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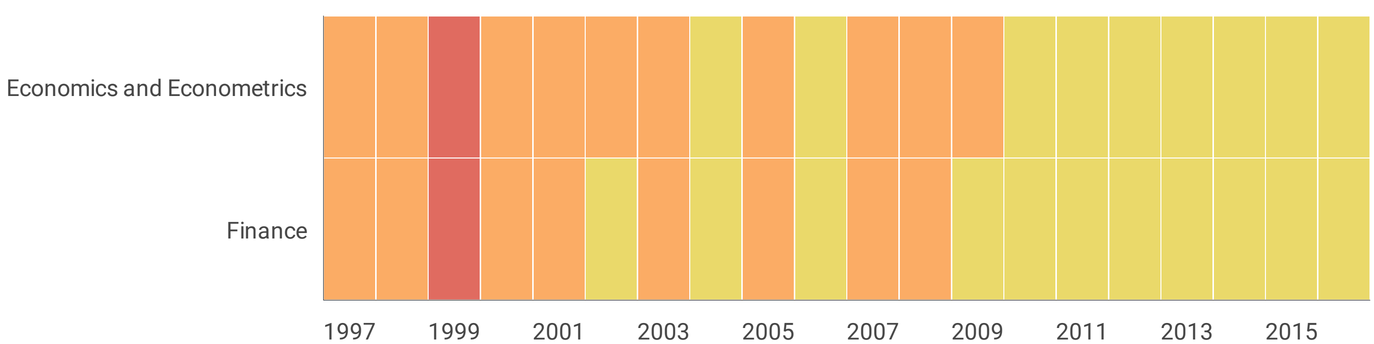

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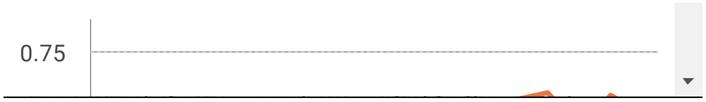

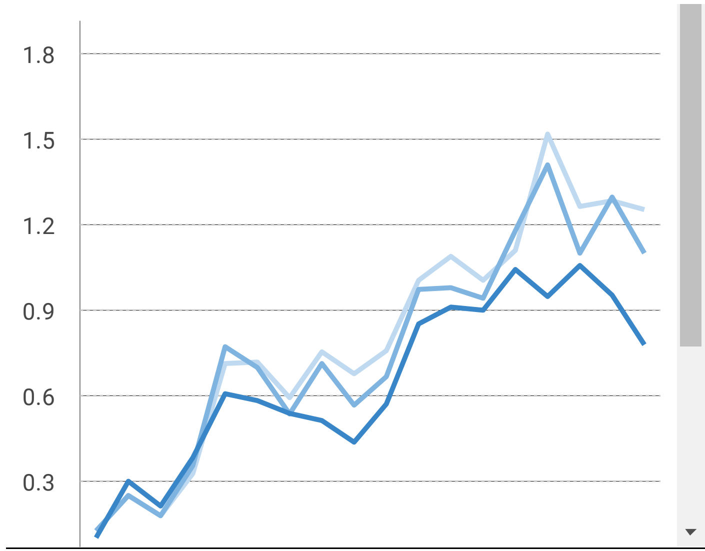

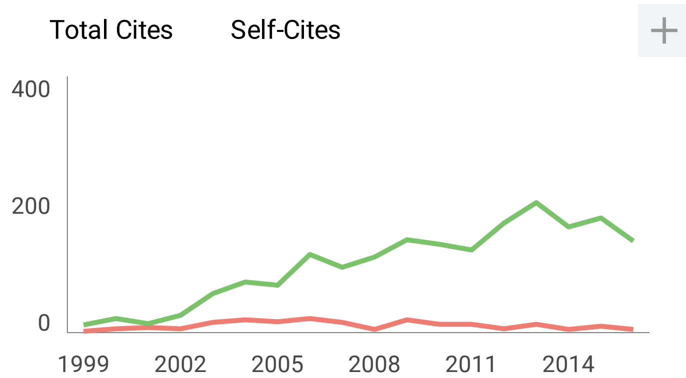

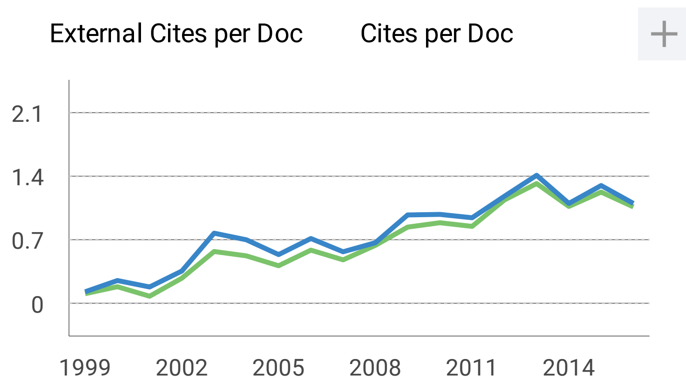

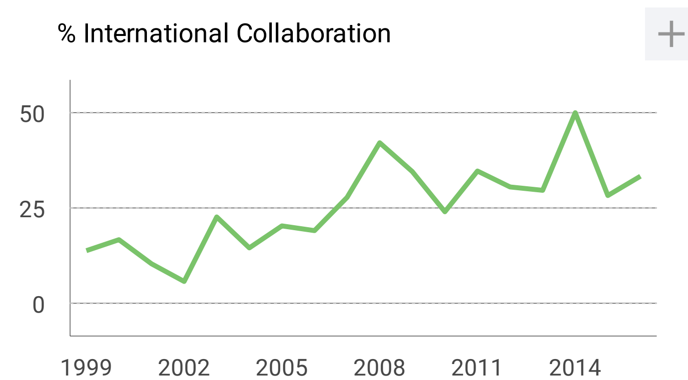

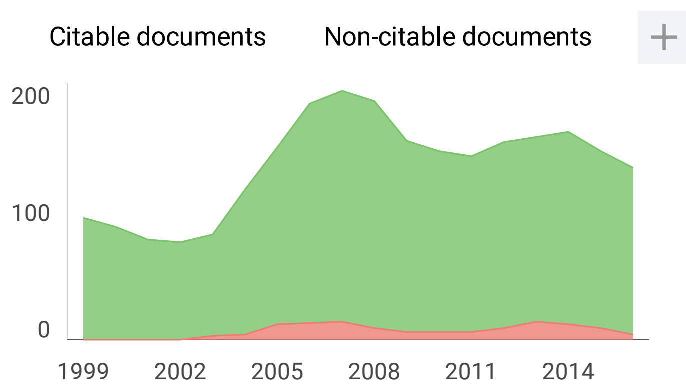

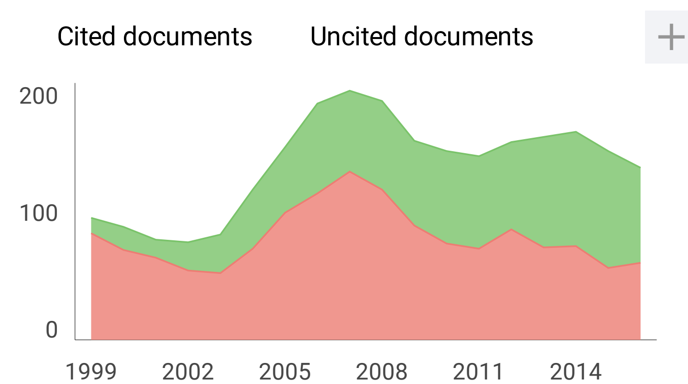

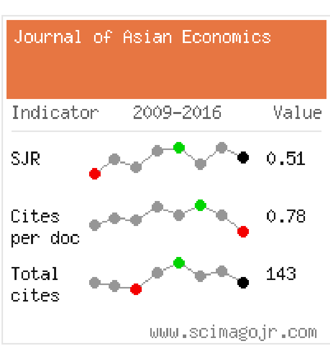

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Which firms benefit from foreign direct investment? Empirical evidence from Indonesian manufacturing

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ABSTRACT

Despite growing concern regarding the productivity benefits of foreign direct investment (FDI), very few studies have been conducted on the impact of FDI on firm-level technical efficiency. This study helps fill this gap by empirically examining the spillover effects of FDI on the technical efficiency of Indonesian manufacturing firms. A panel data stochastic production frontier (SPF) method is applied to 3318 firms surveyed over the period 1988–2000. The results reveal evidence of positive FDI spillovers on technical efficiency. Interesting differences emerge however when the samples are divided into two efficiency levels. High-efficiency domestic firms receive negative spillovers, in general, while low-efficiency firms gain positive spillovers. These findings justify the hypothesis of efficiency gaps, that the larger is the efficiency gap between domestic and foreign firms the easier the former extracts spillover benefits from the latter.

1. Introduction

The spillover effects of foreign direct investment (FDI) have been a major concern for researchers and policy makers during the last two decades. A number of studies have examined the spillover effects of FDI on domestic firm productivity (Chakraborty & Nunnenkamp, 2008; Haddad & Harrison, 1993; Hu & Jefferson, 2002; Javorcik, 2004; Liang, 2007; Negara & Firdausy, 2011; Takii, 2005, 2011). These studies provide some useful insights regarding the evidence of the spillover benefits and offer some recommendations to maximize the benefits. However, most existing studies exclude technical efficiency and focus mainly on technology, ignoring that the FDI presence in host countries is the impetus for efficiency improvement through competition and demonstration effects (Wang & Blomstrom, 1992). A study of FDI spillover effects on firm-level technical efficiency is important to provide evidence as to whether the large amount of FDI inflows generate positive externalities to domestic firms through efficiency improvement, thus indicating whether the spillover hypothesis is justified in the context of technical efficiency. Such a study can explore to what extent FDI can induce efficiency spillovers, and which firm types really benefit from the spillovers.

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Among the developing economies, Indonesia is particularly successful in attracting FDI. Net FDI inflows to Indonesia have risen more than 30 times since 1986, reaching a record level of US$8.3 billion in 2008 (the Central Bank of Indonesia, 2011). However, there is a dearth of research on efficiency spillovers in Indonesia. Most empirical studies examine spillover effects under a framework of the long-run equilibrium production function, which assumes that firms are producing at a full efficiency level. Under this framework, the FDI spillovers on technical efficiency are not captured.

Two previous studies by the authors focus on technical efficiency using a stochastic production frontier framework for individual Indonesian manufacturing industries. Suyanto, Salim, and Bloch (2009) examine the pharmaceutical and chemical industries, while Suyanto et al. (2012) examine the electronic and garment industries. However, there are no studies providing comprehensive results for the whole Indonesian manufacturing sector using a stochastic framework.

A study by Temenggung (2007) examines the whole Indonesian manufacturing sector. Our current research differs from Temenggung in three important points. Firstly, Temenggung applies the ordinary least squared (OLS) regression method for panel data, which doesn't distinguish between fixed effects (FE) and random effects (FE). Secondly, the classical production function, employed in Temenggung (2007), assumes that all firms are fully efficient, so that the spillover effects of FDI reflect technological progress. In contrast, the current paper employs the stochastic production frontier, which relaxes the assumption of full efficiency of firms, so that both technological progress and efficiency improvement are examined. Thirdly, we calculate the scores of technical efficiency of each firm and estimates spillover effects separately for high-efficiency and low-efficiency firms, providing a useful insight into the differences in the ability of high-efficiency and low-efficiency firms in absorbing spillover effects from FDI.

This study contributes to the existing literature in several ways. Firstly, it examines the spillover hypothesis by focusing on technical efficiency, an important aspect that is often neglected in the previous studies. The adoption of a stochastic production frontier allows the authors to investigate the effects of FDI spillovers on firm-level technical efficiency. Secondly, this study covers a long series of surveyed firms, which includes also the period of the Asian crisis onwards. Thirdly, this study evaluates horizontal, backward, and forward spillovers of FDI. Most importantly, by examining the whole manufacturing sector, it is possible to identify characteristics of industries that affect the size of the technology and efficiency spillovers to domestic firms from FDI. In particular, we find evidence that the size of the technology gap between foreign and domestic firms is critical, with larger efficiency gaps associated with greater efficiency spillovers from FDI.

We proceed by reviewing the concept of spillover effects in the next section. We then discuss methodology and data. Empirical results are presented in Section 4 and the conclusions are given in the final section.

2. FDI, spillover effects, and technical efficiency: theoretical concept and empirical evidence

2.1. FDI and spillover effects

Foreign direct investment is believed to provide host countries with direct and indirect benefits. The direct benefits take the forms of new investments that boost national income, increase tax revenues, and provide new employment; whereas the indirect benefits are in the forms of externalities that are generated through non-market mechanisms to recipient economies and domestic firms within the economies (Hymer, 1960). These indirect benefits are commonly known as FDI spillovers.

The literature identifies at least three types of FDI spillovers. These are productivity spillovers, market-access spillovers, and pecuniary spillovers. Productivity spillovers are defined as the externalities from FDI that lead to increases in the productivity of domestic firms (Aitken & Harrison, 1999). Market-access spillovers exist when the presence of FDI generates an opportunity for domestic firms to access international markets (Blomstrom & Kokko, 1998). Pecuniary spillovers happen if the existence of FDI affects the profit functions of domestic firms through a reduction in costs or an increase in revenues (Gorg & Strobl, 2005).

Of the three types of FDI spillovers, productivity spillovers have been a particular concern among policy makers and researchers in the last two decades. Various incentives have been provided by policy makers to attract FDI and substantial efforts have been devoted by researchers to evaluate the productivity advantage. However, the empirical evidence is mixed at best. Some studies find evidence of positive productivity spillovers (Caves, 1974; Javorcik, 2004; Kugler, 2006; Schiff & Wang, 2008; Temenggung, 2007), but others discover nonexistent or even negative spillovers (Aitken & Harrison, 1999; Blalock & Gertler, 2008; Djankov & Hoekman, 2000). Thus, the relationship between FDI spillovers and firm productivity remains a controversial issue.

2.2. Spillover effects and firm-specific characteristics

Some researchers argue that the mixed evidence intuitively implies that the spillover effects are not an automatic consequence of the foreign presence in an economy, rather they depend significantly on the characteristics of firms in the industries (Gorg & Greenaway, 2004; Lipsey & Sjoholm, 2005; Smeets, 2008). One important characteristic of firms is the technology gap between foreign and domestic firms. In a study on UK manufacturing firms, Griffith, Redding, and Simpson (2002) find that the wider the technology gap the larger the FDI spillover effects that are obtained by domestic firms. This finding indicates a benefit of being less advanced in terms of technology, which supports the theoretical argument in Findlay (1978). A similar result is discovered also by Castellani and Zanfei (2003) for France and Spain, and by Peri and Urban (2006) for Italy and Germany.

Although there is an advantage in being less advanced, the technology gap should not be too wide (Wang & Blomstrom, 1992). A minimum level of technology is required for domestic firms to absorb the new technology from foreign firms. When the gap is too wide, the limited kind absorptive capacity of domestic firms may not permit assimilation the new technology (Glass & Saggi, 1998).

2.3. Technical efficiency gains from FDI spillovers

Earlier studies on FDI productivity spillovers focus on technology advantages (Gorg & Greenaway, 2004). The knowledge from foreign firms is regarded synonymously with technological knowledge, as this is consistent with the use of a conventional production function. Managerial and organizational knowledge that may lead to efficiency spillovers are not portrayed since firms are assumed to be producing at the long-run equilibrium with a full efficiency capacity. Thus, the productivity spillovers in these early studies are identically measured as technology spillovers.

More recent studies focus on both efficiency and technology advantages. In these studies, knowledge is defined broadly as product, process, managerial, and organizational knowledge. Hence, productivity spillovers lead to both technology and efficiency advantages. Unfortunately, studies that investigate efficiency advantages are not plentiful. In a study on Greek manufacturing firms, Dimelis and Lauri (2002) examine the effect of foreign equity shares on efficiency and find a positive relationship between these two variables. Also, Ghali and Rezgui (2008) analyze the Tunisian manufacturing sector and find that higher foreign share increase firm efficiency. Addressing the same issue but employing a different estimation method, our study investigates the efficiency spillovers in Indonesian manufacturing firms. We extend the studies by Dimelis and Lauri (2002) and Ghali and Rezgui (2008) by focusing on vertical spillovers as well as horizontal spillovers.

3. Methodology, data set, and variables

3.1. Methodology

There are two commonly used methods in measuring efficiencies and productivity at the firm level, namely data envelopment analysis (DEA) and stochastic frontier analysis (SFA).[1] Each of the two methods has its advantages and disadvantages, as explained below. The choice between these methods thus depends on the objective of the research, the type of firms in the chosen industry, and the nature of the data (Coelli, Rao, O'Donnell, & Battese, 2005; Olesen, Peterson, & Lovell, 1996).

DEA is a linear programming method that observes production possibilities using the technique of envelopment and measures efficiency as the distance to the frontier (Banker, Charnes, & Cooper, 1984; Charnes, Cooper, & Rhodes, 1978). This method has the primary advantage of being of a non-parametric nature and has the ability to handle multiple outputs and multiple inputs.[2] However, it has the disadvantage of producing biased estimates in the presence of measurement error and other statistical noise, as this method does not separate the stochastic random noise from the inefficiency effects (Schmidt, 1985). Hence, the estimation results under this method tend to be very sensitive to small changes in the data.

Alternatively, the stochastic frontier method is a regression-based method that assumes two separate unobserved error terms, one represents efficiency and the other represents statistical noise (Aigner, Lovell, & Schmidt, 1977; Meeusen & van den Broeck, 1977). It has a chief advantage in the ability to measure efficiency in the presence of statistical noise. However, this method is parametric and requires a specific functional form and distributional assumptions for the error terms (Coelli et al., 2005).

In this study the stochastic frontier method is applied to analyze the spillover effects from FDI. The one-stage stochastic production frontier (SPF) is used to estimate a production frontier and a technical inefficiency function simultaneously. As pointed out by Kumbhakar, Ghosh, and McGuckin (1991) and Wang and Schmidt (2002), the one-stage approach is preferable than the two-stage approach, as the latter exhibits at least two limitations in estimation that can lead to potentially severe bias. The first limitation is that technical efficiency might be correlated with the production inputs, which may cause inconsistent estimates of the production frontier. The second limitation is the OLS method in the second stage is inappropriate since technical efficiency distribution is assumed to be one-sided. Considering the advantages, the current study adopts the one-stage approach, following Battese and Coelli (1995).

The Battese–Coelli production frontier can be expressed as follows:

$$y_{it} = f(x_{it}, t; \beta)\exp(v_{it} - u_{it}) \tag{1}$$

and the inefficiency function may be written as:

$$u_{it} = z_{it}\delta + w_{it} \tag{2}$$

[1] Comprehensive reviews of the two methods are provided by Forsund et al. (1980), Bauer (1990), Bjurek et al. (1990), Bravo-Ureta and Pinheiro (1993), Greene (1993), Lovell (1993), and Coelli (1995).

[2] The non-parametric nature of DEA allows for measuring efficiency without imposing a specific functional form and a distributional assumption on data.

where y_{it} denotes the production of the ith firm ($i = 1, 2, \ldots, N$) in the tth time period ($t = 1, 2, \ldots, T$), x_{it} denotes a $(1 \times k)$ vector of explanatory variables, β represents the $(k \times 1)$ vector of parameters to be estimated, *exp* denotes exponential, v_{it} is the time specific and stochastic error, with *iid* $N(0, \sigma^2_v)$, and u_{it} represents technical inefficiency, which is assumed as a function of a $(1 \times j)$ vector of observable non-stochastic explanatory variables, z_{it}, and a $(j \times 1)$ vector of unknown parameters to be estimated, δ, and w_{it} is an unobservable random variable.

The parameters of Eqs. (1) and (2) are estimated using the maximum likelihood estimator (MLE) by following the three steps as explained in Coelli (1996). With simultaneous equation estimation, the MLE estimates are unbiased and efficient. The variance parameters of the Battese-Coelli's model are defined as $\sigma^2_s \equiv \sigma^2_v + \sigma^2_u$ and $\gamma \equiv \sigma^2_u / \sigma^2_s$.[3]

γ is an important parameter to decide whether there is technical inefficiency or not in the model. If the estimated value of γ is not statistically significant, there is no technical inefficiency and the results obtained from estimating Eq. (1) by ordinary least squares (OLS) would be efficient. In contrast, if the estimated value of γ is statistically significant, then there is technical inefficiency and Eqs. (1) and (2) should be estimated simultaneously.

The technical efficiency of the ith firm calculated from the Eqs. (1) and (2) is the ratio of observed output of the firm to its potential maximum output, which can be written as:

$$TE_{it} = \frac{y_{it}}{y^P_{it}} = \exp(-u_{it}) \tag{3}$$

Following Battese and Coelli (1988), the best estimator of the $\exp(-u_{it})$ is its conditional expectation, $E[\exp(-u_{it})]$, so technical efficiency can be written as:

$$TE_{it} = E[\exp(-u_{it})] \tag{4}$$

If it is assumed that the production frontier takes the form of a log-linear production function and there are four input variables (labour, capital, material, and energy) in the production process, the empirical model can be expressed in natural logarithms of variables as:

$$\ln Y_{it} = \beta_o + \beta_1 \ln L_{it} + \beta_2 \ln K_{it} + \beta_3 \ln M_{it} + \beta_4 \ln E_{it} + +\beta_5 T + \beta_6 \ln FDI\_Sector + v_{it} - u_{it} \tag{5}$$

where Y is output, L is labour, K is capital, M is material, E is energy, T is a time-trend variable that increases by one for each year, *FDI_Sector* is a measure of FDI horizontal spillovers as explained in the next section and the other variables are as previously defined.

The inefficiency effect as a function of a set of FDI variables, a year dummy, an industry dummy, and a firm dummy can be written as:

$$u_{it} = \delta_0 + \delta_1 FDI\_Firm_{it} + \delta_2 FDI\_Sector_{jt} + \delta_3 FDI\_Firm_{it} \times FDI\_Sector_{jt} + \delta_4 Year + \delta_5 Industry + \delta_6 Firm + w_{it} \tag{6}$$

where *FDI_Firm* is a dummy variable for foreign direct investment that takes a value of zero if a firm has no foreign ownership share and takes a value of one if a foreign firm has a positive share, *FDI_Sector* is as defined above, *Year* is a year dummy variable, *Industry* is an industry dummy and *Firm* is a firm dummy. The interaction term of *FDI_Firm* × *FDI_Sector* is included in the inefficiency equation to estimate whether foreign and domestic firms benefit equally from the presence of a new foreign firm. A positive (negative) coefficient on the interaction term indicates less (more) efficiency gain for foreign firms than for domestic firms.

Eq. (6) is used to estimate the intra-industry spillovers, which capture the effects of foreign presence on the technical efficiency of firms in the same industry. The inter-industry spillovers are commonly estimated by replacing the horizontal-spillover variable (*FDI_Sector*) with vertical-spillover variables. The inefficiency function for the inter-industry spillovers can be expressed as:

$$u_{it} = \delta_0 + \delta_1 FDI\_Firm_{it} + \delta_2 FDI\_Downstream\_Sector_{jt} + \delta_3 FDI\_Firm_{it} * FDI\_Downstream\_Sector_{jt} + \delta_4 Year + \delta_5 Industry + \delta_6 Firm + w_{it} \tag{7}$$

or

$$u_{it} = \delta_0 + \delta_1 FDI\_Firm_{it} + \delta_2 FDI\_Upstream\_Sector_{jt} + \delta_3 FDI\_Firm_{it} * FDI\_Upstream\_Sector_{jt} + \delta_4 Year + \delta_5 Industry + \delta_6 Firm + w_{it} \tag{8}$$

where *FDI_Downstream_Sector* is a proxy for spillover effects from foreign firms to foreign and domestic suppliers and *FDI_Upstream_Sector* is a proxy for spillover effects from foreign firms to foreign and domestic buyers.

[3] The complete derivation the log-likelihood function of the Battese-Coelli model and its related variance parameters are discussed in Battese and Coelli (1993).

3.2. Data and data set construction

The primary data for our study are the annual surveys of medium and large manufacturing establishments (*Survey Tahunan Statistik Industri* or *SI*) conducted by the Indonesian Central Board of Statistics (*Badan Pusat Statistik* or *BPS*). These annual surveys cover a wide range of information from each surveyed establishment. The basic information includes year of starting production, industrial classification, location, and the specific identification code. There is also information regarding ownership, which includes foreign and domestic ownership, and information related to production, such as gross output, number of workers in production and non-production, value of fixed capital, material usage, and energy consumption.

The annual surveys have been conducted since 1975 and the most recent available data relates to the year 2007. However, this study uses the data from 1988 to 2000. The year 1988 is chosen as a starting year since it is the first year that the replacement value of fixed assets, which is used as a measure for capital, is available. The year 2000 is selected as the last year because the BPS changed the specific identification code in 2001 to the new identification code (KIPN) without providing a concordance table to the previous used identification code (PSID). Efforts to match the observations in the years 2001–2005 to the years 1988–2000 using output values and labour do not yield consistent results. Therefore, the longest possible period for this study is 1988–2000.

In constructing a consistent data set, several adjustments are conducted. These include adjustment for industrial code, adjustment for variable definitions, cleaning for noise and typological errors, back casting missing values of capital, matching firms for a balanced panel, and choosing industries with foreign firms. The balanced panel data are preferable in this study due to two advantages: (1) it enables tracing the technical efficiency scores of each observed firm during the period of study; (2) it removes the influence of a firm that appears only in one or two years, while the period of estimation is for 13 years. The details of adjustments are presented in Appendix 1. After the adjustments, the final balanced panel of data consists of 3318 establishments with 43,225 observations.

To show the influence of the construction of the balanced panel dataset, the descriptive statistics of the related variables are calculated for the balanced panel data and for the original data before the adjustment process. The original data consist of establishments that do not report complete information on output, labour, capital, material, or energy. Therefore these establishments are not included in the calculation of the descriptive statistics for original data. Following Takii (2005), (1) 0.5 percent observations with the lowest values of output and 1.5 percent observations with the highest values of output are removed. After these deletions, the descriptive statistics for the original total data, as presented in Table 1, consists of 24,188 establishments for an unbalanced panel of 238,628 observations.

Table 1 shows that the minimum values of variables *lnY*, *lnL*, *lnK*, *lnM*, *lnE* for the original data are lower if compared to the minimum values of those variables from the balanced panel. This makes sense as the balanced panel data removes some observations during the adjustment process. The maximum values of those variables are higher in the original data compared to those in balanced panel data. The mean values of these five variables are higher in the balanced panel data compared to those in original data, while the standard deviations of these five variables are lower in balanced panel when compared to those in original data.

For *FDI_Firm*, the minimum value is zero and the maximum value is one both for original data and the balanced panel data, because this variable is a dummy variable. Further, the minimum value and the maximum value of variables *FDI_Sector*,

Table 1
Descriptive statistics for the original data and the balanced panel data.

	Original data[a]				Balanced panel data			
	Min	Max	Mean	SD	Min	Max	Mean	SD
Production Frontier								
lnY	6.461	20.980	12.514	2.256	6.591	20.761	13.964	2.006
lnL	2.398	10.649	4.079	1.327	2.639	10.292	4.702	1.088
lnK	4.105	23.398	12.308	2.268	4.220	23.106	13.152	2.245
lnM	3.871	20.033	11.765	2.418	4.239	19.454	12.164	2.221
lnE	1.791	16.583	9.377	2.221	1.882	15.836	9.587	2.077
FDI_Sector	0	1.492	0.208	0.218	0	1.492	0.234	0.209
Inefficiency Function								
FDI_Firm	0	1	0.064	0.273	0	1	0.072	0.258
FDI_Sector	0	1.492	0.208	0.218	0	1.492	0.234	0.209
FDI_Downstream_Sector	0.002	5.443	0.176	0.212	0.002	5.443	0.176	0.204
FDI_Upstream_Sector	0	0.921	0.160	0.181	0	0.921	0.160	0.174
Number of Establishments	24,188	24,188	24,188	24,188	3318	3318	3318	3318
Number of Observation	231,064	231,064	231,064	231,064	43,225	43,225	43,225	43,225

Source: Authors' calculations from the annual surveys of the Indonesian Central Board of Statistics (*Badan Pusat Statistik* or *BPS*).
Y = output, L = labour, K = capital, M = material and E = energy.
[a] The original data in this table exclude: (1) the establishments that do not report information on output, labour, capital, material, or energy; (2) 1.5 percent observations with the lowest values of output and 1.5 percent observations the highest values of output.

FDI_Backward, and FDI_Forward are the same for original data and for the balanced panel, as the calculation of these inter-industry variables is based on all firms in the original data as in Blalock and Gertler (2008). The mean values of these three spillover variables are higher in the balanced panel compared to those in the original data, whereas the standard deviations are lower in balanced panel. From the descriptive statistics in Table 1, the authors conclude that there is no substantial bias in the adjustment process since there is no substantial difference in the maximum value, minimum value, mean value, and standard deviation.

3.3. Measurement of variables

There are two sets of variables included in this study: production variables and inefficiency variables. The production variables consist of output, labour, capital, material, energy, time trend and *FDI_Sector*, while the inefficiency variables include FDI variables (*FDI_Firm*, *FDI_Sector*, *FDI_Upstream_Sector*, and *FDI_Downstream_Sector*), a year dummy, an industry dummy, and a firm dummy. The precise definition of each variable is given in Appendix 2.

In this study, gross output is used as the measure for output (y). It refers to the total value of output produced by a firm. The number of employees directly and indirectly engaged in production is used for the measure of labour (L). As a measure of capital (K), this study uses the replacement value of capital, while material (M) is measured using the total value of raw and intermediate materials and energy (E) is measured as the sum of electricity and fuel expenses.

FDI_Firm is measured by a dummy of foreign direct investment, which takes a value of one if a firm has a positive foreign ownership and takes a value of zero if otherwise. As a measure for the FDI horizontal spillovers, this study uses the share of foreign firm output to the total output at the five-digit ISIC sectoral level, which is expressed as in Aitken and Harrison (1999):

$$FDI\_Sector_{jt} = \frac{\sum_{i \forall i \in j} FDI\_Firm_{it} \times y_{it}}{\sum_{i \forall i \in j} y_{it}} \tag{9}$$

Eq. (9) captures the effect of FDI at the sectoral level on productivity at the firm level. It shows the spillover effects of foreign presence on domestic firms in the same five-digit ISIC industry.

Two alternative measures of FDI spillovers in this study are measures of inter-industry spillovers. The presence of foreign firms in certain five-digit ISIC industries may create productivity externalities for firms in upstream and downstream industries. This study measures the inter-industry spillovers by using variables that reflect the extent of backward and forward linkages between industries. Following Javorcik (2004), the measure for FDI spillovers from foreign firms in industries $k (k \neq j)$ that are being supplied by domestic firms in industries j is:

$$FDI\_Downstream\_Sector_{jt} = \sum_{k\, if\, k \neq j} \alpha_{jk} \times FDI\_Sector_{kt} \tag{10}$$

where α_{jk} is the proportion of sector j's output supplied to sector k, which is taken from the input–output (IO) matrix of four-digit industries.[4] Similarly, the measure for FDI spillovers from foreign firms in industries m whose products are bought by domestic firms in industries n is:

$$FDI\_Upstream\_Sector_{mt} = \sum_{n\, if\, n \neq m} \gamma_{mn} \times FDI\_Sector_{nt} \tag{11}$$

where γ_{mn} is the proportion of inputs purchased by industry n from industry m in total input sourced by industry n, which is taken from the input–output (IO) matrix of four-digit industries.

A time-trend variable is incorporated in the production function to measure technical change. The time-trend variable takes a value of one for the year 1988, a value of two for the year 1989, and so on. An industry dummy captures effects specific to a particular industry and has a value of one for an industry for an observation of that industry and a value of zero otherwise. A similar procedure is also applied to the firm dummy and year dummy variables.

4. Empirical results

We estimate a stochastic frontier estimation and first test for constant returns to scale to check whether the Cobb–Douglas production frontier is best suited to the data. Following the procedure of joint restriction test in Baltagi (2011, p. 80), the test of constant returns to scale is conducted under the null hypothesis that the sum of the estimated parameters (β_i) in

[4] During the selected period in this study, there are four available IO matrixes, which were published in 1990, 1993, 1995, and 2000. This study uses these four input-output matrixes for calculating the backward coefficient α_{jk}. The following is the procedure for obtaining values of α_{jk}. Values of α_{jk} before and including 1990 are taken from the 1990 IO matrix. Values of α_{jk} for 1991 and 1992 are linearly interpolated from the 1990 and 1993 IO matrixes. Values of α_{jk} for 1993 are taken from the 1993 IO matrix. Values of α_{jk} for 1994 are calculated from the linear interpolation of the 1993 and 1995 IO matrixes. Values of α_{jk} for 1995 are taken from the 1995 IO matrix. Values of α_{jk} from 1996 to 1999 are linearly interpolated from the 1995 and the 2000 IO matrixes. Finally, values of α_{jk} for 2000 are taken from the 2000 IO matrix.

production frontier in Eq. (5) is equal to one. The regression sum of squares for unrestricted model (RSS_U) is 39,631.63, whereas the regression sum of squared for restricted model (RSS_R) is 25,549.50. The *F*-statistics is 392.52, suggesting that the null hypothesis is rejected. This result confirms that the Cobb–Douglas production frontier is not the best suited model for the stochastic frontier estimation. Rather, as the sum of the coefficients of the input variables is greater than one, the unrestricted model with variable returns to scale is appropriate and is used below

4.1. Intra-industry spillovers

We begin with estimation of intra-industry spillovers. Using Eqs. (5) and (6), the production frontier and the inefficiency function are estimated simultaneously for observing the effects of foreign investment on the production frontier and technical efficiency of firms. For the inefficiency function, the technical efficiency variable (u_{it}) is specified as a function of a foreign share dummy (*FDI_Firm*), the share of foreign firms' outputs over total outputs in the four-digit industry (*FDI_Sector*), and an interacting term between *FDI_Firm* and *FDI_Sector*. When foreign investment increases the firm's technical efficiency, the coefficient of *FDI_Firm* is negative.[5] When technology spills over from firms with foreign direct investment to purely domestic firms in the same industry, the coefficient of *FDI_Sector* is negative. As for the interaction term, the sign of the coefficient shows whether or not foreign direct investment affects the firm's ability to benefit from spillovers originating from other foreign-owned firms in the same industry.

We estimate four alternative models in order to test the robustness of the estimated parameters. In the first model, a year dummy and an industry dummy are included in the inefficiency equation. The estimated parameters are presented in the Model (1) column of Table 2. The results from the production frontier show that the four input variables contribute positively and significantly to output, suggesting a positive elasticity of each input on output. There is also a positive and statistically significant coefficient of the time-trend variable indicating that technical change contributes positively to output. The positive and statistically significant coefficient of *FDI_Sector* suggests horizontal spillovers from intra-industry foreign direct investment increase the production frontier for all firms.

From the estimates of the inefficiency function, which is the main focus of this study, the coefficient of *FDI_Firm* is negative and highly significant, indicating that foreign direct investment decreases the firm's technical inefficiency. This suggests that firms with foreign ownership are, on average, more efficient than purely domestic firms. This finding confirms the argument in Caves (1971) and Dunning (1988) that foreign firms are more likely to operate on the production frontier. Furthermore, the negative and statistically significant estimate of *FDI_Sector* suggests that knowledge spills over from foreign-owned firms increases the technical efficiency of all firms in the industry. This result is in line with the argument in Wang and Blomstrom (1992) and findings in Ghali and Rezgui (2008). This result is also consistent with findings in Takii (2005), Temenggung (2007) and Blalock and Gertler (2008), which use different methods of analysis.

The positive significant estimate of interacting term means that, although the foreign-owned firms also benefit from the presence of other foreign investment in the industry, the benefit is smaller than for domestic firms. Given that the estimated coefficient of *FDI_Firm* and the estimated coefficient of *FDI_Sector* are negative and statistically significant, the positive coefficient of the interaction term means that $u_{it}/FDI\_Firm = -0.5763 + 0.0330 \times FDI\_Sector$ and that $u_{it}/FDI\_Sector = -0.2224 + 0.0330 \times FDI\_Firm$. As both *FDI_Firm* and *FDI_Sector* are each always less than or equal to one by construction, the net effect of *FDI_Sector* is negative for all foreign firms as well as domestic firms. However, the magnitude of the improvement in efficiency from having foreign firms in the industry is always greater for domestic firms than for foreign firms.

In addition, we conduct joint significance test (*F*-test) on the magnitude of spillovers for foreign establishments in order to check significance of the direct effect and the interacting effect of spillovers on foreign firms.[6] The value of *F*-statistic is calculated from the log-likelihood value of the unrestricted model and the log likelihood value of the restricted model (when both the coefficient of *FDI_Sector* and the coefficient of interacting variable *FDI_Firm* × *FDI_Sector* equal to zero). The value of log likelihood for the unrestricted model is 7704.48, whereas the value of log likelihood for the restricted model is 7643.00, So that, the *F*-statistic is 13.22, which suggests that the unrestricted model (by including variables *FDI_Sector* and interacting variable *FDI_Firm* × *FDI_Sector*) is the correct model and the two variables are jointly significant affecting spillovers on foreign establishments at 1% level.

The estimated coefficient of year dummy is not statistically significant, suggesting that on average there is no significant difference in technical inefficiency scores of firms across the sample years. The statistically significant estimated coefficient of industry dummy suggests that there is a significant difference in inefficiency scores across five-digit industries.

The highly significant estimate of gamma implicates that estimation of stochastic frontier should include an inefficiency effect. This finding provides the justification for the simultaneous estimation of stochastic production frontier and inefficiency equation. In other words, the model is appropriately representing the observed firms.

In the second model, industry dummies are replaced by firm dummies, in order to control for firm heterogeneity across the sample. The results are given in the Model (2) column of Table 2. The sign and significance of estimates are similar to

[5] The dependent variable for the inefficiency function is technical inefficiency. The negative coefficient of *FDI_Firm* indicates that foreign investment decreases inefficiency, which implies an increase in the firm's efficiency.

[6] We are grateful to one of the reviewers for suggesting this point.

Table 2
Estimating intra-industry spillovers.

Variables	Model (1)	Model (2)	Model (3)	Model (4)
Production frontier				
lnL	0.2227*** (0.0033)	0.2256*** (0.0031)	0.2197*** (0.0030)	0.2167*** (0.0031)
lnK	0.1018*** (0.0019)	0.1043*** (0.0017)	0.1023*** (0.0018)	0.1097*** (0.0012)
lnM	0.6263*** (0.0018)	0.6218*** (0.0018)	0.6223*** (0.0017)	0.6191*** (0.0022)
lnE	0.1128*** (0.0017)	0.1160*** (0.0017)	0.1165*** (0.0017)	0.1176*** (0.0016)
T	0.0007* (0.0005)	0.0039** (0.0006)	0.0066*** (0.0028)	0.0012*** (0.0003)
FDI_Sector	0.1224*** (0.0055)	0.2044*** (0.0065)	0.2687*** (0.0096)	0.1577*** (0.0065)
Inefficiency function				
FDI_Firm	−0.5763*** (0.0264)	−0.1550*** (0.0018)	−0.1960*** (0.0104)	−0.2362*** (0.0092)
FDI_Sector	−0.2224*** (0.0896)	−0.2000*** (0.0149)	−0.1780*** (0.0027)	−0.1819*** (0.0034)
FDI_Firm × *FDI_Sector*	0.0330*** (0.0028)	0.0460*** (0.0036)	0.1035** (0.0184)	0.0673*** (0.0086)
Year Dummy	−0.0002 (0.0031)	−0.0010 (0.0009)	−0.0010 (0.0019)	–
Industry Dummy	−0.0039* (0.0008)	–	–	–
Firm Dummy	–	−0.0001** (0.0000)[a]	–	–
Sigma-squared	0.0416*** (0.0010)	0.0416*** (0.0005)	0.0413*** (0.0003)	0.0418*** (0.0003)
Gamma	0.0380*** (0.0038)	0.0224*** (0.0083)	0.0086*** (0.0002)	0.0151*** (0.0020)
Log-likelihood	7704.484	7759.086	7618.974	7572.755
Number of Observations	43,225	43,225	43,225	43,225

Source: Authors' calculations.
Notes: Y = output, L = labour, K = capital, M = material, E = energy, T = time trend. Standard errors are in parentheses.
[a] The estimated standard error is 0.000009.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

those in the first model. The notable difference is only in the magnitude of the estimates. Focusing on the FDI variables, the magnitudes of coefficients are smaller in this second model compared to those in the first model. In other words, the inclusion of firm dummy and the exclusion of industry dummy in the second estimation (Model 2) results in a smaller effect of FDI spillovers on technical inefficiency. This is not surprising. Firm-specific effects are largely captured by the firm dummy, which removes a potential source of bias in the estimates of other coefficients. Notably, the results regarding the direction of spillover effects are the same as in the first model, as the coefficient of *FDI_Sector* is negative and statistically significant in both models.

For the third model, only a time dummy is included as a controlling variable in the estimation. The resulting estimates, which are presented in the Model (3) column, are very comparable with the results in Model (1) and Model (2). Similar findings are also observed in Model (4), when the time dummy, industry dummy and firm dummy and are all excluded from estimation. The results from these four models confirm the robustness of the estimates of the positive spillovers from FDI on the technical efficiency of domestic firms.

4.2. Inter-industry spillovers

Besides the effects on domestic firms in the same industry, FDI can also generate spillovers on domestic firms in other industries. We estimate six models of the inter-industry spillovers, and the results of each model are presented in Table 3. The first three models are estimated on the full sample and the last three models are estimated on the sub-sample of only domestic firms. In the three full-sample models, the first model is to capture the simultaneous effect of the three spillover variables on technical inefficiency. The second and the third model focus on the individual effect of each of the vertical FDI spillovers (i.e. the downstream spillover and the upstream spillover). The same structure is also applied to the sub-sample of only domestic firms, with Model 4 captures the simultaneous effect of the three spillover variables, Model 5 captures the downstream effect only, and model 6 captures only the upstream effect.

In the first model (the first results column of Table 3), the three proxies of spillover variables are included in the estimations. The results show that the horizontal spillover variable (*FDI_Sector*) has a negative and statistically significant coefficient, suggesting that an increase in the share of foreign firm output decreases technical inefficiency across firms in the industry. Similarly, the spillovers from FDI in downstream industries also decrease inefficiency of suppliers, as demonstrated by the negative and highly significant coefficient of the backward spillover variable (*FDI_Downstream_Sector*). In addition, the coefficient of the forward spillover variable (*FDI_Upstream_Sector*) is negative and highly significant, indicating a negative relationship between FDI in supplier industries and the industry's own technical inefficiency. Although we employ a different methodology and use a different data set, the findings are similar to those in Liang (2007).

In the second and the third models (the second and the third columns of Table 3), the impacts of backward spillover variable and the forward spillover variable are estimated separately. In each model, the magnitude of the coefficient of the included spillovers variable is larger than in Model 1, but neither the sign nor the statistical significance of the coefficient changes. Clearly, there is multi-colinearity among the spillovers variables that makes the identification of separate effects

Table 3
Estimating inter-industry spillovers.

Variables	Full sample (1)	Full sample (2)	Full sample (3)	Domestic sample (4)	Domestic sample (5)	Domestic sample (6)
Production frontier						
lnL	0.2264*** (0.0030)	0.2209*** (0.0030)	0.2197*** (0.0029)	0.2258*** (0.0012)	0.2238*** (0.0033)	0.2256*** (0.0033)
lnK	0.1007*** (0.0018)	0.1023*** (0.0018)	0.1019*** (0.0018)	0.0986*** (0.0018)	0.0999*** (0.0022)	0.0981*** (0.0019)
lnM	0.6255*** (0.0018)	0.6271*** (0.0018)	0.6268*** (0.0017)	0.6225*** (0.0014)	0.6236*** (0.0020)	0.6229*** (0.0017)
lnE	0.1117*** (0.0017)	0.1144*** (0.00170)	0.1159*** (0.0016)	0.1217*** (0.0014)	0.1226*** (0.0018)	0.1227*** (0.0018)
T	0.0002** (0.0000)[a]	0.0028* (0.0013)	0.0004*** (0.0001)	0.0009** (0.0006)	0.0021** (0.0001)	0.0010*** (0.0002)
FDI_Sector	0.0375*** (0.0013)	0.0308*** (0.0038)	0.0217*** (0.0007)	0.0056*** (0.0007)	0.0572*** (0.0035)	0.0323*** 0.0064
Inefficiency function						
FDI_Firm	−0.2945*** (0.0137)	−0.3920*** (0.0393)	−0.1257*** (0.0130)	–	–	–
FDI_Sector	−0.1901*** (0.0061)	–	–	−0.2766*** (0.0275)	–	–
FDI_Downstream_Sector	−0.0216*** (0.0021)	−0.0715*** (0.0043)	–	−0.0279*** (0.0047)	−0.0548*** (0.0027)	–
FDI_Upstream_Sector	−0.0462*** (0.0060)	–	−0.1842*** (0.0097)	−0.0682*** (0.0175)	–	−0.3067*** (0.0214)
Year Dummy	−0.0018* (0.0006)	−0.0050* (0.0017)	−0.0017** (0.0003)	0.0011*** (0.0002)	0.0046** (0.0005)	0.0002*** (0.0010)
Firm Dummy	−0.0000[b]*** (0.0000)[c]	−0.0000[d]*** (0.0000)[e]	−0.0000[f] *** (0.0000)[g]	−0.0001*** (0.0000)[h]	−0.0001** (0.0000)[i]	−0.0001*** (0.0000)[j]*
Sigma-squared	0.0401*** (0.0003)	0.0416*** (0.0003)	0.0405*** (0.0003)	0.0411*** (0.0007)	0.0418*** (0.0001)	0.0405*** (0.0004)
Gamma	0.0194*** (0.0013)	0.0417*** (0.0040)	0.0124*** (0.0008)	0.0612*** (0.0111)	0.0709*** (0.0019)	0.0561*** (0.0045)
Log-likelihood	7849.487	7668.081	7750.109	8118.497	8001.479	8040.274
Number of Observations	43,225	43,225	43,225	40,042	40,042	40,042

Source: Authors' calculations.

Notes: Y = output, L = labour, K = capital, M = material, E = energy, T = Time trend. Actual estimates are [a] 0.00004, [b] 0.000034, [c] 0.0000017, [d] 0.000034, [e] 0.0000019, [f] 0.000034, [g] 0.0000014, [h] 0.0000024, [i] 0.000012, [j] 0.0000035. Standard errors are in parentheses.

* Significant at the 10% level.

** Significant at the 5% level.

*** Significant at the 1% level.

Table 4
Estimating intra-industry spillovers in high-efficiency and low-efficiency firms.

Variables	Full sample		Domestic sample	
	High-efficiency firms (1)	Low-efficiency firms (2)	High-efficiency firms (3)	Low-efficiency firms (4)
Production frontier				
lnL	0.2049*** (0.0047)	0.2258*** (0.0040)	0.2372*** (0.0018)	0.2012*** (0.0038)
lnK	0.1080*** (0.0032)	0.0985*** (0.0024)	0.1025*** (0.0024)	0.0911*** (0.0021)
lnM	0.6038*** (0.0023)	0.6634*** (0.0027)	0.5883*** (0.0036)	0.6900*** (0.0026)
lnE	0.1316*** (0.0027)	0.0835*** (0.0023)	0.1429*** (0.0013)	0.0791*** (0.0018)
T	0.0021** (0.0009)	0.0001** (0.0000)[b]	0.0022*** (0.0004)	0.0064*** (0.0003)
FDI_Sector	0.0940*** (0.0058)	0.0492** (0.0141)	0.0849*** (0.0032)	0.0727** (0.0133)
Inefficiency function				
FDI_Firm	−0.0617*** (0.0088)	−0.0096* (0.0063)	–	–
FDI_Sector	0.0742*** (0.0062)	−0.0556*** (0.0035)	0.0657*** (0.0038)	−0.0660*** (0.0115)
Year Dummy	0.0020* (0.0014)	−0.0027*** (0.0007)	0.0029*** (0.0004)	0.0015*** (0.0001)
Firm Dummy	0.0001*** (0.0000)[a]	0.0001*** (0.0000)[c]	0.0001*** (0.0000)[d]	0.0000[e]** (0.0000)[f]
Sigma-squared	0.0425*** (0.0004)	0.0382*** (0.0004)	0.0414*** (0.0005)	0.0341*** (0.0006)
Gamma	0.0369*** (0.0043)	0.0151*** (0.0023)	0.0540*** (0.0036)	0.0746*** (0.0019)
Log-likelihood	3493.823	4697.164	3597.36	5417.533
Number of Observations	21,612	21,613	20,021	20,021

Source: Authors' calculations.
Notes: *Y* = output, *L* = labour, *K* = capital, *M* = material, *E* = energy and T = time trend Actual estimates are: [a] 0.0000042, [b] 0.000037 [c] 0.000005 [d] 0.0000076, [e] 0.000018, [f] 0.0000066. Standard errors are in parentheses.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

difficult. The coefficient of the *FDI_Downstream_Sector* being negative and statistically significant at the 1% level in both Model 1 and Model 2, indicates a robust finding that the foreign entry in a three-digit industry decreases the technical inefficiency of domestic suppliers (i.e. positive backward spillovers). Similarly, the negative and statistically significant coefficient of the *FDI_Upstream_Sector* in both Model 1 and Model 3 indicates a robust finding that the presence of foreign firms in a three-digit industry decreases the inefficiency of domestic buyers (i.e. positive forward spillovers).

To isolate the spillover effects on only domestic firms, we estimate the Models 1 through 3 for the sub-sample of only domestic firms. The estimation results are presented in the fourth through sixth result columns in Table 3. The results are similar to those for the full sample of firms in terms of the signs and significance of the coefficients. However, it is notable that the coefficients for the spillovers variables in the domestic firm sample are generally of larger magnitude than the corresponding coefficients for the full sample. This provides further evidence to support that from the results in Table 2 showing that spillovers from foreign firms are more beneficial for purely domestic owned firms than for firms with direct foreign investment.

Given the results from Table 3, we conclude that the spillover effects from FDI decrease technical inefficiency of domestic firms in upstream and downstream industries. These findings confirm the argument in Javorcik (2004) that a foreign presence in a domestic market may generate not only spillover effects on domestic firms in the same industry but also provide spillover benefits to domestic firms in the upstream and downstream industries.

4.3. Spillover effects and the level of technical efficiency

So far, the analysis pools together all firms with different levels of efficiency. It has advantage of showing the average effect of FDI spillovers on a firm's technical efficiency. However, it has a disadvantage in that the spillover effects are assumed to be uniform for all firms. Thus, the analysis does not clearly distinguish which firms gain the most spillover effect from FDI.

In this section, the analysis is extended to answer a question of whether the level of efficiency influences the ability of firms in absorbing spillover benefits. The firms are divided into two groups: firms with a high-efficiency level and those with a low-efficiency level. The procedure to group the firms is by sorting the firms from the one with the highest technical efficiency level to the firm with the lowest efficiency level, and then the sorted firms are divided into two. The upper half of the data is categorized as the high-efficiency firms and the lower half is the low-efficiency firms. The estimation results for these two groups of firms are presented in Table 4. We estimate results for the full sample of firms as well as for the sub-sample of only domestic firms.

Starting from the full sample estimations, the coefficient of *FDI_Firm* is negative and statistically significant both among high-efficiency firms (column 1 of Table 4) and among low-efficiency firms (column 2), suggesting that foreign-owned firms have a higher technical efficiency level in both groups of firms. The positive and significant coefficient of *FDI_Sector* demonstrates that spillovers at the industrial level increase the inefficiency of the firms (i.e. a negative efficiency spillover). In contrast, the low-efficiency firms experience a decrease in technical inefficiency when foreign firms are more important in the industry (i.e. a positive efficiency spillover), as indicated by a negative and highly significant coefficient of *FDI_Sector* (column 2).

The coefficients of *FDI_Sector* for the sub-sample of only domestic firms (columns 3 and 4) are of the same sign and significance as in the corresponding full sample estimation, but the magnitude of impact is somewhat lower in the domestic firm sub-sample. This suggests that FDI spillovers have smaller impact on domestic firms than on foreign firms in industries with large technology gaps.

The results in Table 4 demonstrate that firms with different efficiency levels may receive different effects of FDI spillovers. High-efficiency firms tend to obtain negative spillover effects, while low-efficiency firms experience positive spillover effects. These findings confirm the argument that there is advantage from being less advanced in terms of efficiency in terms of benefitting from spillovers (Glass & Saggi, 1998; Wang & Blomstrom, 1992) and are consistent with the results in Griffith et al. (2002), Castellani and Zanfei (2003), and Peri and Urban (2006).

5. Conclusion

This article empirically examines the spillover effects of FDI on firm technical efficiency in the Indonesian manufacturing sector for the period between 1988 and 2000. Using the framework of Battese and Coelli's (1995) stochastic production frontier, we find evidence of a positive spillover effect of FDI to firms in the same industry (competitors), firms in an upstream industry (suppliers), and firms in a downstream industry (buyers). The positive spillover effect is observed in both the estimation for the full sample of firms and the estimation for the sub-sample of only domestic firms. Notably, the effects on domestic firms are generally more powerful than on other foreign firms in the same industry.

An interesting finding emerges when the samples are divided into two groups based on the level of efficiency. It is found that the low-efficiency firms receive a positive spillover effect from FDI across firms in the same industry. In contrast, the high-efficiency firms obtain a negative spillover effect. These findings support the argument of the advantage for absorbing spillovers goes to firms that are less advanced in terms of efficiency.

Outcomes from this study provide support on policies that encourage FDI. On the basis of these findings, policy makers should continue providing an FDI-friendly environment in order to maximize the spillover gains. Additional incentives may be provided for foreign firms that are willing to transfer their knowledge to domestic firms, especially those domestic firms in upstream and downstream industries that do not directly compete with the foreign firm. Variations in incentives may need to be considered, with more focus on FDI in sectors where purely domestic firms have a low-efficiency level compared to firms with direct foreign investment.

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Appendix 1. Adjustments for constructing a consistent panel data

The steps of adjustment for constructing a consistent panel data are described as follows:

Step 1: Adjustment for industrial code.

The BPS reclassified the industrial codes twice: in 1990 and in 1998. This study adjusts the industrial codes to the 1990 code (KKI-1990) in order to obtain a consistent industrial code for the observation years (1988–2000). This adjustment involves two phases. First, the data from 1988 to 1989 (which use KKI-1985) are adjusted to KKI-1990 using the establishment identification code and a special map provided by the BPS. Observations in 1988–1989 not observed in 1990–1998 are removed, since there is no code from KKI-1990 that could be assigned to these observations. This first phase of adjustment removes 1346 out of the original 29,340 establishments. Second, the data from 1998 to 2000 (which use KKI-1998) are adjusted to KKI-1990 by the following concordance table provided by the BPS. There are several concordance issues that arise during this second phase of adjustment, which include unmatched classifications and incomplete entries. An example of an incomplete entry is an observation recorded only with a two-, three-, or four-digit classification code. For dealing with this problem, only observations with four-digit classification codes are retained, while those with two- and three-digit classification codes are removed. The retained observations with four-digit codes are then assigned as five-digit codes using the establishment specific identification code. By doing so, all establishments in the 1988–2000 panel data have consistent and integrated classification codes. The total establishments removed after these industrial code adjustments are 3078 out of 29,340 establishments, which include those with Oil and Gas classification (ISIC 353 and 354) as these sub-sectors are not observed in the 1988 and 1989 surveys.

Step 2: Adjustment for the variable definitions.

In some years, the variable definitions provided by the BPS are not consistent, even though the variables are the same. The author compared the variable definitions in each year's survey questionnaires (which are provided by the BPS together with the SI data) and recalculated the inconsistent variables for obtaining consistent definitions throughout the selected period.

Step 3: Cleaning for noise and typographical errors.

This study applied several steps for data cleaning in order to minimize noises and typographical errors:

a. Observations with zero or a negative value of output, labour, material, or energy have been removed. This removes around 4.5 percent of the total observations.
b. If a firm reports a missing value for a particular variable in a given time but reports values in the year before and after, an interpolation is carried out to fill the gap. The interpolation for the missing data was not more than 1 percent of the total observations.
c. Typographical errors (or key-punch errors) in the raw data are adjusted for consistency. For example, if in the raw data, foreign share in a firm for the whole of the selected period was typed as 100 percent, except for a certain year being typed as 0 percent, then the 0 percent share is adjusted to 100 percent.
d. Observations that are considered as outliers are removed from the data set by following a procedure suggested by Takii (2005). First, observations are sorted from the lowest to the highest value of output. Second, 1.5 percent of the lowest values and 1.5 percent of the highest values are removed.

Step 4: Back-casting the missing values of capital.

In some years, the values of capital are missing for quite a large number of observations. To fill these gaps, this study follows the methodology introduced by Vial (2006).

Step 5: Matching firms for a balanced panel

A balanced panel data set is constructed for the selected period by matching firms based on the specific identification code (PSID). This study utilizes STATA10 software for the matching.

Step 6: Choosing Industries with Foreign Firms

Since the purpose of the study is to estimate the FDI spillovers, industries (at a five-digit level) without foreign firms are excluded from the balanced panel.

Step 7: All monetary variables (output, capital, material, and energy) are deflated using price indexes. The output and material values are deflated using the wholesale price index (for four-digit ISIC industries); the machinery price index is used for deflating the value of capital; the nominal values of energy, which are a sum of electricity and fuel expenditures, are deflated using the electricity price index and the fuel price index. All price indexes are at a constant price of the year 1993.

By following the steps of adjustment, the final balance panel data consists of 3318 establishments with 43,225 observations.

Appendix 2. Definitions of variables

Symbol	Category	Unit	Definitions
Production frontier			
Y	Output	Million of 1993 rupiah	Gross output, which is deflated using a wholesale price index of four-digit ISIC industries at a constant price of 1993
L	Labour	Number of workers	Total number of employees directly and indirectly engaged in production, which covers all workers, including technical, administration, marketing, storage, and clerical staffs, who work full-time or part-time, and also family members.
K	Capital	Million of 1993 rupiah	Replacement value of fixed assets, which is deflated using a wholesale price index for machinery of four-digit ISIC industries at a constant price of 1993.
M	Material	Million of 1993 rupiah	Total value of material used in production, which cover raw and intermediate materials, both domestically produced and imported deflated using a wholesale price index of four-digit ISIC industries at a constant price of 1993.
E	Energy	Million of 1993 rupiah	Total value of electricity and fuel used by a firm. The value of electricity is calculated from the electricity provided by the state energy company (*Perusahaan Listrik Negara* or PLN) and those provided by private power firms, and it is deflated using the wholesale electricity index at a constant price of 1993. The value of fuels are calculated from nine types of fuels, namely premium, solar, kerosene, coal, cokes, gas, firewood, lubricant, and other fuels, and it is deflated using the OECD price of fuels published by *DX for Windows* at the 1993 constant price.
T	Time trend		Take a value of one for 1988, value of two for 1989, and so on.
FDI_Sector	FDI Variable	Ratio	The share of foreign firms' output over total outputs in a five-digit industry, or can be expressed as in Eq. (5). This variable measures the intra-industry (or horizontal) spillovers.
Inefficiency function			
FDI_Firm	FDI variable	Binary (one or zero)	The FDI at the firm level, which takes a value of one if a firm has a positive foreign ownership and take a value of zero if otherwise.
FDI_Sector	FDI variable	Ratio	The share of foreign firms' output over total outputs in a five-digit industry, or can be expressed as in Eq. (5). This variable measures the intra-industry (or horizontal) spillovers.
FDI_Downstream_Sector	FDI variable	Ratio	Spillovers from foreign firms in industries k ($k \neq j$) that are being supplied by domestic firms in industries j is defined as in Eq. (6).

Appendix 1 (*Continued*)

Symbol	Category	Unit	Definitions
FDI_Upstream_Sector	FDI variable	Ratio	Spillovers from foreign firms in industries m ($m \neq n$) that sell their outputs to domestic firms in industries n is defined as in Eq. (6).
Year	Dummy variable		A year dummy, which takes a value of one for all observations for the year in question,and a value of zero for other years.
Industry	Dummy variable		An industry dummy, which has a value of one for all observations for the industry in question and a value of zero for other industries.
Firm	Dummy variable		A firm dummy, which has a value of one for all observations for the firm in question and a value of zero for every other.

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Abstract

Despite growing concern regarding the productivity benefits of foreign direct investment (FDI), very few studies has been conducted on the impact of FDI on firm-level technical efficiency. This study helps fill this gap by empirically examining the spillover effects of FDI on the technical efficiency of Indonesian manufacturing firms. A panel data stochastic production frontier (SPF) method is applied to 3,318 firms surveyed over the period 1988-2000. The results reveal evidence of positive FDI spillovers on technical efficiency. Interesting differences emerge however when the samples are divided into two efficiency levels. High-efficiency domestic firms receive negative spillovers, in general, while low-efficiency firms gain positive spillovers. These findings justify the hypothesis of efficiency gaps, that the larger the efficiency gap between domestic and foreign firms the easier the former extracts spillover benefits from the latter.

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Scopus coverage years: 1990-on going. CiteScore 1,07 and SJR 0,508. Journal Rank #199/533 untuk kategori Economics and Econometrics dan #68/216 untuk kategori Finance. Telah dilakukan cek similarity. Tulisan baik dengan penekanan pada keseluruhan perusahaan manufaktur di Indonesia yang disurvey oleh BPS. Kontribusi utama terletak pada cakupan data yang komprehensif dan analisis yang mencakup dampak dalam industri dan antar industri. Matriks input-output dipergunakan sebagai patokan evaluasi inter-industri spillovers.

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LEMBAR
HASIL PENILAIAN SEJAWAT SEBIDANG ATAU *PEER REVIEW*
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	Total = (100%)	**40**	---	---	23,1
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Cek web Scopus: journal coverage years 1990 – on going, Cite Score 2016 sebesar 1.07 dan Scimago Journal Ranking 0.508. Penerbit Elsevier berlokasi Kiddlington, Oxford, UK. Sudah similarity check dengan Turnitin. Kualitas tulisan baik. Referensi cukup up-to-date. Tulisan kemungkinan merupakan kelanjutan dari tulisan sebelumnya di Journal of Development Studies (2012) dengan pengembangan pada cakupan data observasi sejumlah 43.225 observasi, jauh lebih besar daripada penelitian sebelumnya. Inter-industri spillovers dimunculkan untuk memperlihatkan keterhubungan pengaruh antar industri. Kontribusi tambahan berupa adanya estimasi terhadap perusahaan dengan efisiensi tinggi dan perusahaan dengan efisiensi rendah.

Surabaya, 14 Juni 2016
Reviewer 2

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Which Firm Benefit From Foreign Direct Investment? Empirical Evidence From Indonesian Manufacturing

by 4 Suyanto

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Which firms benefit from foreign direct investment? Empirical evidence from Indonesian manufacturing

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ABSTRACT

Despite growing concern regarding the productivity benefits of foreign direct investment (FDI), very few studies have been conducted on the impact of FDI on firm-level technical efficiency. This study helps fill this gap by empirically examining the spillover effects of FDI on the technical efficiency of Indonesian manufacturing firms. A panel data stochastic production frontier (SPF) method is applied to 3318 firms surveyed over the period 1988–2000. The results reveal evidence of positive FDI spillovers on technical efficiency. Interesting differences emerge however when the samples are divided into two efficiency levels. High-efficiency domestic firms receive negative spillovers, in general, while low-efficiency firms gain positive spillovers. These findings justify the hypothesis of efficiency gaps, that the larger is the efficiency gap between domestic and foreign firms the easier the former extracts spillover benefits from the latter.

1. Introduction

The spillover effects of foreign direct investment (FDI) have been a major concern for researchers and policy makers during the last two decades. A number of studies have examined the spillover effects of FDI on domestic firm productivity (Chakraborty & Nunnenkamp, 2008; Haddad & Harrison, 1993; Hu & Jefferson, 2002; Javorcik, 2004; Liang, 2007; Negara & Firdausy, 2011; Takii, 2005, 2011). These studies provide some useful insights regarding the evidence of the spillover benefits and offer some recommendations to maximize the benefits. However, most existing studies exclude technical efficiency and focus mainly on technology, ignoring that the FDI presence in host countries is the impetus for efficiency improvement through competition and demonstration effects (Wang & Blomstrom, 1992). A study of FDI spillover effects on firm-level technical efficiency is important to provide evidence as to whether the large amount of FDI inflows generate positive externalities to domestic firms through efficiency improvement, thus indicating whether the spillover hypothesis is justified in the context of technical efficiency. Such a study can explore to what extent FDI can induce efficiency spillovers, and which firm types really benefit from the spillovers.

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Among the developing economies, Indonesia is particularly successful in attracting FDI. Net FDI inflows to Indonesia have risen more than 30 times since 1986, reaching a record level of US$8.3 billion in 2008 (the Central Bank of Indonesia, 2011). However, there is a dearth of research on efficiency spillovers in Indonesia. Most empirical studies examine spillover effects under a framework of the long-run equilibrium production function, which assumes that firms are producing at a full efficiency level. Under this framework, the FDI spillovers on technical efficiency are not captured.

Two previous studies by the authors focus on technical efficiency using a stochastic production frontier framework for individual Indonesian manufacturing industries. Suyanto, Salim, and Bloch (2009) examine the pharmaceutical and chemical industries, while Suyanto et al. (2012) examine the electronic and garment industries. However, there are no studies providing comprehensive results for the whole Indonesian manufacturing sector using a stochastic framework.

A study by Temenggung (2007) examines the whole Indonesian manufacturing sector. Our current research differs from Temenggung in three important points. Firstly, Temenggung applies the ordinary least squared (OLS) regression method for panel data, which doesn't distinguish between fixed effects (FE) and random effects (FE). Secondly, the classical production function, employed in Temenggung (2007), assumes that all firms are fully efficient, so that the spillover effects of FDI reflect technological progress. In contrast, the current paper employs the stochastic production frontier, which relaxes the assumption of full efficiency of firms, so that both technological progress and efficiency improvement are examined. Thirdly, we calculate the scores of technical efficiency of each firm and estimates spillover effects separately for high-efficiency and low-efficiency firms, providing a useful insight into the differences in the ability of high-efficiency and low-efficiency firms in absorbing spillover effects from FDI.

This study contributes to the existing literature in several ways. Firstly, it examines the spillover hypothesis by focusing on technical efficiency, an important aspect that is often neglected in the previous studies. The adoption of a stochastic production frontier allows the authors to investigate the effects of FDI spillovers on firm-level technical efficiency. Secondly, this study covers a long series of surveyed firms, which includes also the period of the Asian crisis onwards. Thirdly, this study evaluates horizontal, backward, and forward spillovers of FDI. Most importantly, by examining the whole manufacturing sector, it is possible to identify characteristics of industries that affect the size of the technology and efficiency spillovers to domestic firms from FDI. In particular, we find evidence that the size of the technology gap between foreign and domestic firms is critical, with larger efficiency gaps associated with greater efficiency spillovers from FDI.

We proceed by reviewing the concept of spillover effects in the next section. We then discuss methodology and data. Empirical results are presented in Section 4 and the conclusions are given in the final section.

2. FDI, spillover effects, and technical efficiency: theoretical concept and empirical evidence

2.1. *FDI and spillover effects*

Foreign direct investment is believed to provide host countries with direct and indirect benefits. The direct benefits take the forms of new investments that boost national income, increase tax revenues, and provide new employment; whereas the indirect benefits are in the forms of externalities that are generated through non-market mechanisms to recipient economies and domestic firms within the economies (Hymer, 1960). These indirect benefits are commonly known as FDI spillovers.

The literature identifies at least three types of FDI spillovers. These are productivity spillovers, market-access spillovers, and pecuniary spillovers. Productivity spillovers are defined as the externalities from FDI that lead to increases in the productivity of domestic firms (Aitken & Harrison, 1999). Market-access spillovers exist when the presence of FDI generates an opportunity for domestic firms to access international markets (Blomstrom & Kokko, 1998). Pecuniary spillovers happen if the existence of FDI affects the profit functions of domestic firms through a reduction in costs or an increase in revenues (Gorg & Strobl, 2005).

Of the three types of FDI spillovers, productivity spillovers have been a particular concern among policy makers and researchers in the last two decades. Various incentives have been provided by policy makers to attract FDI and substantial efforts have been devoted by researchers to evaluate the productivity advantage. However, the empirical evidence is mixed at best. Some studies find evidence of positive productivity spillovers (Caves, 1974; Javorcik, 2004; Kugler, 2006; Schiff & Wang, 2008; Temenggung, 2007), but others discover nonexistent or even negative spillovers (Aitken & Harrison, 1999; Blalock & Gertler, 2008; Djankov & Hoekman, 2000). Thus, the relationship between FDI spillovers and firm productivity remains a controversial issue.

2.2. *Spillover effects and firm-specific characteristics*

Some researchers argue that the mixed evidence intuitively implies that the spillover effects are not an automatic consequence of the foreign presence in an economy, rather they depend significantly on the characteristics of firms in the industries (Gorg & Greenaway, 2004; Lipsey & Sjoholm, 2005; Smeets, 2008). One important characteristic of firms is the technology gap between foreign and domestic firms. In a study on UK manufacturing firms, Griffith, Redding, and Simpson (2002) find that the wider the technology gap the larger the FDI spillover effects that are obtained by domestic firms. This finding indicates a benefit of being less advanced in terms of technology, which supports the theoretical argument in Findlay (1978). A similar result is discovered also by Castellani and Zanfei (2003) for France and Spain, and by Peri and Urban (2006) for Italy and Germany.

Although there is an advantage in being less advanced, the technology gap should not be too wide (Wang & Blomstrom, 1992). A minimum level of technology is required for domestic firms to absorb the new technology from foreign firms. When the gap is too wide, the limited kind absorptive capacity of domestic firms may not permit assimilation the new technology (Glass & Saggi, 1998).

2.3. Technical efficiency gains from FDI spillovers

Earlier studies on FDI productivity spillovers focus on technology advantages (Gorg & Greenaway, 2004). The knowledge from foreign firms is regarded synonymously with technological knowledge, as this is consistent with the use of a conventional production function. Managerial and organizational knowledge that may lead to efficiency spillovers are not portrayed since firms are assumed to be producing at the long-run equilibrium with a full efficiency capacity. Thus, the productivity spillovers in these early studies are identically measured as technology spillovers.

More recent studies focus on both efficiency and technology advantages. In these studies, knowledge is defined broadly as product, process, managerial, and organizational knowledge. Hence, productivity spillovers lead to both technology and efficiency advantages. Unfortunately, studies that investigate efficiency advantages are not plentiful. In a study on Greek manufacturing firms, Dimelis and Lauri (2002) examine the effect of foreign equity shares on efficiency and find a positive relationship between these two variables. Also, Ghali and Rezgui (2008) analyze the Tunisian manufacturing sector and find that higher foreign share increase firm efficiency. Addressing the same issue but employing a different estimation method, our study investigates the efficiency spillovers in Indonesian manufacturing firms. We extend the studies by Dimelis and Lauri (2002) and Ghali and Rezgui (2008) by focusing on vertical spillovers as well as horizontal spillovers.

3. Methodology, data set, and variables

3.1. Methodology

There are two commonly used methods in measuring efficiencies and productivity at the firm level, namely data envelopment analysis (DEA) and stochastic frontier analysis (SFA).[1] Each of the two methods has its advantages and disadvantages, as explained below. The choice between these methods thus depends on the objective of the research, the type of firms in the chosen industry, and the nature of the data (Coelli, Rao, O'Donnell, & Battese, 2005; Olesen, Peterson, & Lovell, 1996).

DEA is a linear programming method that observes production possibilities using the technique of envelopment and measures efficiency as the distance to the frontier (Banker, Charnes, & Cooper, 1984; Charnes, Cooper, & Rhodes, 1978). This method has the primary advantage of being of a non-parametric nature and has the ability to handle multiple outputs and multiple inputs.[2] However, it has the disadvantage of producing biased estimates in the presence of measurement error and other statistical noise, as this method does not separate the stochastic random noise from the inefficiency effects (Schmidt, 1985). Hence, the estimation results under this method tend to be very sensitive to small changes in the data.

Alternatively, the stochastic frontier method is a regression-based method that assumes two separate unobserved error terms, one represents efficiency and the other represents statistical noise (Aigner, Lovell, & Schmidt, 1977; Meeusen & van den Broeck, 1977). It has a chief advantage in the ability to measure efficiency in the presence of statistical noise. However, this method is parametric and requires a specific functional form and distributional assumptions for the error terms (Coelli et al., 2005).

In this study the stochastic frontier method is applied to analyze the spillover effects from FDI. The one-stage stochastic production frontier (SPF) is used to estimate a production frontier and a technical inefficiency function simultaneously. As pointed out by Kumbhakar, Ghosh, and McGuckin (1991) and Wang and Schmidt (2002), the one-stage approach is preferable than the two-stage approach, as the latter exhibits at least two limitations in estimation that can lead to potentially severe bias. The first limitation is that technical efficiency might be correlated with the production inputs, which may cause inconsistent estimates of the production frontier. The second limitation is the OLS method in the second stage is inappropriate since technical efficiency distribution is assumed to be one-sided. Considering the advantages, the current study adopts the one-stage approach, following Battese and Coelli (1995).

The Battese–Coelli production frontier can be expressed as follows:

$$y_{it} = f(x_{it}, t; \beta)\exp(v_{it} - u_{it}) \quad (1)$$

and the inefficiency function may be written as:

$$u_{it} = z_{it}\delta + w_{it} \quad (2)$$

[1] Comprehensive reviews of the two methods are provided by Forsund et al. (1980), Bauer (1990), Bjurek et al. (1990), Bravo-Ureta and Pinheiro (1993), Greene (1993), Lovell (1993), and Coelli (1995).

[2] The non-parametric nature of DEA allows for measuring efficiency without imposing a specific functional form and a distributional assumption on data.

where y_{it} denotes the production of the ith firm ($i = 1, 2, \ldots, N$) in the tth time period ($t = 1, 2, \ldots, T$), x_{it} denotes a $(1 \times k)$ vector of explanatory variables, β represents the $(k \times 1)$ vector of parameters to be estimated, exp denotes exponential, v_{it} is the time specific and stochastic error, with $iid\ N(0, \sigma^2_v)$, and u_{it} represents technical inefficiency, which is assumed as a function of a $(1 \times j)$ vector of observable non-stochastic explanatory variables, z_{it}, and a $(j \times 1)$ vector of unknown parameters to be estimated, δ, and w_{it} is an unobservable random variable.

The parameters of Eqs. (1) and (2) are estimated using the maximum likelihood estimator (MLE) by following the three steps as explained in Coelli (1996). With simultaneous equation estimation, the MLE estimates are unbiased and efficient. The variance parameters of the Battese-Coelli's model are defined as $\sigma^2_s \equiv \sigma^2_v + \sigma^2_u$ and $\gamma \equiv \sigma^2_u / \sigma^2_s$.[3]

γ is an important parameter to decide whether there is technical inefficiency or not in the model. If the estimated value of γ is not statistically significant, there is no technical inefficiency and the results obtained from estimating Eq. (1) by ordinary least squares (OLS) would be efficient. In contrast, if the estimated value of γ is statistically significant, then there is technical inefficiency and Eqs. (1) and (2) should be estimated simultaneously.

The technical efficiency of the ith firm calculated from the Eqs. (1) and (2) is the ratio of observed output of the firm to its potential maximum output, which can be written as:

$$TE_{it} = \frac{y_{it}}{y^P_{it}} = \exp(-u_{it}) \tag{3}$$

Following Battese and Coelli (1988), the best estimator of the $\exp(-u_{it})$ is its conditional expectation, $E[\exp(-u_{it})]$, so technical efficiency can be written as:

$$TE_{it} = E[\exp(-u_{it})] \tag{4}$$

If it is assumed that the production frontier takes the form of a log-linear production function and there are four input variables (labour, capital, material, and energy) in the production process, the empirical model can be expressed in natural logarithms of variables as:

$$\ln Y_{it} = \beta_o + \beta_1 \ln L_{it} + \beta_2 \ln K_{it} + \beta_3 \ln M_{it} + \beta_4 \ln E_{it} + +\beta_5 T + \beta_6 \ln FDI\_Sector + v_{it} - u_{it} \tag{5}$$

where Y is output, L is labour, K is capital, M is material, E is energy, T is a time-trend variable that increases by one for each year, *FDI_Sector* is a measure of FDI horizontal spillovers as explained in the next section and the other variables are as previously defined.

The inefficiency effect as a function of a set of FDI variables, a year dummy, an industry dummy, and a firm dummy can be written as:

$$u_{it} = \delta_0 + \delta_1 FDI\_Firm_{it} + \delta_2 FDI\_Sector_{jt} + \delta_3 FDI\_Firm_{it} \times FDI\_Sector_{jt} + \delta_4 Year + \delta_5 Industry + \delta_6 Firm + w_{it} \tag{6}$$

where *FDI_Firm* is a dummy variable for foreign direct investment that takes a value of zero if a firm has no foreign ownership share and takes a value of one if a foreign firm has a positive share, *FDI_Sector* is as defined above, *Year* is a year dummy variable, *Industry* is an industry dummy and *Firm* is a firm dummy. The interaction term of *FDI_Firm* × *FDI_Sector* is included in the inefficiency equation to estimate whether foreign and domestic firms benefit equally from the presence of a new foreign firm. A positive (negative) coefficient on the interaction term indicates less (more) efficiency gain for foreign firms than for domestic firms.

Eq. (6) is used to estimate the intra-industry spillovers, which capture the effects of foreign presence on the technical efficiency of firms in the same industry. The inter-industry spillovers are commonly estimated by replacing the horizontal-spillover variable (*FDI_Sector*) with vertical-spillover variables. The inefficiency function for the inter-industry spillovers can be expressed as:

$$u_{it} = \delta_0 + \delta_1 FDI\_Firm_{it} + \delta_2 FDI\_Downstream\_Sector_{jt} + \delta_3 FDI\_Firm_{it} * FDI\_Downstream\_Sector_{jt} + \delta_4 Year + \delta_5 Industry + \delta_6 Firm + w_{it} \tag{7}$$

or

$$u_{it} = \delta_0 + \delta_1 FDI\_Firm_{it} + \delta_2 FDI\_Upstream\_Sector_{jt} + \delta_3 FDI\_Firm_{it} * FDI\_Upstream\_Sector_{jt} + \delta_4 Year + \delta_5 Industry + \delta_6 Firm + w_{it} \tag{8}$$

where *FDI_Downstream_Sector* is a proxy for spillover effects from foreign firms to foreign and domestic suppliers and *FDI_Upstream_Sector* is a proxy for spillover effects from foreign firms to foreign and domestic buyers.

[3] The complete derivation the log-likelihood function of the Battese-Coelli model and its related variance parameters are discussed in Battese and Coelli (1993).

3.2. Data and data set construction

The primary data for our study are the annual surveys of medium and large manufacturing establishments (*Survey Tahunan Statistik Industri* or *SI*) conducted by the Indonesian Central Board of Statistics (*Badan Pusat Statistik* or *BPS*). These annual surveys cover a wide range of information from each surveyed establishment. The basic information includes year of starting production, industrial classification, location, and the specific identification code. There is also information regarding ownership, which includes foreign and domestic ownership, and information related to production, such as gross output, number of workers in production and non-production, value of fixed capital, material usage, and energy consumption.

The annual surveys have been conducted since 1975 and the most recent available data relates to the year 2007. However, this study uses the data from 1988 to 2000. The year 1988 is chosen as a starting year since it is the first year that the replacement value of fixed assets, which is used as a measure for capital, is available. The year 2000 is selected as the last year because the BPS changed the specific identification code in 2001 to the new identification code (KIPN) without providing a concordance table to the previous used identification code (PSID). Efforts to match the observations in the years 2001–2005 to the years 1988–2000 using output values and labour do not yield consistent results. Therefore, the longest possible period for this study is 1988–2000.

In constructing a consistent data set, several adjustments are conducted. These include adjustment for industrial code, adjustment for variable definitions, cleaning for noise and typological errors, back casting missing values of capital, matching firms for a balanced panel, and choosing industries with foreign firms. The balanced panel data are preferable in this study due to two advantages: (1) it enables tracing the technical efficiency scores of each observed firm during the period of study; (2) it removes the influence of a firm that appears only in one or two years, while the period of estimation is for 13 years. The details of adjustments are presented in Appendix 1. After the adjustments, the final balanced panel of data consists of 3318 establishments with 43,225 observations.

To show the influence of the construction of the balanced panel dataset, the descriptive statistics of the related variables are calculated for the balanced panel data and for the original data before the adjustment process. The original data consist of establishments that do not report complete information on output, labour, capital, material, or energy. Therefore these establishments are not included in the calculation of the descriptive statistics for original data. Following Takii (2005), (1) 0.5 percent observations with the lowest values of output and 1.5 percent observations with the highest values of output are removed. After these deletions, the descriptive statistics for the original total data, as presented in Table 1, consists of 24,188 establishments for an unbalanced panel of 238,628 observations.

Table 1 shows that the minimum values of variables *lnY*, *lnL*, *lnK*, *lnM*, *lnE* for the original data are lower if compared to the minimum values of those variables from the balanced panel. This makes sense as the balanced panel data removes some observations during the adjustment process. The maximum values of those variables are higher in the original data compared to those in balanced panel data. The mean values of these five variables are higher in the balanced panel data compared to those in original data, while the standard deviations of these five variables are lower in balanced panel when compared to those in original data.

For *FDI_Firm*, the minimum value is zero and the maximum value is one both for original data and the balanced panel data, because this variable is a dummy variable. Further, the minimum value and the maximum value of variables *FDI_Sector*,

Table 1
Descriptive statistics for the original data and the balanced panel data.

	Original data[a]				Balanced panel data			
	Min	Max	Mean	SD	Min	Max	Mean	SD
Production Frontier								
lnY	6.461	20.980	12.514	2.256	6.591	20.761	13.964	2.006
lnL	2.398	10.649	4.079	1.327	2.639	10.292	4.702	1.088
lnK	4.105	23.398	12.308	2.268	4.220	23.106	13.152	2.245
lnM	3.871	20.033	11.765	2.418	4.239	19.454	12.164	2.221
lnE	1.791	16.583	9.377	2.221	1.882	15.836	9.587	2.077
FDI_Sector	0	1.492	0.208	0.218	0	1.492	0.234	0.209
Inefficiency Function								
FDI_Firm	0	1	0.064	0.273	0	1	0.072	0.258
FDI_Sector	0	1.492	0.208	0.218	0	1.492	0.234	0.209
FDI_Downstream_Sector	0.002	5.443	0.176	0.212	0.002	5.443	0.176	0.204
FDI_Upstream_Sector	0	0.921	0.160	0.181	0	0.921	0.160	0.174
Number of Establishments	24,188	24,188	24,188	24,188	3318	3318	3318	3318
Number of Observation	231,064	231,064	231,064	231,064	43,225	43,225	43,225	43,225

Source: Authors' calculations from the annual surveys of the Indonesian Central Board of Statistics (*Badan Pusat Statistik* or *BPS*).
Y = output, *L* = labour, *K* = capital, *M* = material and *E* = energy.
[a] The original data in this table exclude: (1) the establishments that do not report information on output, labour, capital, material, or energy; (2) 1.5 percent observations with the lowest values of output and 1.5 percent observations the highest values of output.

FDI_Backward, and *FDI_Forward* are the same for original data and for the balanced panel, as the calculation of these inter-industry variables is based on all firms in the original data as in Blalock and Gertler (2008). The mean values of these three spillover variables are higher in the balanced panel compared to those in the original data, whereas the standard deviations are lower in balanced panel. From the descriptive statistics in Table 1, the authors conclude that there is no substantial bias in the adjustment process since there is no substantial difference in the maximum value, minimum value, mean value, and standard deviation.

3.3. *Measurement of variables*

There are two sets of variables included in this study: production variables and inefficiency variables. The production variables consist of output, labour, capital, material, energy, time trend and *FDI_Sector*, while the inefficiency variables include FDI variables (*FDI_Firm*, *FDI_Sector*, *FDI_Upstream_Sector*, and *FDI_Downstream_Sector*), a year dummy, an industry dummy, and a firm dummy. The precise definition of each variable is given in Appendix 2.

In this study, gross output is used as the measure for output (y). It refers to the total value of output produced by a firm. The number of employees directly and indirectly engaged in production is used for the measure of labour (L). As a measure of capital (K), this study uses the replacement value of capital, while material (M) is measured using the total value of raw and intermediate materials and energy (E) is measured as the sum of electricity and fuel expenses.

FDI_Firm is measured by a dummy of foreign direct investment, which takes a value of one if a firm has a positive foreign ownership and takes a value of zero if otherwise. As a measure for the FDI horizontal spillovers, this study uses the share of foreign firm output to the total output at the five-digit ISIC sectoral level, which is expressed as in Aitken and Harrison (1999):

$$FDI\_Sector_{jt} = \frac{\sum_{i \forall i \in j} FDI\_Firm_{it} \times y_{it}}{\sum_{i \forall i \in j} y_{it}} \quad (9)$$

Eq. (9) captures the effect of FDI at the sectoral level on productivity at the firm level. It shows the spillover effects of foreign presence on domestic firms in the same five-digit ISIC industry.

Two alternative measures of FDI spillovers in this study are measures of inter-industry spillovers. The presence of foreign firms in certain five-digit ISIC industries may create productivity externalities for firms in upstream and downstream industries. This study measures the inter-industry spillovers by using variables that reflect the extent of backward and forward linkages between industries. Following Javorcik (2004), the measure for FDI spillovers from foreign firms in industries $k(k \neq j)$ that are being supplied by domestic firms in industries j is:

$$FDI\_Downstream\_Sector_{jt} = \sum_{k\,if\,k \neq j} \alpha_{jk} \times FDI\_Sector_{kt} \quad (10)$$

where α_{jk} is the proportion of sector j's output supplied to sector k, which is taken from the input–output (IO) matrix of four-digit industries.[4] Similarly, the measure for FDI spillovers from foreign firms in industries m whose products are bought by domestic firms in industries n is:

$$FDI\_Upstream\_Sector_{mt} = \sum_{n\,if\,n \neq m} \gamma_{mn} \times FDI\_Sector_{nt} \quad (11)$$

where γ_{mn} is the proportion of inputs purchased by industry n from industry m in total input sourced by industry n, which is taken from the input–output (IO) matrix of four-digit industries.

A time-trend variable is incorporated in the production function to measure technical change. The time-trend variable takes a value of one for the year 1988, a value of two for the year 1989, and so on. An industry dummy captures effects specific to a particular industry and has a value of one for an industry for an observation of that industry and a value of zero otherwise. A similar procedure is also applied to the firm dummy and year dummy variables.

4. Empirical results

We estimate a stochastic frontier estimation and first test for constant returns to scale to check whether the Cobb–Douglas production frontier is best suited to the data. Following the procedure of joint restriction test in Baltagi (2011, p. 80), the test of constant returns to scale is conducted under the null hypothesis that the sum of the estimated parameters (β_i) in

[4] During the selected period in this study, there are four available IO matrixes, which were published in 1990, 1993, 1995, and 2000. This study uses these four input-output matrixes for calculating the backward coefficient α_{jk}. The following is the procedure for obtaining values of α_{jk}. Values of α_{jk} before and including 1990 are taken from the 1990 IO matrix. Values of α_{jk} for 1991 and 1992 are linearly interpolated from the 1990 and 1993 IO matrixes. Values of α_{jk} for 1993 are taken from the 1993 IO matrix. Values of α_{jk} for 1994 are calculated from the linear interpolation of the 1993 and 1995 IO matrixes. Values of α_{jk} for 1995 are taken from the 1995 IO matrix. Values of α_{jk} from 1996 to 1999 are linearly interpolated from the 1995 and the 2000 IO matrixes. Finally, values of α_{jk} for 2000 are taken from the 2000 IO matrix.

production frontier in Eq. (5) is equal to one. The regression sum of squares for unrestricted model (RSS_U) is 39,631.63, whereas the regression sum of squared for restricted model (RSS_R) is 25,549.50. The *F*-statistics is 392.52, suggesting that the null hypothesis is rejected. This result confirms that the Cobb–Douglas production frontier is not the best suited model for the stochastic frontier estimation. Rather, as the sum of the coefficients of the input variables is greater than one, the unrestricted model with variable returns to scale is appropriate and is used below

4.1. Intra-industry spillovers

We begin with estimation of intra-industry spillovers. Using Eqs. (5) and (6), the production frontier and the inefficiency function are estimated simultaneously for observing the effects of foreign investment on the production frontier and technical efficiency of firms. For the inefficiency function, the technical efficiency variable (u_{it}) is specified as a function of a foreign share dummy (*FDI_Firm*), the share of foreign firms' outputs over total outputs in the four-digit industry (*FDI_Sector*), and an interacting term between *FDI_Firm* and *FDI_Sector*. When foreign investment increases the firm's technical efficiency, the coefficient of *FDI_Firm* is negative.[5] When technology spills over from firms with foreign direct investment to purely domestic firms in the same industry, the coefficient of *FDI_Sector* is negative. As for the interaction term, the sign of the coefficient shows whether or not foreign direct investment affects the firm's ability to benefit from spillovers originating from other foreign-owned firms in the same industry.

We estimate four alternative models in order to test the robustness of the estimated parameters. In the first model, a year dummy and an industry dummy are included in the inefficiency equation. The estimated parameters are presented in the Model (1) column of Table 2. The results from the production frontier show that the four input variables contribute positively and significantly to output, suggesting a positive elasticity of each input on output. There is also a positive and statistically significant coefficient of the time-trend variable indicating that technical change contributes positively to output. The positive and statistically significant coefficient of *FDI_Sector* suggests horizontal spillovers from intra-industry foreign direct investment increase the production frontier for all firms.

From the estimates of the inefficiency function, which is the main focus of this study, the coefficient of *FDI_Firm* is negative and highly significant, indicating that foreign direct investment decreases the firm's technical inefficiency. This suggests that firms with foreign ownership are, on average, more efficient than purely domestic firms. This finding confirms the argument in Caves (1971) and Dunning (1988) that foreign firms are more likely to operate on the production frontier. Furthermore, the negative and statistically significant estimate of *FDI_Sector* suggests that knowledge spills over from foreign-owned firms increases the technical efficiency of all firms in the industry. This result is in line with the argument in Wang and Blomstrom (1992) and findings in Ghali and Rezgui (2008). This result is also consistent with findings in Takii (2005), Temenggung (2007) and Blalock and Gertler (2008), which use different methods of analysis.

The positive significant estimate of interacting term means that, although the foreign-owned firms also benefit from the presence of other foreign investment in the industry, the benefit is smaller than for domestic firms. Given that the estimated coefficient of *FDI_Firm* and the estimated coefficient of *FDI_Sector* are negative and statistically significant, the positive coefficient of the interaction term means that $u_{it}/FDI\_Firm = -0.5763 + 0.0330 \times FDI\_Sector$ and that $u_{it}/FDI\_Sector = -0.2224 + 0.0330 \times FDI\_Firm$. As both *FDI_Firm* and *FDI_Sector* are each always less than or equal to one by construction, the net effect of *FDI_Sector* is negative for all foreign firms as well as domestic firms. However, the magnitude of the improvement in efficiency from having foreign firms in the industry is always greater for domestic firms than for foreign firms.

In addition, we conduct joint significance test (*F*-test) on the magnitude of spillovers for foreign establishments in order to check significance of the direct effect and the interacting effect of spillovers on foreign firms.[6] The value of *F*-statistic is calculated from the log-likelihood value of the unrestricted model and the log likelihood value of the restricted model (when both the coefficient of *FDI_Sector* and the coefficient of interacting variable *FDI_Firm* × *FDI_Sector* equal to zero). The value of log likelihood for the unrestricted model is 7704.48, whereas the value of log likelihood for the restricted model is 7643.00, So that, the *F*-statistic is 13.22, which suggests that the unrestricted model (by including variables *FDI_Sector* and interacting variable *FDI_Firm* × *FDI_Sector*) is the correct model and the two variables are jointly significant affecting spillovers on foreign establishments at 1% level.

The estimated coefficient of year dummy is not statistically significant, suggesting that on average there is no significant difference in technical inefficiency scores of firms across the sample years. The statistically significant estimated coefficient of industry dummy suggests that there is a significant difference in inefficiency scores across five-digit industries.

The highly significant estimate of gamma implicates that estimation of stochastic frontier should include an inefficiency effect. This finding provides the justification for the simultaneous estimation of stochastic production frontier and inefficiency equation. In other words, the model is appropriately representing the observed firms.

In the second model, industry dummies are replaced by firm dummies, in order to control for firm heterogeneity across the sample. The results are given in the Model (2) column of Table 2. The sign and significance of estimates are similar to

[5] The dependent variable for the inefficiency function is technical inefficiency. The negative coefficient of *FDI_Firm* indicates that foreign investment decreases inefficiency, which implies an increase in the firm's efficiency.

[6] We are grateful to one of the reviewers for suggesting this point.

Table 2
Estimating intra-industry spillovers.

Variables	Model (1)	Model (2)	Model (3)	Model (4)
Production frontier				
lnL	0.2227*** (0.0033)	0.2256*** (0.0031)	0.2197*** (0.0030)	0.2167*** (0.0031)
lnK	0.1018*** (0.0019)	0.1043*** (0.0017)	0.1023*** (0.0018)	0.1097*** (0.0012)
lnM	0.6263*** (0.0018)	0.6218*** (0.0018)	0.6223*** (0.0017)	0.6191*** (0.0022)
lnE	0.1128*** (0.0017)	0.1160*** (0.0017)	0.1165*** (0.0017)	0.1176*** (0.0016)
T	0.0007* (0.0005)	0.0039** (0.0006)	0.0066*** (0.0028)	0.0012*** (0.0003)
FDI_Sector	0.1224*** (0.0055)	0.2044*** (0.0065)	0.2687*** (0.0096)	0.1577*** (0.0065)
Inefficiency function				
FDI_Firm	−0.5763*** (0.0264)	−0.1550*** (0.0018)	−0.1960*** (0.0104)	−0.2362*** (0.0092)
FDI_Sector	−0.2224*** (0.0896)	−0.2000*** (0.0149)	−0.1780*** (0.0027)	−0.1819*** (0.0034)
FDI_Firm × *FDI_Sector*	0.0330*** (0.0028)	0.0460*** (0.0036)	0.1035** (0.0184)	0.0673*** (0.0086)
Year Dummy	−0.0002 (0.0031)	−0.0010 (0.0009)	−0.0010 (0.0019)	–
Industry Dummy	−0.0039* (0.0008)	–	–	–
Firm Dummy	–	−0.0001** (0.0000)[a]	–	–
Sigma-squared	0.0416*** (0.0010)	0.0416*** (0.0005)	0.0413*** (0.0003)	0.0418*** (0.0003)
Gamma	0.0380*** (0.0038)	0.0224*** (0.0083)	0.0086*** (0.0002)	0.0151*** (0.0020)
Log-likelihood	7704.484	7759.086	7618.974	7572.755
Number of Observations	43,225	43,225	43,225	43,225

Source: Authors' calculations.
Notes: Y = output, L = labour, K = capital, M = material, E = energy, T = time trend. Standard errors are in parentheses.
[a] The estimated standard error is 0.000009.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

those in the first model. The notable difference is only in the magnitude of the estimates. Focusing on the FDI variables, the magnitudes of coefficients are smaller in this second model compared to those in the first model. In other words, the inclusion of firm dummy and the exclusion of industry dummy in the second estimation (Model 2) results in a smaller effect of FDI spillovers on technical inefficiency. This is not surprising. Firm-specific effects are largely captured by the firm dummy, which removes a potential source of bias in the estimates of other coefficients. Notably, the results regarding the direction of spillover effects are the same as in the first model, as the coefficient of *FDI_Sector* is negative and statistically significant in both models.

For the third model, only a time dummy is included as a controlling variable in the estimation. The resulting estimates, which are presented in the Model (3) column, are very comparable with the results in Model (1) and Model (2). Similar findings are also observed in Model (4), when the time dummy, industry dummy and firm dummy and are all excluded from estimation. The results from these four models confirm the robustness of the estimates of the positive spillovers from FDI on the technical efficiency of domestic firms.

4.2. Inter-industry spillovers

Besides the effects on domestic firms in the same industry, FDI can also generate spillovers on domestic firms in other industries. We estimate six models of the inter-industry spillovers, and the results of each model are presented in Table 3. The first three models are estimated on the full sample and the last three models are estimated on the sub-sample of only domestic firms. In the three full-sample models, the first model is to capture the simultaneous effect of the three spillover variables on technical inefficiency. The second and the third model focus on the individual effect of each of the vertical FDI spillovers (i.e. the downstream spillover and the upstream spillover). The same structure is also applied to the sub-sample of only domestic firms, with Model 4 captures the simultaneous effect of the three spillover variables, Model 5 captures the downstream effect only, and model 6 captures only the upstream effect.

In the first model (the first results column of Table 3), the three proxies of spillover variables are included in the estimations. The results show that the horizontal spillover variable (*FDI_Sector*) has a negative and statistically significant coefficient, suggesting that an increase in the share of foreign firm output decreases technical inefficiency across firms in the industry. Similarly, the spillovers from FDI in downstream industries also decrease inefficiency of suppliers, as demonstrated by the negative and highly significant coefficient of the backward spillover variable (*FDI_Downstream_Sector*). In addition, the coefficient of the forward spillover variable (*FDI_Upstream_Sector*) is negative and highly significant, indicating a negative relationship between FDI in supplier industries and the industry's own technical inefficiency. Although we employ a different methodology and use a different data set, the findings are similar to those in Liang (2007).

In the second and the third models (the second and the third columns of Table 3), the impacts of backward spillover variable and the forward spillover variable are estimated separately. In each model, the magnitude of the coefficient of the included spillovers variable is larger than in Model 1, but neither the sign nor the statistical significance of the coefficient changes. Clearly, there is multi-colinearity among the spillovers variables that makes the identification of separate effects

Table 3
Estimating inter-industry spillovers.

Variables	Full sample (1)	Full sample (2)	Full sample (3)	Domestic sample (4)	Domestic sample (5)	Domestic sample (6)
Production frontier						
lnL	0.2264*** (0.0030)	0.2209*** (0.0030)	0.2197*** (0.0029)	0.2258*** (0.0012)	0.2238*** (0.0033)	0.2256*** (0.0033)
lnK	0.1007*** (0.0018)	0.1023*** (0.0018)	0.1019*** (0.0018)	0.0986*** (0.0018)	0.0999*** (0.0022)	0.0981*** (0.0019)
lnM	0.6255*** (0.0018)	0.6271*** (0.0018)	0.6268*** (0.0017)	0.6225*** (0.0014)	0.6236*** (0.0020)	0.6229*** (0.0017)
lnE	0.1117*** (0.0017)	0.1144*** (0.00170)	0.1159*** (0.0016)	0.1217*** (0.0014)	0.1226*** (0.0018)	0.1227*** (0.0018)
T	0.0002** (0.0000)[a]	0.0028* (0.0013)	0.0004*** (0.0001)	0.0009** (0.0006)	0.0021** (0.0001)	0.0010*** (0.0002)
FDI_Sector	0.0375*** (0.0013)	0.0308*** (0.0038)	0.0217*** (0.0007)	0.0056*** (0.0007)	0.0572*** (0.0035)	0.0323*** 0.0064
Inefficiency function						
FDI_Firm	−0.2945*** (0.0137)	−0.3920*** (0.0393)	−0.1257*** (0.0130)	–	–	–
FDI_Sector	−0.1901*** (0.0061)	–	–	−0.2766*** (0.0275)	–	–
FDI_Downstream_Sector	−0.0216*** (0.0021)	−0.0715*** (0.0043)	–	−0.0279*** (0.0047)	−0.0548*** (0.0027)	–
FDI_Upstream_Sector	−0.0462*** (0.0060)	–	−0.1842*** (0.0097)	−0.0682*** (0.0175)	–	−0.3067*** (0.0214)
Year Dummy	−0.0018* (0.0006)	−0.0050* (0.0017)	−0.0017** (0.0003)	0.0011*** (0.0002)	0.0046** (0.0005)	0.0002*** (0.0010)
Firm Dummy	−0.0000[b]*** (0.0000)[c]	−0.0000[d]*** (0.0000)[e]	−0.0000[f]*** (0.0000)[g]	−0.0001*** (0.0000)[h]	−0.0001** (0.0000)[i]	−0.0001*** (0.0000)[j]
Sigma-squared	0.0401*** (0.0003)	0.0416*** (0.0003)	0.0405*** (0.0003)	0.0411*** (0.0007)	0.0418*** (0.0001)	0.0405*** (0.0004)
Gamma	0.0194*** (0.0013)	0.0417*** (0.0040)	0.0124*** (0.0008)	0.0612*** (0.0111)	0.0709*** (0.0019)	0.0561*** (0.0045)
Log-likelihood	7849.487	7668.081	7750.109	8118.497	8001.479	8040.274
Number of Observations	43,225	43,225	43,225	40,042	40,042	40,042

Source: Authors' calculations.
Notes: Y = output, L = labour, K = capital, M = material, E = energy, T = Time trend. Actual estimates are [a] 0.00004, [b] 0.000034, [c] 0.0000017, [d] 0.000034, [e] 0.0000019, [f] 0.000034, [g] 0.0000014, [h] 0.0000024, [i] 0.000012, [j] 0.0000035. Standard errors are in parentheses.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

Table 4
Estimating intra-industry spillovers in high-efficiency and low-efficiency firms.

Variables	Full sample		Domestic sample	
	High-efficiency firms (1)	Low-efficiency firms (2)	High-efficiency firms (3)	Low-efficiency firms (4)
Production frontier				
lnL	0.2049*** (0.0047)	0.2258*** (0.0040)	0.2372*** (0.0018)	0.2012*** (0.0038)
lnK	0.1080*** (0.0032)	0.0985*** (0.0024)	0.1025*** (0.0024)	0.0911*** (0.0021)
lnM	0.6038*** (0.0023)	0.6634*** (0.0027)	0.5883*** (0.0036)	0.6900*** (0.0026)
lnE	0.1316*** (0.0027)	0.0835*** (0.0023)	0.1429*** (0.0013)	0.0791*** (0.0018)
T	0.0021** (0.0009)	0.0001** (0.0000)[b]	0.0022*** (0.0004)	0.0054*** (0.0003)
FDI_Sector	0.0940*** (0.0058)	0.0492** (0.0141)	0.0849*** (0.0032)	0.0727** (0.0133)
Inefficiency function				
FDI_Firm	−0.0617*** (0.0088)	−0.0096* (0.0063)	–	–
FDI_Sector	0.0742*** (0.0062)	−0.0556*** (0.0035)	0.0657*** (0.0038)	−0.0660*** (0.0115)
Year Dummy	0.0020* (0.0014)	−0.0027*** (0.0007)	0.0029*** (0.0004)	0.0015*** (0.0001)
Firm Dummy	0.0001*** (0.0000)[a]	0.0001*** (0.0000)[c]	0.0001*** (0.0000)[d]	0.0000[e]** (0.0000)[f]
Sigma-squared	0.0425*** (0.0004)	0.0382*** (0.0004)	0.0414*** (0.0005)	0.0341*** (0.0006)
Gamma	0.0369*** (0.0043)	0.0151*** (0.0023)	0.0540*** (0.0036)	0.0746*** (0.0019)
Log-likelihood	3493.823	4697.164	3597.36	5417.533
Number of Observations	21,612	21,613	20,021	20,021

Source: Authors' calculations.
Notes: *Y* = output, *L* = labour, *K* = capital, *M* = material, *E* = energy and T = time trend Actual estimates are: [a] 0.0000042, [b] 0.000037 [c] 0.000005 [d] 0.0000076, [e] 0.000018, [f] 0.0000066. Standard errors are in parentheses.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

difficult. The coefficient of the *FDI_Downstream_Sector* being negative and statistically significant at the 1% level in both Model 1 and Model 2, indicates a robust finding that the foreign entry in a three-digit industry decreases the technical inefficiency of domestic suppliers (i.e. positive backward spillovers). Similarly, the negative and statistically significant coefficient of the *FDI_Upstream_Sector* in both Model 1 and Model 3 indicates a robust finding that the presence of foreign firms in a three-digit industry decreases the inefficiency of domestic buyers (i.e. positive forward spillovers).

To isolate the spillover effects on only domestic firms, we estimate the Models 1 through 3 for the sub-sample of only domestic firms. The estimation results are presented in the fourth through sixth result columns in Table 3. The results are similar to those for the full sample of firms in terms of the signs and significance of the coefficients. However, it is notable that the coefficients for the spillovers variables in the domestic firm sample are generally of larger magnitude than the corresponding coefficients for the full sample. This provides further evidence to support that from the results in Table 2 showing that spillovers from foreign firms are more beneficial for purely domestic owned firms than for firms with direct foreign investment.

Given the results from Table 3, we conclude that the spillover effects from FDI decrease technical inefficiency of domestic firms in upstream and downstream industries. These findings confirm the argument in Javorcik (2004) that a foreign presence in a domestic market may generate not only spillover effects on domestic firms in the same industry but also provide spillover benefits to domestic firms in the upstream and downstream industries.

4.3. Spillover effects and the level of technical efficiency

So far, the analysis pools together all firms with different levels of efficiency. It has advantage of showing the average effect of FDI spillovers on a firm's technical efficiency. However, it has a disadvantage in that the spillover effects are assumed to be uniform for all firms. Thus, the analysis does not clearly distinguish which firms gain the most spillover effect from FDI.

In this section, the analysis is extended to answer a question of whether the level of efficiency influences the ability of firms in absorbing spillover benefits. The firms are divided into two groups: firms with a high-efficiency level and those with a low-efficiency level. The procedure to group the firms is by sorting the firms from the one with the highest technical efficiency level to the firm with the lowest efficiency level, and then the sorted firms are divided into two. The upper half of the data is categorized as the high-efficiency firms and the lower half is the low-efficiency firms. The estimation results for these two groups of firms are presented in Table 4. We estimate results for the full sample of firms as well as for the sub-sample of only domestic firms.

Starting from the full sample estimations, the coefficient of *FDI_Firm* is negative and statistically significant both among high-efficiency firms (column 1 of Table 4) and among low-efficiency firms (column 2), suggesting that foreign-owned firms have a higher technical efficiency level in both groups of firms. The positive and significant coefficient of *FDI_Sector* demonstrates that spillovers at the industrial level increase the inefficiency of the firms (i.e. a negative efficiency spillover). In contrast, the low-efficiency firms experience a decrease in technical inefficiency when foreign firms are more important in the industry (i.e. a positive efficiency spillover), as indicated by a negative and highly significant coefficient of *FDI_Sector* (column 2).

The coefficients of *FDI_Sector* for the sub-sample of only domestic firms (columns 3 and 4) are of the same sign and significance as in the corresponding full sample estimation, but the magnitude of impact is somewhat lower in the domestic firm sub-sample. This suggests that FDI spillovers have smaller impact on domestic firms than on foreign firms in industries with large technology gaps.

The results in Table 4 demonstrate that firms with different efficiency levels may receive different effects of FDI spillovers. High-efficiency firms tend to obtain negative spillover effects, while low-efficiency firms experience positive spillover effects. These findings confirm the argument that there is advantage from being less advanced in terms of efficiency in terms of benefitting from spillovers (Glass & Saggi, 1998; Wang & Blomstrom, 1992) and are consistent with the results in Griffith et al. (2002), Castellani and Zanfei (2003), and Peri and Urban (2006).

5. Conclusion

This article empirically examines the spillover effects of FDI on firm technical efficiency in the Indonesian manufacturing sector for the period between 1988 and 2000. Using the framework of Battese and Coelli's (1995) stochastic production frontier, we find evidence of a positive spillover effect of FDI to firms in the same industry (competitors), firms in an upstream industry (suppliers), and firms in a downstream industry (buyers). The positive spillover effect is observed in both the estimation for the full sample of firms and the estimation for the sub-sample of only domestic firms. Notably, the effects on domestic firms are generally more powerful than on other foreign firms in the same industry.

An interesting finding emerges when the samples are divided into two groups based on the level of efficiency. It is found that the low-efficiency firms receive a positive spillover effect from FDI across firms in the same industry. In contrast, the high-efficiency firms obtain a negative spillover effect. These findings support the argument of the advantage for absorbing spillovers goes to firms that are less advanced in terms of efficiency.

Outcomes from this study provide support on policies that encourage FDI. On the basis of these findings, policy makers should continue providing an FDI-friendly environment in order to maximize the spillover gains. Additional incentives may be provided for foreign firms that are willing to transfer their knowledge to domestic firms, especially those domestic firms in upstream and downstream industries that do not directly compete with the foreign firm. Variations in incentives may need to be considered, with more focus on FDI in sectors where purely domestic firms have a low-efficiency level compared to firms with direct foreign investment.

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Appendix 1. Adjustments for constructing a consistent panel data

The steps of adjustment for constructing a consistent panel data are described as follows:

Step 1: Adjustment for industrial code.

The BPS reclassified the industrial codes twice: in 1990 and in 1998. This study adjusts the industrial codes to the 1990 code (KKI-1990) in order to obtain a consistent industrial code for the observation years (1988–2000). This adjustment involves two phases. First, the data from 1988 to 1989 (which use KKI-1985) are adjusted to KKI-1990 using the establishment identification code and a special map provided by the BPS. Observations in 1988–1989 not observed in 1990–1998 are removed, since there is no code from KKI-1990 that could be assigned to these observations. This first phase of adjustment removes 1345 out of the original 29,340 establishments. Second, the data from 1998 to 2000 (which use KKI-1998) are adjusted to KKI-1990 by the following concordance table provided by the BPS. There are several concordance issues that arise during this second phase of adjustment, which include unmatched classifications and incomplete entries. An example of an incomplete entry is an observation recorded only with a two-, three-, or four-digit classification code. For dealing with this problem, only observations with four-digit classification codes are retained, while those with two- and three-digit classification codes are removed. The retained observations with four-digit codes are then assigned as five-digit codes using the establishment specific identification code. By doing so, all establishments in the 1988–2000 panel data have consistent and integrated classification codes. The total establishments removed after these industrial code adjustments are 3078 out of 29,340 establishments, which include those with Oil and Gas classification (ISIC 353 and 354) as these sub-sectors are not observed in the 1988 and 1989 surveys.

Step 2: Adjustment for the variable definitions.

In some years, the variable definitions provided by the BPS are not consistent, even though the variables are the same. The author compared the variable definitions in each year's survey questionnaires (which are provided by the BPS together with the SI data) and recalculated the inconsistent variables for obtaining consistent definitions throughout the selected period.

Step 3: Cleaning for noise and typographical errors.

This study applied several steps for data cleaning in order to minimize noises and typographical errors:

a. Observations with zero or a negative value of output, labour, material, or energy have been removed. This removes around 4.5 percent of the total observations.
b. If a firm reports a missing value for a particular variable in a given time but reports values in the year before and after, an interpolation is carried out to fill the gap. The interpolation for the missing data was not more than 1 percent of the total observations.
c. Typographical errors (or key-punch errors) in the raw data are adjusted for consistency. For example, if in the raw data, foreign share in a firm for the whole of the selected period was typed as 100 percent, except for a certain year being typed as 0 percent, then the 0 percent share is adjusted to 100 percent.
d. Observations that are considered as outliers are removed from the data set by following a procedure suggested by Takii (2005). First, observations are sorted from the lowest to the highest value of output. Second, 1.5 percent of the lowest values and 1.5 percent of the highest values are removed.

Step 4: Back-casting the missing values of capital.

In some years, the values of capital are missing for quite a large number of observations. To fill these gaps, this study follows the methodology introduced by Vial (2006).

Step 5: Matching firms for a balanced panel

A balanced panel data set is constructed for the selected period by matching firms based on the specific identification code (PSID). This study utilizes STATA10 software for the matching.

Step 6: Choosing Industries with Foreign Firms

Since the purpose of the study is to estimate the FDI spillovers, industries (at a five-digit level) without foreign firms are excluded from the balanced panel.

Step 7: All monetary variables (output, capital, material, and energy) are deflated using price indexes. The output and material values are deflated using the wholesale price index (for four-digit ISIC industries); the machinery price index is used for deflating the value of capital; the nominal values of energy, which are a sum of electricity and fuel expenditures, are deflated using the electricity price index and the fuel price index. All price indexes are at a constant price of the year 1993.

By following the steps of adjustment, the final balance panel data consists of 3318 establishments with 43,225 observations.

Appendix 2. Definitions of variables

Symbol	Category	Unit	Definitions
Production frontier			
Y	Output	Million of 1993 rupiah	Gross output, which is deflated using a wholesale price index of four-digit ISIC industries at a constant price of 1993
L	Labour	Number of workers	Total number of employees directly and indirectly engaged in production, which covers all workers, including technical, administration, marketing, storage, and clerical staffs, who work full-time or part-time, and also family members.
K	Capital	Million of 1993 rupiah	Replacement value of fixed assets, which is deflated using a wholesale price index for machinery of four-digit ISIC industries at a constant price of 1993.
M	Material	Million of 1993 rupiah	Total value of material used in production, which cover raw and intermediate materials, both domestically produced and imported deflated using a wholesale price index of four-digit ISIC industries at a constant price of 1993.
E	Energy	Million of 1993 rupiah	Total value of electricity and fuel used by a firm. The value of electricity is calculated from the electricity provided by the state energy company (*Perusahaan Listrik Negara* or PLN) and those provided by private power firms, and it is deflated using the wholesale electricity index at a constant price of 1993. The value of fuels are calculated from nine types of fuels, namely premium, solar, kerosene, coal, cokes, gas, firewood, lubricant, and other fuels, and it is deflated using the OECD price of fuels published by *DX for Windows* at the 1993 constant price.
T	Time trend		Take a value of one for 1988, value of two for 1989, and so on.
FDI_Sector	FDI Variable	Ratio	The share of foreign firms' output over total outputs in a five-digit industry, or can be expressed as in Eq. (5). This variable measures the intra-industry (or horizontal) spillovers.
Inefficiency function			
FDI_Firm	FDI variable	Binary (one or zero)	The FDI at the firm level, which takes a value of one if a firm has a positive foreign ownership and take a value of zero if otherwise.
FDI_Sector	FDI variable	Ratio	The share of foreign firms' output over total outputs in a five-digit industry, or can be expressed as in Eq. (5). This variable measures the intra-industry (or horizontal) spillovers.
FDI_Downstream_Sector	FDI variable	Ratio	Spillovers from foreign firms in industries k ($k \neq j$) that are being supplied by domestic firms in industries j is defined as in Eq. (6).

Appendix 1 (*Continued*)

Symbol	Category	Unit	Definitions
FDI_Upstream_Sector	FDI variable	Ratio	Spillovers from foreign firms in industries m ($m \neq n$) that sell their outputs to domestic firms in industries n is defined as in Eq. (6).
Year	Dummy variable		A year dummy, which takes a value of one for all observations for the year in question,and a value of zero for other years.
Industry	Dummy variable		An industry dummy, which has a value of one for all observations for the industry in question and a value of zero for other industries.
Firm	Dummy variable		A firm dummy, which has a value of one for all observations for the firm in question and a value of zero for every other.

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