is also included in the model. When applying observations with covering a lot of industries and using aggregation, *FSize* is necessary for controlling industry effects. The $FSize_{it}$ is calculated from firm i's output over total output of industry j at period t.

All variables of output and inputs are expressed in deviations from their geometric sample means. These cause the units of measurement will change but the underlying data will not change. Therefore, the first-order derivative of translog or subtranslog production functions will be directly interpreted as output elasticity with respect to its input, evaluated at the sample means. These transformed data of output and inputs are following Coelli (2003). Table 1 presents the statistical summary of all variables discussed above.

4. Empirical Results

The estimation coefficients of horizontal and vertical spillover will be accurate when a correct stochastic production function is chosen. Table 2 provides the results of subvarious models of

Table 1. *A Statistical Summary of Variables*

Variables	Units	Obs	Mean	Std. Dev.	Min	Max
y (output$_t$)	*ln (thousand rupiah)*	108,504	0.00	2.14	−7.56	9.72
c (capital$_t$)	*ln (thousand rupiah)*	108,504	0.00	2.38	−8.40	13.28
l (labour$_t$)	*ln (worker)*	108,504	0.00	1.23	−1.32	6.63
m (material$_t$)	*ln (thousand rupiah)*	108,504	0.00	2.27	−9.92	9.81
e (energy$_t$)	*ln (thousand rupiah)*	108,504	0.00	2.24	−8.13	9.59
t (time)	*annual*	108,504	0.00	1.71	−2.50	2.50
FOR (foreign share$_t$)	*binary dummy*	108,504	0.11	0.31	0.00	1.00
Horspill (Horizontal spillover$_t$)	*ratio*	108,504	0.22	0.21	0.00	1.00
l.Horspill (Horizontal spillover$_{t-1}$)	*ratio*	108,504	0.23	0.22	0.00	1.00
Backspill (backward spillover$_t$)	*ratio*	108,504	1.44	1.83	0.00	14.65
l.Backspill (backward spillover$_{t-1}$)	*ratio*	108,504	1.28	1.63	0.00	14.65
Forspill (Forwad spillover$_t$)	*ratio*	108,504	1.63	1.58	0.00	11.88
l.Forspill (Forwad spillover$_{t-1}$)	*ratio*	108,504	1.49	1.34	0.02	10.42
Fsize (Firm Size$_t$)	*ratio*	108,504	0.01	0.05	0.00	1.00
HHI (Herfindahl-Hirschman Index$_t$)	*ratio*	108,504	0.02	0.07	0.00	1.00

Notes: Mean = arithmetical average; SD = standard deviation; Min = minimum; and Max = maximum; estimates of *y*, *k*, *l*, *m* and *e* are the natural logarithm of their value minus the natural logarithm of their geometric mean.

production functions, which are tested against a translog model. Based on the generalized likelihood test, subvarious models of production functions are inadequate representation of the data. Hence, the estimation results from a translog stochastic production function (Model 1) will be used for the interpretation of horizontal and vertical spillover effects on the firm's technical inefficiency level.

In the first part of model 1 (Table 3), the estimated coefficients of the translog stochastic model have no economic meaning. Therefore, we derived output elasticity with respect to each input, such as capital, labour, material and energy. The output elasticities are attained by taking first-order partial derivatives of model 1. They will be evaluated at the particular values of variables, which are calculated at the mean value of the full sample.

Table 4 presents the results of estimates output elasticities with respect to each input. These output elasticities describe how much the percentage change of output will rise when the percentage change of input increases. The average elasticity of output with respect to capital for local firms appears to be less than foreign firms, which are around 0.1366 and 0.1413, respectively. The elasticity of output with respect to labour of domestic firms (0.1327) is greater than foreign firms (0.0937). This indicates that foreign firms implement more capital and use less labour to produce the same amount of output than domestic firm. This is a common phenomenon in developing countries such as Indonesia that local firms are more labour intensive than foreign firms. In material inputs, the average score of output elasticity of domestic firms (0.5916) is greater than foreign firms (0.5887), but the output elasticity to energy of domestic firms (0.1616) is less than foreign firms (0.1799). To produce the same

Table 2. *Hypothesis Testing of Stochastic Production Function Frontier Models*

Models	H_0	λ	χ^2 1%	Conclusion
Hicks-neutral	$\beta_{kt} = 0$	295.278	13.277	H_0 rejected
No-technological progress	$\beta_t = \beta_{tt} = \beta_{kt} = 0$	3837.186	16.812	H_0 rejected
Cobb–Douglas	$\beta_{kl} = \beta_{kt} = \beta_t = \beta_{tt} = 0$	26,441.86	23.209	H_0 rejected
No-inefficiency effects	$\gamma = \delta_0 = \delta_Z = 0$	5132.780	20.972	H_0 rejected

Note: Calculation of λ from the generalized likelihood ratio statistic.

Table 3. *Maximum-Likelihood Estimation of the Stochastic Production Frontier*

Variables	Coefficients	Model 1	Model 2	Model 3	Model 4
Production function					
Constant	β_0	0.1684†	0.1682†	0.1021†	0.0677†
		(0.0037)	(0.0032)	(0.0033)	(0.0020)
k	β_{κ}	0.1347†	0.1352†	0.1046†	0.1025†
		(0.0011)	(0.0011)	(0.0009)	(0.0004)
l	β_{λ}	0.1452†	0.1452†	0.1494†	0.1610†
		(0.0014)	(0.0014)	(0.0013)	(0.0012)
m	β_{μ}	0.5548†	0.5536†	0.5731†	0.5372†
		(0.0013)	(0.0013)	(0.0014)	(0.0016)
e	β_{ε}	0.2000†	0.2006†	0.2070†	0.2456†
		(0.0012)	(0.0013)	(0.0013)	(0.0015)
k^2	$\beta_{\kappa\kappa}$	−0.0228†	−0.0222†	−0.0336†	
		(0.0009)	(0.0009)	(0.0009)	
l^2	$\beta_{\lambda\lambda}$	0.0327†	0.0346†	0.0355†	
		(0.0018)	(0.0017)	(0.0016)	
m^2	$\beta_{\mu\mu}$	0.2141†	0.2085†	0.2172†	
		(0.0019)	(0.0019)	(0.0019)	
e^2	$\beta_{\varepsilon\varepsilon}$	0.1345†	0.1392†	0.1442†	
		(0.0025)	(0.0025)	(0.0025)	
kl	$\beta_{\kappa\lambda}$	0.0082†	0.0049†	0.0100†	
		(0.0011)	(0.0009)	(0.0009)	
km	$\beta_{\kappa\mu}$	−0.0188†	−0.0122†	−0.0099†	
		(0.0011)	(0.0010)	(0.0010)	
ke	$\beta_{\kappa\varepsilon}$	0.0389†	0.0322†	0.0357†	
		(0.0011)	(0.0010)	(0.0010)	
lm	$\beta_{\lambda\mu}$	−0.0466†	−0.0468†	−0.0512†	
		(0.0014)	(0.0013)	(0.0014)	
le	$\beta_{\lambda\varepsilon}$	0.0029‡	0.0053†	0.0038†	
		(0.0015)	(0.0015)	(0.0015)	
me	$\beta_{\mu\varepsilon}$	−0.1690†	−0.1686†	−0.1753†	
		(0.0019)	(0.0019)	(0.0020)	
t	β_{τ}	−0.0242†	−0.0241†		
		(0.0007)	(0.0007)		
t^2	$\beta_{\tau\tau}$	−0.0528†			
		(0.0010)			
kt	$\beta_{\kappa\tau}$	0.0007			
		(0.0005)			
lt	$\beta_{\lambda\tau}$	−0.0047†			
		(0.0008)			
mt	$\beta_{\mu\tau}$	0.0104†			
		(0.0008)			
et	$\beta_{\varepsilon\tau}$	−0.0104†			
		(0.0008)			
Inefficiency function					
Constant	δ_0	0.2524†	0.2521†	0.2568†	0.1499†
		(0.0035)	0.0030	(0.0046)	(0.0040)
FOR	δ_{FOR}	−0.0399†	−0.0392	−0.0511†	−0.0768†

(*Continued*)

Variables	Coefficients	Model 1	Model 2	Model 3	Model 4
		(0.0044)	0.0037	(0.0036)	(0.0254)
HorSpill	$\delta_{HorSpill}$	−0.2271†	−0.2229†	−0.1986†	−0.2070†
		(0.0057)	0.0053	(0.0086)	(0.0181)
L.HorSpill	$\delta_{LHorSpill}$	−0.1522†	−0.1486†	−0.0846†	−0.0495†
		(0.0051)	0.0041	(0.0102)	(0.0064)
ForSpill	$\delta_{ForSpill}$	−0.0009	−0.0010†	−0.0200†	−0.0475†
		(0.0014)	0.0010	(0.0012)	(0.0030)
L.ForSpill	$\delta_{L.ForSpill}$	−0.0062†	−0.0061†	−0.0149†	−0.0404†
		(0.0006)	0.0006	(0.0016)	(0.0018)
BackSpill	$\delta_{BackSpill}$	−0.0005	−0.0011†	0.0043†	0.0106†
		(0.0006)	0.0005	(0.0007)	(0.0012)
L.BackSpill	$\delta_{L.BackSpill}$	0.0096†	0.0103†	0.0267†	0.0658†
		(0.0012)	0.0006	(0.0011)	(0.0012)
HHI	δ_{HHI}	1.2721†	1.3114†	1.5997†	0.0971†
		(0.0519)	0.0206	(0.1462)	(0.0520)
FSize	δ_{FSize}	−1.3007†	−1.3373†	−1.6660†	−0.1231†
		(0.0531)	0.0124	(0.1427)	(0.0324)
Sigma-squared	σ^2	0.0853†	0.0855†	0.0885†	0.1102†
		(0.0004)	0.0004	(0.0004)	(0.0005)
Gamma	γ	0.0196†	0.0200†	0.0317†	0.0289†
		(0.0017)	0.0008	(0.0028)	(0.0031)
Log-likelihood function		−22,174.3	−20,403.3	−22,174.3	−33,476.6
LR test of the one-sided error		5135.4	5078.6	5079.0	2452.7

Note: Model 1 is a translog production function, and Model 2 and Model 3 represent a Hicks-neutral and no-technological progress production functions. Model 4 is Cobb-Douglas production functions. Standard errors are in parentheses and presented significances until α = 10 per cent.
*Significance at 1 per cent; **Significance at 5 per cent.

amount of output, foreign firms use fewer material input but consumes more energy compared to domestic firms.

In Model 1, the coefficient of foreign ownership (*FOR*) in the inefficiency function is statistically significant and has negative sign. This means local companies are more inefficient than their foreign competitor assuming other variables constant. This evidence is consistent with former studies that the foreign subsidiaries typically serve more efficient than their local establishments in the market (Wang, 2010; Suyanto & Salim, 2013). The foreign firms in Indonesia commonly use larger scale and higher capital intensive production processes. They have more new knowledge and advance technology than domestic firms. Therefore, local companies are less efficient than foreign companies.

Table 4. *Elasticity of Output with Respect to Each Input*

	Domestics Firms	Foreign Firms	All Firms
Elasticity of capital (ε_k)	0.1366	0.1413	0.1371
Elasticity of labour (ε_l)	0.1327	0.0937	0.1286
Elasticity of material (ε_m)	0.5916	0.5887	0.5913
Elasticity of energy (ε_e)	0.1616	0.1799	0.1635
Total elasticity (ε)	1.0225	1.0017	1.0205

Note: Total elasticity is $\varepsilon = \varepsilon_k + \varepsilon_l + \varepsilon_m + \varepsilon_e$.

Moreover, this study is particularly interested on the estimated horizontal and vertical spillover coefficients of the inefficiency functions. Most studies of the FDI spillovers only examine the impact of horizontal and vertical spillovers to firms' performance in the same period. However, this study includes not only their current variables but also lagged variables of FDI spillovers. This is done because of anticipating the possibility of FDI spillover impacts that are not contemporaneous.

The horizontal spillover (*HorSpill* and *L.HorSpill*) coefficients are statistically different from zero, and both have negative signs. The prior empirical studies of horizontal spillovers from FDI to the Indonesian manufacturing sector support this finding (Sjöholm, 1999, as well as Blalock & Gertler, 2008). The presence of foreign competitors has impact instantaneously to the local firms. Furthermore, a negative *L.HorSpill* coefficient proves that foreign firms have impact one year ahead to the firms' efficiency. This means that the local firms become more competitive within the markets. The higher foreign share has consequences to local firms using more efficient technique to utilize their existing resources, and then results in productivity benefits.

On the other side, the coefficients of forward and backward spillover (*ForSpill* and *BackSpill*) are not statistically different from zero. These findings verify that the existence of FDI does not have an impact directly to the downstream and upstream industries, but the coefficients of lagged forward and lagged backward spillover (*L.ForSpill* and *L.BackSpill*) are statistically significant. A negative sign of *L.ForSpill* variable shows that after a year the foreign companies take place in Indonesia, it will decrease firms' efficiency level of downstream manufacturing sectors. The local companies may not need to import their materials input from abroad, and they can buy their input from downstream markets, which supplied by foreign companies. Consequently, foreign affiliates have stimulus to boost the efficiency level of local firms through decrease their input cost and enhancement the quality in return.

However, the results on across industry spillovers do not entirely develop firms' efficiency level. The finding shows that a sign of lagged backward spillover (*L.BackSpill*) coefficient is positive and significant. This points out there is a negative learning from MNCs in the upstream industry, after one period they come to Indonesia. This means the intermediary goods manufactured by indigenous producers are not utilized frequently by foreign companies because the quality of local inputs does not match with the desire of foreign companies, and then, they buy their intermediary inputs from aboard. Besides that, it is possible that the bargaining power from multinational enterprise towards policy-makers is very strong. This may bring unfavouring contractual agreements towards local industry. Henceforth, the production of local industries will drop and may shrink their benefits.

This finding suggests that the policies of encouraging FDI in manufacturing industries may not be directly supported. The government should take into consideration whether the presence of FDI will bring advantages towards the domestic demands or suppliers. Since foreign companies have potential effects to steal the markets from local companies, the government as a policy-maker should ensure to minimize the negative impact from incoming FDI. In other words, the total benefits, which come from FDI on domestic firms, should excess the undesirable impacts from incoming FDI.

Moreover, the high concentration or less competitive firms in the Indonesian manufacturing industries increase their efficiency. High concentration firms have incentives to improve their efficiency through the use of better technology for organizing their material inputs. This reduces their input cost and improves their quality in return, which then leads to their productivity benefits. This is shown by the positive sign and statistically significant coefficient of Herfindahl–Hirschman index (*HHI*) in the inefficiency function.

The remaining regressor, the coefficient of firm size (*FSize*), seems to be statistically different from zero and has a negative sign. This confirms that lager size of the firms will have less inefficiency. This empirical evidence is not surprising, because of technology diffusion. The bigger size of firms is expected to have modern technology for operating their capital equipment compared to the smaller size of firms.

5. Final Remarks

This empirical study proves that foreign manufacturers are more efficient than local manufacturers. There are positive and instantaneous impacts of horizontal spillovers. The impacts of forward and backward spillovers are not derived directly, but they come a year later. The results show that there is a positive evidence for one lagged forward spillover and a negative evidence for one lagged backward spillovers. Hence, it can be said that the presence of FDI does not completely enhance the efficiency of domestic firms. Nevertheless, the local firms have still possibilities to compete with foreign firms within markets and buy their intermediary goods in downstream markets. All of these will make domestic firms better-offs.

This finding has a policy implication for promoting FDI. However, the inward FDI does not support entirely and directly Indonesian manufacturing industries. Government should deliberate whether the presence of FDI carries out benefits to the domestic manufacturers. In this situation where multinational companies cause potential losses, the government as policy-makers must be careful to the existence of foreign companies. They should make sure that the negative impacts from incoming FDI do not exceed their overall benefits. Nevertheless, where the positive impacts from FDI are greater than the losses, the policy-makers must have a programme to promote entering MNCs to Indonesia as a host country. To support this programme, the government should provide institutional reforms such as building modern infrastructure, good government administration, supporting and strengthening the institutions for fast-tracking economic growth. All the reforms are expected to build a more competitive environment in the entire economy.

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