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   Gujarati, Damodar N., 2003, *Basic Econometrics*, 4th edition, McGraw-Hill International Edition, Boston.

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EKONOMI
dan BISNIS

SPILLOVER EFFECTS FROM FOREIGN DIRECT INVESTMENT ON FIRM-LEVEL PRODUCTIVE EFFICIENCY: THE IMPORTANCE OF R&D

Suyanto

ABSTRACT

This study examines empirically the effects of foreign direct investment (FDI) on firm-level productive efficiency in Indonesian manufacturing. Utilizing the data from the Annual Survey of manufacturing industries between 1988 and 2000, the results confirm a positive spillover effect of FDI on technical efficiency level. An interesting finding appears when the observed firms are divided into two groups: firms with research and development (R&D) expenditure and those without R&D expenditure. The R&D firms receive higher magnitude of spillovers than those without R&D. This finding supports the argument that R&D is a key absorptive capacity for domestic firms to gain FDI spillover benefits.

Keywords: *Foreign Direct Investment, Spillover Effects, Productive-Efficiency Level*

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Spillover effects have recently been regarded as a substantial contribution of FDI to economic performance of production units in host countries. Although the spillover effects have been theoretically demonstrated as consequences of FDI presence, the empirical evidence has revealed a mixed conclusion for at least two reasons. As noted in Suyanto *et al.* (2009), differences in research methods lead to evidence of either positive or negative spillover effects and absorptive capacities are important in influencing the ability of domestic firms to gain from foreign presence. A study on FDI spillovers using a more rigorous method and taking into account absorptive capacities is expected to provide a significant contribution to the literature.

The contribution is particularly important because the recent reforms on investment policies by developing countries, including Indonesia, are in the expectation of gaining spillover benefits (Blomstrom and Kokko, 2003). Drawing on the arguments of Gorg and Strobl (2001) and Girma and Gorg (2007) that spillover effects might be some part of residuals in a production equation, a stochastic production frontier method is employed for the analysis in this study. The Battese and Coelli (1995) model is chosen as an empirical model.

The stochastic production frontier method is used in this study to estimate spillover effects from FDI on Indonesian manufacturing firms. This study starts by discussing the empirical model and the estimation method. Data sources and construction of dataset are then discussed, followed by the definition and measurement of variables. Results and interpretations are provided in the second last section. Conclusions are drawn at the final section.

Empirical Model and Estimation Method

The theoretical model of Battese and Coelli (1995) is specified as follow:

$$Y_{it} = f(\mathbf{X}_{it};\boldsymbol{\beta}).\exp(v_{it} - u_{it}) \tag{1}$$

$$u_{it} = \mathbf{z}_{it}\boldsymbol{\delta} + \omega_{it} \tag{2}$$

where Y_{it} denotes the scalar output of firm i *(i = 1, 2, ..., N)* at time t *(t=1,2,...,T)*, $\mathbf{X}_{it}$ is a *(1xk)* vector of inputs used by firm i at time t, $\boldsymbol{\beta}$ is a *(kx1)* vector of unknown parameters to be estimated; the v_{it} is a random error; u_{it} is the technical inefficiency effect; $\mathbf{z}_{it}$ is a *(1xm)* vector of observable non-stochastic explanatory variables affecting technical inefficiency for firm i at time t, $\boldsymbol{\delta}$ denotes a *(mx1)* vector of unknown parameters of the inefficiency effect to be estimated; ω is an unobservable random error.

Based on the theoretical model in Equations (1) and (2), this study starts with a flexible *translog* (Transcendental Logarithmic) production frontier. This frontier is characterized by a non-fixed substitution elasticity and is therefore subject to fewer constraints than a general logarithm linear model (Christensen *et al.*, 1973; Heathfield and Wibe, 1987). In addition, the *translog* functional form provides more generalized estimates than other logarithm linear models as it imposes relatively fewer *a priori* restrictions on the structure of production (Kopp and Smith, 1980). Therefore, adopting a *translog* functional form might reduce the risk of error in the model specification.

The functional form of the *translog* production frontier is as follows:

$$
\begin{aligned}
\ln y_{it} = {} & \beta_0 + \beta_L \ln L_{it} + \beta_K \ln K_{it} + \beta_M \ln M_{it} + \beta_E \ln E_{it} + \beta_{LL} \left(\ln L_{it}\right)^2 + \beta_{LK} \ln L_{it} * \ln K_{it} \\
& + \beta_{LM} \ln L_{it} * \ln M_{it} + \beta_{LE} \ln L_{it} * \ln E_{it} + \beta_{KK} \left(\ln K_{it}\right)^2 + \beta_{KM} \ln K_{it} * \ln M_{it} \\
& + \beta_{KE} \ln K_{it} * \ln E_{it} + \beta_{MM} \left(\ln M_{it}\right)^2 + \beta_{ME} \ln M_{it} * \ln E_{it} + \beta_{EE} \left(\ln E_{it}\right)^2 + \beta_t t \\
& + \beta_{Lt} \left[\ln L_{it} * t\right] + \beta_{Kt} \left[\ln K_{it} * t\right] + \beta_{Mt} \left[\ln M_{it} * t\right] + \beta_{Et} \left[\ln E_{it} * t\right] + \beta_{tt} t^2 + v_{it} - u_{it}
\end{aligned}
\tag{3}
$$

where y represents output, L represents labour, K is capital, M is material, E is energy, t is time, i is firm, βs are parameters to be estimated, ln denotes natural logarithm, v_{it} is the stochastic error term, and u_{it} is the technical inefficiency. In this study, the technical inefficiency effect is a function of a set of FDI variables: foreign ownership (*FDI*), horizontal spillover (*FDIHorisontal*), backward spillover (*FDIBackward*), and forward spillover (*FDIForward*); Also included are a set of other variables affecting efficiency, age of firm (*AGE*) and a dummy crisis (*CRISIS*). Hence, the inefficiency function can be written as:

$$
\begin{aligned}
u_{it} = {} & \delta_0 + \delta_1 FDI_{it} + \delta_2 FDIHorisontal_{it} + \delta_3 FDIBackward_{it} + \delta_4 FDIForward_{it} \\
& + \delta_5 AGE_{it} + \delta_6 CRISIS_{it} + w_{it}
\end{aligned}
\tag{4}
$$

where w is an error term.

Various sub-models of the *translog* are considered and tested under a number of null hypotheses, given the specification of the *translog* model in Equation (3).

A null hypothesis of the second order parameters equal zero (*i.e.* $\beta_{LL} = \beta_{LK} = \beta_{LM} = \beta_{LE} = \beta_{KK} = \beta_{KM} = \beta_{KE} = \beta_{MM} = \beta_{ME} = \beta_{EE} = 0$) is to test whether the Cobb-Douglas frontier is appropriate for the data set, and a null hypothesis of the interacting parameters of input and time equal zero (*i.e.* $\beta_{Lt} = \beta_{Kt} = \beta_{Mt} = \beta_{Et} = 0$) is for a Hicks-neutral technological progress. Similarly, a null hypothesis of the time parameters equal zero (*i.e.* $\beta_t = \beta_{tt} = \beta_{Lt} = \beta_{Kt} = \beta_{Mt} = \beta_{Et} = 0$) is for a no technology progress in the frontier, and a null hypothesis of the parameters of inefficiency function equal zero (*i.e.* $\gamma = \delta_0 = \delta_1 = ... = \delta_6 = 0$) are for a no-inefficiency effect. γ is a parameter associated with variance of inefficiency effect, u_{it}, in the Battese and Coelli's (1995) model. If γ is zero, the model reduces to a traditional mean response function in which the variables, *FDI*, *FDIHorizontal*, *FDIBackward*, *FDIForward*, *AGE*, and *CRISIS*, can be directly included into the production frontier.

For performing tests of the relevant null hypotheses, a generalized likelihood ratio statistic is employed. This ratio statistic can be expressed as follow

$$\lambda = -2\left[l\left(H_0\right) - l\left(H_1\right)\right] \tag{5}$$

where $l(H_0)$ is the log-likelihood value of the restricted frontier model, and $l(H_1)$ is the log-likelihood value of the model defined in Equation (3). If the null hypothesis is true, the test statistic has approximately a *chi*-square distribution with degrees of freedom equal to the number of parameters involved in the restrictions. The test statistic under the null hypothesis of no inefficiency effects has approximately a mixed *chi*-square distribution, and the critical value for this test is taken from Table 1 of Kodde and Palm (1986).[1]

The computer program FRONTIER4.1 is used to jointly estimate the stochastic production frontier of Equation (3) and the inefficiency function of Equation (4) under the maximum likelihood method (Coelli, 1996).[2] This computer program

[1] For explanation regarding a mixed *chi*-square and a test for no inefficiency effect, see Battese and Coelli (1988).

[2] FRONTIER4.1 was developed by Tim Coelli in the Department of Econometrics, University of New England. The program, written in Shazam, can be run on an IBM-PC. In this program, the execution of a stochastic frontier model can be either by modifying the available instruction file or writing a

follows a three-step estimation method to obtain the final maximum likelihood estimates. The first step estimates the frontier production function in Equation (3) using OLS and obtains all β estimators, which are unbiased (except the intercept, β_0). In the second step, a two-phase grid search for γ is conducted; with the β parameters (except β_0) set to the OLS values, the β_0 and σ_S^2 parameters adjusted to the Corrected OLS (COLS) values and other parameters set to zero.[3] The third step applies an iterative procedure of the *Davidon-Fletcher-Powell Quasi-Newton* method to obtain final maximum likelihood estimates using the value selected in the grid search as starting values.

Data Sources and Construction of the Dataset

1. Description of Data Sources

The primary data source in this study is the Annual Surveys of medium and large manufacturing establishments (*Survei Tahunan Statistik Industri* or SI) conducted by the Indonesian Central Board of Statistics (*Badan Pusat Statistik* or BPS). The data are available in an electronic format (d-base file) and can be obtained under a license. The survey covers the basic information of each establishment, such as specific identification code, industrial classification, year of starting production, and location. It also covers the ownership information (domestic and foreign ownerships), production information (gross output, number of workers in production and non-production, value of fixed capital and investment, material, and energy consumption), and other information (share of production exported, value of material imported, and expenditure on research and development). The numbers of establishments surveyed vary with the year of survey, with the minimum number of 7,469 manufacturing establishments in 1975 and the maximum number of 21,671 establishments in 1996.

The annual surveys (SI) have been conducted since 1975, and the recent available data are for the year 2005. However, this study uses only the period of data from 1988 to 2000. The year of 1988 is chosen as a starting year because the data on the replacement value of capital are not available before 1988. The 2001 to 2005 period is excluded, because the BPS changed the specific identification code in 2001

program language. This program is available online from the Centre for Efficiency and Productivity Analysis website (http://www.uq.edu.au/economics/cepa/frontier.htm). A detailed procedure for running FRONTIER4.1 is discussed in Coelli (1996).

[3] σ_S^2 is a parameter associated with the variance of random variable v_{it} in the Battese and Coelli's (1995) model.

to 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 don't yield reliable results. Therefore, the longest possible period for this study is 1988-2000.

The classification of the establishment-level data in SI is up to five-digit industrial codes. This classification is based on the Indonesian Commodity Classification (*Klasifikasi Komoditi Indonesia* or KKI), which basically follows the International Standard Industrial Classification (ISIC) with some modification to suit Indonesian conditions. During the observation years, from 1988 to 2000, the KKI was reclassified twice in order to accommodate the growing number of manufacturing establishments and to comply with the revisions of ISIC.

The first reclassification took place in 1990 when the last digit of five-digit KKI was updated for some sub-sectors (in this case, the BPS replaced KKI-1985 with KKI-1990). For example, the basic organic and inorganic chemicals sub-sector (*i.e.* the 35110 manufacturing code) was updated into nine sub-sectors, namely inorganic chloral and alkaline (the 35111 code), industrial gas (35112), inorganic pigment (35113), inorganic chemicals not else classified (35114), organic chemicals from woods and gum (35115), organic pigment (35116), organic chemicals from oil and gases (35117), special organic chemicals (35118), and organic chemicals that not else classified (35119).

The second reclassification was published in 1998 to follow the change in ISIC, from ISIC Revision 2 to ISIC Revision 3 (the KKI-1990 was changed into KKI-1998). In this reclassification, the BPS changed completely the manufacturing code. For example, the code for bakeries was 31179 in KKI-1990, but it was changed to 15410 in KKI-1998.

As a supplementary for the SI, this study also utilizes data from several sources when constructing the final panel dataset. The types and sources of the supplementary data are presented in Table 1. The wholesale price index (WPI) is used as a monetary deflator for output and material. Similarly, the machinery price index and the electricity price index are used as a deflator for capital and electricity, respectively. To deflate the monetary value of fuel, the fuel price index is calculated from the OPEC fuel basket price from *DX for Windows*.[4] The input-output tables are

[4] The OPEC fuel prices are converted from US$ values to Indonesia rupiah (IDR) using average yearly exchange rates published by the central Bank of Indonesia in Statistics of Economic and Finance Indonesia (*Statistik Ekonomi dan Keuangan Indonesia* or SEKI).

used for calculating spillover variables for downstream and upstream industries (*i.e.* variables of backward and forward spillovers).

Table 1. Sources and Descriptions of Data

No.	Data	Source	Description
Primary Data			
1	Survey of Industries (SI)	The Indonesian Central Board of Statistics (BPS)	The SI is an annual survey of medium and large manufacturing establishments, which cover up to 21,671 establishments with at least 20 employees and consist of more than 160 variables.
Supplementary Data			
2	Wholesale Price Index (WPI)	The Indonesian Central Board of Statistics (BPS)	The WPI used in this study is a WPI of 150 commodities categorized by ISIC four-digit.
3	WPI of Machinery	The Indonesian Central Board of Statistics (BPS)	The machinery price index covers prices of all machinery, except electricity machinery, used by manufacturing industries.
4	WPI of Electricity	The Indonesian Central Board of Statistics (BPS)	The electricity price index is calculated from the price of electricity supplied by the state energy company (*Perusahaan Listrik Negara* or PLN) and published by the BPS as a part of the WPI.
5	Fuel Price Index	*DX* for Windows	The fuel price index is calculated from the OPEC fuel basket prices.
6	Input-Output Table	The Indonesian Central Board of Statistics (BPS)	The Indonesian input-output table consists of the value of inputs used by sector i from sector j and value of output sold to sector j by sector i at a certain year. It captures 161 sectors of all industries in Indonesia. For the purpose of this study, only input-output values of manufacturing industries (88 sectors) are used.

Source: Author's compilation

2. Procedure for Constructing a Consistent Balanced Panel Set

Constructing a consistent and integrated dataset is necessary for obtaining reliable and unbiased empirical analysis. In this study, the possible inconsistency and other problems in the SI data are identified. A consistent and integrated balance panel set is then constructed by following several steps of adjustment. The steps of adjustment are described as follow:

Step 1: Adjustment for industrial code.

As noted above, the BPS reclassified the industrial codes twice: in 1990 and 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 1,346 out of the original 29,340 establishments. Second, the data from 1998 to 2000 (which use KKI-1998) are adjusted to KKI-1990 by following the 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.[5] 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 3,078 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 applies several steps for data cleaning in order to minimize noises and typographical errors:

[5] 1,732 out of 22,175 establishments are removed since they are only assigned with two- and three digit industrial codes.

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 is 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 is 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 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). The replacement values of fixed capitals are regressed against the one-year lagged output in order to obtain the estimated coefficient of capital. The estimated coefficient is then used to calculate the predicted values of fixed capital for the missing data.

Step 5: Matching firms for a balanced panel

A balanced panel dataset 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 4-digit ISIC industries); the machinery price index is used for deflating the value of capital; the nominal values of energy are a sum of electricity and fuel expenditures, which are deflated using the electricity price index and the fuel price index. All price indexes are at a constant price of 1993.

By following the steps of adjustment, the final balanced panel dataset consists of 3,218 establishments with 43,134 observations.

Definition and Measurement of Variables

A crucial part in empirical studies is the measurement of variables. The reliability of empirical results depends heavily on the accuracy of measures of variables. From the available SI data, supported by the most up-to-date information from the literature, this study constructs variables for the empirical model in Equations (3) and (4). The variables are divided into two groups based on the two simultaneous equations: a stochastic production frontier and an inefficiency function. The variables for the inefficiency function are divided further into two, namely FDI variables and other variables. The constructions of the variables are discussed below and the definitions are given in Table 2.

Table 2. Definitions of Variables

Variables	Definition
Production Function	
Y	Output (in million rupiah), which is deflated using a wholesale price index (WPI) at a constant price of 1993
L	Labor (number of workers) is the total number of employees directly and indirectly engaged in productions
K	Capital (million rupiah), which is deflated using WPI for machinery at a constant price of 1993
M	Material (million rupiah), which is deflated using a wholesale price index at a constant price of 1993
E	Energy (million rupiah) is the sum of electricity and fuel expenditures, which are deflated using a WPI for electricity and fuel price index at a constant price of 1993
Inefficiency Function	
FDI	Foreign ownership, which is measured by a dummy variable: 1 if the share of foreign ownership is greater than 0 percent; and 0 if otherwise.
FDIHorisontal	Spillovers of FDI on domestic firms in the same industries, which is measured by the share of foreign firms' output over total output of the five-digit industry
FDIBackward	Spillovers of FDI on upstream industries, which is calculated from the share of the total output of an industry that is sold to foreign buyers across all five-digit industries.
FDIForward	Spillovers of FDI on downstream industries, which is calculated from the share of the total output of an industry that is bought from foreign suppliers across all five-digit industries.
Age	Age of firms is measured by the different between year of survey and year of starting production
Crisis	Economic crisis is measured by a dummy variable: 1 if the year of observation is 1997 onward, and 0 if the year of observation is before 1997.

Results and Interpretation

1. Testing For Model Specification

Given the general *translog* frontier, as specified in Equations (3), this study tests a number of null hypotheses for finding the appropriate model for the dataset. The results of the relevant null hypotheses tests are presented in Table 3. The first null hypothesis is to confirm whether the Cobb-Douglas production frontier is an appropriate specification for the dataset, by imposing the following restrictions: $\beta_{LL} = \beta_{LK} = \beta_{LM} = \beta_{LE} = \beta_{KK} = \beta_{KM} = \beta_{KE} = \beta_{MM} = \beta_{ME} = \beta_{EE} = 0$, on Equation (1). The result of the log-likelihood test shows a strong rejection of the null hypothesis at the 1% level of significance, suggesting that the Cobb-Douglas model is an inappropriate specification, given the *translog* model.

Table 3. Log-Likelihood Tests for Model Specification of The Stochastic Production Frontier

Restrictions	Full Samples	Critical Values (α=0.10)	Critical Values (α=0.05)	Critical Values (α=0.01)
Cobb-Douglas ($\beta_{LL}=\beta_{LK}=\beta_{LM}=\beta_{LE}=\beta_{KK}=\beta_{KM}=\beta_{KE}=\beta_{MM}=\beta_{ME}=\beta_{EE}=0$)	9801.42***	22.31	25	30.58
Hicks-Neutral ($\beta_{Lt}=\beta_{Kt}=\beta_{Mt}=\beta_{Et}=0$)	266.34***	7.78	9.49	13.28
No TP ($\beta_t=\beta_{tt}=\beta_{Lt}=\beta_{Kt}=\beta_{Mt}=\beta_{Et}=0$)	69.22***	10.64	12.59	16.81
No Inefficiency Effect ($\gamma=\delta_0=\delta_1=\ldots=\delta_6=0$)	1403.86***	7.09	8.76	12.48

Source: Author's calculations. Note: the log-likelihood ratio statistics are calculated from Equation (3) based on the restricted and unrestricted models for horizontal spillovers. The log-likelihood ratio statistics on models for backward spillovers or forward spillovers provide similar conclusions. ***, **, and * denote significance at 1%, 5%, and 10%, respectively. The critical values are based on Chi-squared distribution. For the null hypothesis of no- inefficiency effect, the critical value is based on a mixed chi-squared distribution provided by Kodde and Palm (1986).

The second null hypothesis test, for Hicks-neutral technical progress (TP) under a restriction: $\beta_{Lt} = \beta_{Kt} = \beta_{Mt} = \beta_{Et} = 0$, also rejects the null hypothesis, but the levels of significance vary between 1% and 10%. Similarly, when imposing a restriction: $\beta_t = \beta_{tt} = \beta_{Lt} = \beta_{Kt} = \beta_{Mt} = \beta_{Et} = 0$, for a null hypothesis of no-technological progress (TP), the statistical results suggest that the no-TP specification is inappropriate, given the *translog* specification. The last null hypothesis for no inefficiency effect, which imposes the restriction: $\gamma = \delta_0 = \delta_1 = ... = \delta_6 = 0$, shows also a rejection of null hypothesis at the 1% level of significance.

Given these statistical results, one can conclude that the flexible *translog* model, as specified in Equation (1), appears to be the appropriate specification for the firms in the analysis. Therefore, the estimations of the stochastic frontiers in this study follows the *translog* production frontier.

2. FDI Spillover Effects on Manufacturing Firms

Using the *translog* stochastic frontier and the inefficiency function specified in Equations (3) and (4), this study begins the estimation of FDI spillover effects for all manufacturing firms in the dataset. Three spillover variables, as constructed above, are used for testing the spillover hypothesis. These three variables are estimated separately because the partial correlation tests shows that these variables are moderately correlated each other, particularly between *FDIHorizontal* and *FDIForward*, which have a 0.82 correlation coefficient. Estimating them together in one equation may result in a near multicollinearity problem, with a consequence of insignificance in estimated coefficients (Gujarati, 2003). The selected parameter estimates for the manufacturing firms are presented in Table 4.

The first three columns of Table 4 display estimation results for all manufacturing establishments using three different spillover variables. The coefficients of the *translog* stochastic production frontier (the upper part of the table) has no immediate economic implication, as the impacts of each input to output depend on the combination of the coefficients of all terms involving the input (first and second orders). Therefore, output elasticity with respect to labour, capital, material and energy, along with return to scale coefficients, has been calculated.[6] The annual average industry-wise elasticities and return to scale (RTS) coefficients are presented in Appendix 1. The firm-specific results are not presented due to space limitation but can be obtained from the author upon request.

From the calculated elasticity scores, it is apparent that the average output elasticity with respect to labour is positive for all the observed years, ranging from

[6] The output elasticity of each input is obtained by taking a partial derivative of the *translog* model and evaluating them at particulate values of variables. Based on the *translog* model in Equation (3), the output elasticity of labour is defined as $\varepsilon_L=\beta_L+2\beta_{LL}[lnL]+\beta_{LK}[lnK]+\beta_{LM}[lnM]+\beta_{LE}[lnE]+\beta_{LT}T$. Similarly, the output elasticity of capital, material, and energy are obtained by the partial derivatives of output to capital, output to material, and output to energy, respectively.

0.20 to 0.23 (Appendix 2). Similarly, the elasticity to capital and elasticity to material are also positive, with the average scores of 0.09 for the former and 0.69 for the latter. The same is also true for energy, as the average scores of output elasticity are positive. Furthermore, the four output elasticity scores sum up to return to scale (RTS) coefficient. The annual average score of RTS is 1.06 between 1988 and 2000, suggesting an increasing return to scale (IRTS) of the Indonesian manufacturing industry.[7] This average RTS increases steadily during the observed years, from 1.03 in 1988 to 1.14 in 2000, indicating that the benefits of operating on a larger scale have been increased over time.

The finding of increasing returns to scale is consistent with the rejection of the Cobb-Douglas function, which basically assumes constant return to scale. The increasing returns to scale are mostly contributed by the output elasticity of material (ranging from 0.62 to 0.80 during the observed years), which is not surprising given the heavy reliance on raw material and the nature of the industry. As argued by Aswicahyono (1998), Indonesian manufacturing products are mostly either natural resource based or simple assembly processed, which make the industry rely heavily on material input. In contrast, the output elasticity of capital is relatively low, suggesting a low capital intensity. This result may need to be interpreted with caution as capital is a key factor for output growth. However, this result is somehow unsurprising as the share of capital in total industry outputs is usually low in labour-intensive environment, such as the Indonesian manufacturing industry. High elasticity of capital, as argued by Wacker *et al.* (2006), is usually observed only in manufacturing industries that rely heavily on advanced technologies. Nevertheless, the results are consistent with findings in previous studies on Indonesian manufacturing firms that use more than two factor inputs (Amiti and Konings, 2005; Ikhsan, 2007).

Moving to the inefficiency function (the lower part of Table 4), the estimated coefficients of *FDI* (which take the value of one if the firm is a foreign-owned firm and zero if the firm is a domestic firm) are negative and highly significant at the 1% level, suggesting that foreign-owned firms are, on average, less inefficient than domestic firms, keeping other variables constant. This result supports the mainstream premise that foreign firms generally possess more updated knowledge and have more experience in serving markets, so that they are more efficient than domestic firms.

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[7] The slightly larger than one of average RTS also suggests that larger firms might have slight cost advantages relative to smaller firms.

As expected, the coefficient of *FDIHorizontal* has a negative sign and is statistically significant at the 1% level, meaning that the presence of FDI reduces inefficiency of firms in the same five-digit industries. Similarly, *FDIBackward* and *FDIForward* have also negative and highly significant coefficients, which indicate negative effects of FDI on technical inefficiency (or positive technical efficiency spillovers) on suppliers and buyers, respectively. Although this study uses a longer time period by including the period of crisis, the findings are in line with Blalock and Gertler (2008) and Takii (2005) on the ground that FDI at the industrial level generates positive spillovers to firms in the same industries, firms in upstream industries, and firms in downstream industries.

With regard to variables not associated with foreign ownership, the coefficient of Age is positive for the three spillover models but it is significant only for the horizontal spillover model (the first column of Table 4). This is not a surprise since the impact of age to firms' efficiencies is still a matter of debate in the literature, as noted in Section 5.4.3.1. An older firm could have a higher efficiency due to knowledge accumulation through learning experience, while a younger firm might be more efficient because of possessing up-dated knowledge. Nevertheless, the result is consistent with findings in Lundvall and Battese (2000) for Kenya and Kathuria (2001) for India. Similarly, the coefficients of crisis also show inconclusive findings, with positive and significant effects on inefficiency in horizontal and backward spillover models, but with negative insignificant effects in the forward spillover model. This demonstrates the argument in literature that the impacts of crisis on firms are uneven and depend on heterogeneous characteristics of firms (for example, Narjoko and Hill, 2007).

Table 4. Estimates of Stochastic Production Frontiers on The FDI Spillover Effects in the Indonesian Manufacturing Firms

Variable	Horisontal Spillovers 1 (All firms)	Backward Spillovers 1 (All firms)	Forward Spillovers 1 (All firms)
Production Frontier (Dependent Variable: lnY)			
Constant	1.144***	1.214***	1.117***
	(37.08)	(37.58)	(37.01)
lnL	0.601***	0.608***	0.614***
	(32.87)	(30.65)	(31.07)
lnK	0.180***	0.177***	0.175***
	(17.34)	(16.01)	(15.86)
lnM	0.212***	0.198***	0.192***
	(19.41)	(18.03)	(17.16)
lnE	0.244***	0.253***	0.255***
	(26.16)	(27.08)	(27.42)
$[\ln L]^2$	0.014**	0.011*	0.011**
	(2.42)	(1.84)	(1.96)
lnL*lnK	0.043***	0.041***	0.040***
	(9.73)	(8.65)	(8.38)
Variable	**Horisontal Spillovers 1 (All firms)**	**Backward Spillovers 1 (All firms)**	**Forward Spillovers 1 (All firms)**
Production Frontier (Dependent Variable: lnY)			
lnL*lnM	-0.174***	-0.171***	-0.171***
	(-39.88)	(-38.12)	(-3.82)
lnL*lnE	0.067***	0.067***	0.066**
	(13.93)	(13.81)	(13.76)
$[\ln K]^2$	0.003**	-0.002*	0.002*
	(2.38)	(1.74)	(-1.70)
lnK*lnM	-0.071***	-0.073***	-0.073***
	(-28.17)	(-28.54)	(-28.28)
lnK*lnE	0.057***	0.058***	0.059***
	(22.86)	(21.32)	(21.86)
$[\ln M]^2$	0.164***	0.165***	0.165***
	(98.82)	(99.87)	(100.50)
lnM*lnE	-0.143***	0.143***	-0.143***
	(51.52)	(-51.12)	(-51.64)
$[\ln E]^2$	0.023***	0.022***	0.021***
	(17.69)	(14.76)	(10.59)
T	0.006***	0.006***	0.005***
	(3.79)	(2.88)	(2.96)
lnL*T	-0.001	-0.000	0.001
	(0.54)	(-0.60)	(0.76)
lnK*T	-0.000	-0.000	0.002
	(0.26)	(0.14)	(-0.51)
lnM*T	0.001*	0.001	0.001***
	(1.83)	(1.37)	(3.41)
lnE*T	-0.004	0.000***	-0.001**
	(-1.05)	(-3.69)	(-2.02)
T^2	0.001***	-0.000***	0.001***
	(-5.81)	(-3.69)	(-8.78)

Inefficiency Function (Dependent Variable: u)			
Constant	0.078***	0.124***	0.062***
	(21.59)	(16.05)	(23.09)
FDI	**-0.008*** **	**-0.011*** **	**-0.010*** **
	(-6.56)	(-8.82)	(-10.76)
FDIHorizontal	**-0.126*** **	-	-
	(-88.00)		
FDIBackward	-	**-0.085*** **	-
		(-18.88)	
FDIForward	-	-	**-0.124*** **
			(-25.00)
Age	0.002***	0.000	0.000
	(3.30)	(0.49)	(0.37)
Crisis	0.015***	0.017***	-0.002
	(6.91)	(4.67)	(-1.00)
Sigma-squared	0.033***	0.033***	0.033***
	(195.31)	(144.52)	(140.34)
Gamma	0.005***	0.024***	0.001***
	(20.78)	(10.66)	(8.32)

Source: Author's Calculation using the model specified in Equations (3) and (4). Notes: The t-statistics are in parenthesis. *** denotes 1% significance level, ** denotes 5% significance level, and * denotes 10% significance level.

Table 5. Output Elasticity of Inputs and Return to Scale (RTS) for The Indonesian Manufacturing Sector

Year	Labour	Capital	Material	Energy	RTS
1988	0.22	0.09	0.62	0.10	1.03
1989	0.22	0.09	0.63	0.09	1.03
1990	0.21	0.08	0.66	0.08	1.03
1991	0.22	0.09	0.63	0.09	1.03
1992	0.20	0.08	0.67	0.08	1.03
1993	0.21	0.09	0.66	0.08	1.04
1994	0.21	0.09	0.67	0.07	1.05
1995	0.20	0.09	0.69	0.07	1.06
1996	0.20	0.09	0.72	0.06	1.07
1997	0.20	0.09	0.73	0.06	1.08
1998	0.21	0.10	0.73	0.06	1.10
1999	0.21	0.10	0.76	0.06	1.12
2000	0.20	0.09	0.80	0.05	1.14
1998-1992	0.22	0.09	0.64	0.09	1.03
1993-1996	0.21	0.09	0.68	0.07	1.05
1997-2000	0.21	0.09	0.75	0.06	1.11
1988-2000	0.21	0.09	0.69	0.07	1.06

Source: Author's calculation from the estimates of stochastic production frontier for all firms under the horizontal spillover model (second column of Table 4)

3. FDI Spillovers to R&D and Non-R&D Firms

Research and development (R&D) is a key absorptive capacity for domestic firms to gain FDI spillover benefits. Firms with R&D are likely to receive higher spillover benefits than those without R&D. Incorporating this argument and testing whether it applies in the Indonesian manufacturing sector, this study estimates Equations (3) and (4) on a group of R&D firms and non-R&D firms, separately. Table 7 presents the estimates of these two groups. Interestingly, the estimates show that both R&D and non-R&D firms receive positive horizontal, backward, and forward spillovers from FDI, as suggested by the negative sign and statistical significance of estimates for the three spillover measures. However, coefficients of spillover variables for the first group are greater than those for the second group, indicating that the magnitude of spillovers is larger for the R&D firms than for the non-R&D firms. This finding is not a surprise since R&D firms are generally having up-to-date knowledge. The finding confirms the argument that R&D expenditure increases firms' ability to absorb FDI spillover benefits, which are in line with findings by Kathuria (2002) for India and Marcin (2008) for Poland. This finding justifies that firms with larger absorptive capacities, such as those with R&D expenditure, will receive higher spillover effects from FDI if compared to firms with smaller, which have no R&D expenditure.

Table 6. Estimates of Stochastic Production Frontiers on The FDI Spillover Effects: The Importance of Research and Development (R&D)

Variable	Horisontal Spillovers (R&D Firms)	Backward Spillovers (R&D Firms)	Forward Spillovers (R&D Firms)	Horisontal Spillovers (Non-R&D)	Backward Spillovers (Non-R&D)	Forward Spillovers (Non-R&D)
Production Frontier (Dependent Variable: lnY)						
Constant	0.575***	0.741***	0.816***	1.072***	1.20***	1.178***
	(6.21)	(8.69)	(7.18)	(33.98)	(35.00)	(33.03)
lnL	0.582***	0.641***	0.608***	0.535***	0.571***	0.574***
	(9.49)	(17.30)	(9.91)	(25.06)	(25.76)	(26.32)
lnK	0.216***	0.183**	0.186***	0.234***	0.206***	0.207***
	(6.16)	(2.42)	(5.30)	(20.27)	(17.17)	(17.20)
lnM	0.321***	0.289***	0.269***	0.208***	0.167***	0.169***
	(9.57)	(6.03)	(7.45)	(17.63)	(13.06)	(13.62)
lnE	0.334***	0.321***	0.335***	0.248***	0.256***	0.257***
	(8.58)	(10.63)	(8.49)	(25.22)	(26.05)	(26.04)
$[\ln L]^2$	0.016	0.031***	0.148	0.017***	0.012*	0.014**
	(1.04)	(3.64)	(0.96)	(2.70)	(1.89)	(2.17)
lnL*lnK	0.016	0.016***	0.019	0.060***	0.052***	0.054***
	(1.30)	(11.48)	(1.55)	(11.67)	(9.98)	(10.36)
lnL*lnM	-0.131***	-0.160*	-0.139***	-0.179***	-0.173***	-0.176***
	(-11.21)	(-1.95)	(-11.93)	(-36.31)	(-34.55)	(-34.92)
lnL*lnE	0.054***	0.065	0.055***	0.063***	0.062***	0.061***
	(3.60)	(1.12)	(3.57)	(12.37)	(12.11)	(12.04)
$[\ln K]^2$	0.014***	0.011	0.010***	-0.009***	-0.007***	-0.008***
	(4.99)	(0.69)	(3.12)	(-7.14)	(-5.32)	(-6.14)
lnK*lnM	-0.080***	-0.079***	-0.070***	-0.070***	-0.073***	-0.072***
	(-11.96)	(-4.94)	(-9.79)	(-25.03)	(-25.46)	(-24.98)
lnK*lnE	0.031***	0.031	0.033***	0.053***	0.060***	0.060***
	(3.53)	(1.64)	(3.73)	(18.74)	(20.15)	(20.66)
$[\ln M]^2$	0.150***	0.148***	0.149***	0.162***	0.167***	0.167***
	(35.88)	(78.40)	(34.51)	(90.57)	(81.65)	(89.88)
lnM*lnE	-0.143***	-0.132***	-0.138***	-0.139***	-0.142***	-0.143***
	(17.48)	(-76.61)	(-16.63)	(-46.56)	(-44.89)	(-47.69)
$[\ln E]^2$	0.033***	0.024	0.030***	0.023***	0.021***	0.021***
	(5.48)	(1.36)	(4.91)	(15.45)	(13.75)	(14.14)
T	0.014**	0.020***	0.016***	0.011***	0.006***	0.006***
	(2.34)	(5.49)	(2.69)	(6.05)	(2.90)	(2.90)
lnL*T	-0.001	-0.001	-0.001***	0.001*	-0.002**	-0.002**
	(-0.65)	(-0.40)	(-0.29)	(-1.74)	(-1.99)	(-1.98)
lnK*T	0.002	0.001	0.002	-0.001**	-0.001*	-0.001*
	(1.27)	(1.23)	(1.48)	(-2.31)	(-1.73)	(-1.71)
lnM*T	0.004***	-0.004***	-0.003**	0.002***	0.002***	0.003***
	(-3.00)	(-3.26)	(-2.28)	(3.34)	(5.06)	(5.39)
lnE*T	0.002	0.002***	0.001	-0.000	0.001	-0.001*
	(1.56)	(3.39)	(0.71)	(-0.46)	(1.58)	(-1.66)
T^2	-0.000***	-0.001	-0.001***	-0.001***	-0.001***	0.001***
	(2.50)	(-0.98)	(-3.61)	(-7.44)	(-4.06)	(-5.30)

Inefficiency Function (Dependent Variable: u)						
Constant	0.104***	0.092***	0.117***	0.066***	0.059***	0.049***
	(14.97)	(10.66)	(11.13)	(15.46)	(15.72)	(8.76)
FDI	-0.078***	-0.148**	-0.186***	-0.419***	-0.264***	-0.201***
	(-2.60)	(-2.40)	(-12.96)	(-44.33)	(-29.84)	(-18.33)
FDIHorizontal	-0.107***	-	-	-0.049***	-	-
	(-13.73)			(-3.18)		
FDIBackward	-	-0.114***	-	-	-0.065***	-
		(-28.24)			(-17.30)	
FDIForward	-	-	-0.125***	-		-0.069***
			(-5.25)			(-4.50)
Age	0.001***	0.000	0.000	0.001***	0.001**	0.000**
	(5.09)	(1.34)	(0.034)	(16.75)	(1.99)	(1.98)
Inefficiency Function (Dependent Variable: u)						
Crisis	0.028***	0.027	-0.013	-0.004*	0.022***	0.020***
	(6.49)	(0.17)	(-0.97)	(-1.92)	(7.30)	(4.49)
Sigma-squared	0.042***	0.042**	0.041***	0.030***	0.031***	0.031***
	(65.25)	(2.14)	(59.85)	(266.13)	(126.89)	(130.61)
Gamma	0.006***	0.045**	0.005***	0.070***	0.025***	0.015***
	(2.63)	(2.36)	(4.21)	(17.99)	(16.12)	(9.13)

Source: Author's Calculation using the model specified in Equations (3) and (4). Notes: The t-statistics are in parenthesis. *** denotes 1% significance level, ** denotes 5% significance level, and * denotes 10% significance level.

Conclusions

This study has examined the spillover effects of FDI on firm-level productivity in Indonesian manufacturing industry. Utilizing data from Annual Survey of Indonesian manufacturing firms and employing the Battese and Coelli (1995) stochastic production frontier model, this study finds that FDI generates positive spillover effects on firm-level productivity. An interesting finding emerges when the samples are divided into two groups: firms with R&D spending and firms without R&D spending. The results show that the group of firms with R&D spending receives larger magnitude of spillovers than the group of firms without R&D spending. These findings justify the argument of the importance of absorptive capacity in gaining the productivity spillovers from FDI.

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Surabaya, 13 Mei 2016

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Spillover Effects from Foreign Direct Investment on Firm-Level Productivity Efficiency: The Importance of Research and Development

by 14 Suyanto

Spillover Effects from Foreign Direct Investment on Firm-Level Productive Efficiency: The Importance of R&D

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Abstract
This study examines empirically the effects of foreign direct investment (FDI) on firm-level productive efficiency in Indonesian manufacturing. Utilizing the data from the Annual Survey of manufacturing industries between 1988 and 2000, the results confirm a positive spillover effect of FDI on technical efficiency level. An interesting finding appears when the observed firms are divided into two groups: firms with research and development (R&D) expenditure and those without R&D expenditure. The R&D firms receive higher magnitude of spillovers than those without R&D. This finding supports the argument that R&D is a key absorptive capacity for domestic firms to gain FDI spillover benefits.
Keywords: Foreign Direct Investment, Spillover Effects, Productive-Efficiency Level

Introduction

Spillover effects have recently been regarded as a substantial contribution of FDI to economic performance of production units in host countries. Although the spillover effects have been theoretically demonstrated as consequences of FDI presence, the empirical evidence has revealed a mixed conclusion for at least two reasons. As noted in Suyanto *et al.* (2009), differences in research methods lead to evidence of either positive or negative spillover effects and absorptive capacities are important in influencing the ability of domestic firms to gain from foreign presence. A study on FDI spillovers using a more rigorous method and taking into account absorptive capacities is expected to provide a significant contribution to the literature.

The contribution is particularly important because the recent reforms on investment policies by developing countries, including Indonesia, are in the expectation of gaining spillover benefits (Blomstrom and Kokko, 2003). Drawing on the arguments of Gorg and Strobl (2001) and Girma and Gorg (2007) that spillover effects might be some part of residuals in a production equation, a stochastic production frontier method is employed for the analysis in this study. The Battese and Coelli (1995) model is chosen as an empirical model.

The stochastic production frontier method is used in this study to estimate spillover effects from FDI on Indonesian manufacturing firms. This study starts by discussing the empirical model and the estimation method. Data sources and construction of dataset are then discussed, followed by the definition and measurement of variables. Results and interpretations are provided in the second last section. Conclusions are drawn at the final section.

Empirical Model and Estimation Method

The theoretical model of Battese and Coelli (1995) is specified as follow:

$$Y_{it} = f(\mathbf{X}_{it};\boldsymbol{\beta}).\exp(v_{it} - u_{it}) \quad (1)$$

$$u_{it} = \mathbf{z}_{it}\boldsymbol{\delta} + \omega_{it} \quad (2)$$

where Y_{it} denotes the scalar output of firm i *(i=1, 2, ..., N)* at time t *(t=1,2,...,T)*, $\mathbf{X}_{it}$ is a *(1xk)* vector of inputs used by firm i at time t, $\boldsymbol{\beta}$ is a *(kx1)* vector of unknown parameters to be estimated; the v_{it} is a random error; u_{it} is the technical inefficiency effect; $\mathbf{z}_{it}$ is a *(1xm)* vector of observable non-stochastic explanatory variables affecting technical inefficiency for firm i at time t, $\boldsymbol{\delta}$ denotes a *(mx1)* vector of unknown parameters of the inefficiency effect to be estimated; ω is an unobservable random error.

Based on the theoretical model in Equations (1) and (2), this study starts with a flexible *translog* (Transcendental Logarithmic) production frontier. This frontier is characterized by a non-fixed substitution elasticity and is therefore subject to fewer constraints than a general logarithm linear model (Christensen *et al.*, 1973; Heathfield and Wibe, 1987). In addition, the *translog* functional form provides more generalized estimates than other logarithm linear models as it imposes relatively fewer *a priori* restrictions on the structure of production (Kopp and Smith, 1980). Therefore, adopting a *translog* functional form might reduce the risk of error in the model specification.
The functional form of the *translog* production frontier is as follows:

$$\begin{aligned} \ln y_{it} = \beta_0 &+ \beta_L \ln L_{it} + \beta_K \ln K_{it} + \beta_M \ln M_{it} + \beta_E \ln E_{it} + \beta_{LL}\left[\ln L_{it}\right]^2 + \beta_{LK}\left[\ln L_{it} * \ln K_{it}\right] \\ &+ \beta_{LM}\left[\ln L_{it} * \ln M_{it}\right] + \beta_{LE}\left[\ln L_{it} * \ln E_{it}\right] + \beta_{KK}\left[\ln K_{it}\right]^2 + \beta_{KM}\left[\ln K_{it} * \ln M_{it}\right] \\ &+ \beta_{KE}\left[\ln K_{it} * \ln E_{it}\right] + \beta_{MM}\left[\ln M_{it}\right]^2 + \beta_{ME}\left[\ln M_{it} * \ln E_{it}\right] + \beta_{EE}\left[\ln E_{it}\right]^2 + \beta_t t \\ &+ \beta_{Lt}\left[\ln L_{it} * t\right] + \beta_{Kt}\left[\ln K_{it} * t\right] + \beta_{Mt}\left[\ln M_{it} * t\right] + \beta_{Et}\left[\ln E_{it} * t\right] + \beta_{tt} t^2 + v_{it} - u_{it} \end{aligned} \quad (3)$$

where y represents output, L represents labour, K is capital, M is material, E is energy, t is time, i is firm, βs are parameters to be estimated, ln denotes natural logarithm, v_{it} is the stochastic error term, and u_{it} is the technical inefficiency. In this study, the technical inefficiency effect is a function of a set of FDI variables: foreign ownership (*FDI*), horizontal spillover (*FDIHorisontal*), backward spillover (*FDIBackward*), and forward spillover (*FDIForward*); Also included are a set of other variables affecting efficiency, age of firm (*AGE*) and a dummy crisis (*CRISIS*). Hence, the inefficiency function can be written as:

$$\begin{aligned} u_{it} = \delta_0 &+ \delta_1 FDI_{it} + \delta_2 FDIHorisontal_{it} + \delta_3 FDIBackward_{it} + \delta_4 FDIForward_{it} \\ &+ \delta_5 AGE_{it} + \delta_6 CRISIS_{it} + w_{it} \end{aligned} \quad (4)$$

where w is an error term.

Various sub-models of the *translog* are considered and tested under a number of null hypotheses, given the specification of the *translog* model in Equation (3). A null hypothesis of the second order parameters equal zero (*i.e.*

$\beta_{LL} = \beta_{LK} = \beta_{LM} = \beta_{LE} = \beta_{KK} = \beta_{KM} = \beta_{KE} = \beta_{MM} = \beta_{ME} = \beta_{EE} = 0$) is to test whether the Cobb-Douglas frontier is appropriate for the data set, and a null hypothesis of the interacting parameters of input and time equal zero (*i.e.* $\beta_{Lt} = \beta_{Kt} = \beta_{Mt} = \beta_{Et} = 0$) is for a Hicks-neutral technological progress. Similarly, a null hypothesis of the time parameters equal zero (*i.e.* $\beta_t = \beta_{tt} = \beta_{Lt} = \beta_{Kt} = \beta_{Mt} = \beta_{Et} = 0$) is for a no technology progress in the frontier, and a null hypothesis of the parameters of inefficiency function equal zero (*i.e.* $\gamma = \delta_0 = \delta_1 = \ldots = \delta_6 = 0$) are for a no-inefficiency effect. γ is a parameter associated with variance of inefficiency effect, u_{it}, in the Battese and Coelli's (1995) model. If γ is zero, the model reduces to a traditional mean response function in which the variables, *FDI*, *FDIHorizontal*, *FDIBackward*, *FDIForward*, *AGE*, and *CRISIS*, can be directly included into the production frontier.

For performing tests of the relevant null hypotheses, a generalized likelihood ratio statistic is employed. This ratio statistic can be expressed as follow

$$\lambda = -2\left[l(H_0) - l(H_1) \right] \tag{5}$$

where $l(H_0)$ is the log-likelihood value of the restricted frontier model, and $l(H_1)$ is the log-likelihood value of the model defined in Equation (3). If the null hypothesis is true, the test statistic has approximately a *chi*-square distribution with degrees of freedom equal to the number of parameters involved in the restrictions. The test statistic under the null hypothesis of no inefficiency effects has approximately a mixed *chi*-square distribution, and the critical value for this test is taken from Table 1 of Kodde and Palm (1986).[1]

The computer program FRONTIER4.1 is used to jointly estimate the stochastic production frontier of Equation (3) and the inefficiency function of Equation (4) under the maximum likelihood method (Coelli, 1996).[2] This computer program follows a three-step estimation method to obtain the final maximum likelihood estimates. The first step estimates the frontier production function in Equation (3) using OLS and obtains all β estimators, which are unbiased (except the intercept, β_0). In the second step, a two-phase grid search for γ is conducted; with the β parameters (except β_0) set to the OLS values, the β_0 and σ_S^2 parameters adjusted to the Corrected OLS (COLS) values and other parameters set to zero.[3] The third step applies an iterative procedure of the *Davidon-Fletcher-Powell Quasi-Newton* method to obtain final maximum likelihood estimates using the value selected in the grid search as starting values.

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[1] For explanation regarding a mixed *chi*-square and a test for no inefficiency effect, see Battese and Coelli (1988).

[2] FRONTIER4.1 was developed by Tim Coelli in the Department of Econometrics, University of New England. The program, written in Shazam, can be run on an IBM-PC. In this program, the execution of a stochastic frontier model can be either by modifying the available instruction file or writing a program language. This program is available online from the Centre for Efficiency and Productivity Analysis website (http://www.uq.edu.au/economics/cepa/frontier.htm). A detailed procedure for running FRONTIER4.1 is discussed in Coelli (1996).

[3] σ_S^2 is a parameter associated with the variance of random variable v_{it} in the Battese and Coelli's (1995) model.

Data Sources and Construction of the Dataset

1 Description of Data Sources

The primary data source in this study is the Annual Surveys of medium and large manufacturing establishments (*Survei Tahunan Statistik Industri* or SI) conducted by the Indonesian Central Board of Statistics (*Badan Pusat Statistik* or BPS). The data are available in an electronic format (d-base file) and can be obtained under a license. The survey covers the basic information of each establishment, such as specific identification code, industrial classification, year of starting production, and location. It also covers the ownership information (domestic and foreign ownerships), production information (gross output, number of workers in production and non-production, value of fixed capital and investment, material, and energy consumption), and other information (share of production exported, value of material imported, and expenditure on research and development). The numbers of establishments surveyed vary with the year of survey, with the minimum number of 7,469 manufacturing establishments in 1975 and the maximum number of 21,671 establishments in 1996.

The annual surveys (SI) have been conducted since 1975, and the recent available data are for the year 2005. However, this study uses only the period of data from 1988 to 2000. The year of 1988 is chosen as a starting year because the data on the replacement value of capital are not available before 1988. The 2001 to 2005 period is excluded, because the BPS changed the specific identification code in 2001 to 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 don't yield reliable results. Therefore, the longest possible period for this study is 1988-2000.

The classification of the establishment-level data in SI is up to five-digit industrial codes. This classification is based on the Indonesian Commodity Classification (*Klasifikasi Komoditi Indonesia* or KKI), which basically follows the International Standard Industrial Classification (ISIC) with some modification to suit Indonesian conditions. During the observation years, from 1988 to 2000, the KKI was reclassified twice in order to accommodate the growing number of manufacturing establishments and to comply with the revisions of ISIC.

The first reclassification took place in 1990 when the last digit of five-digit KKI was updated for some sub-sectors (in this case, the BPS replaced KKI-1985 with KKI-1990). For example, the basic organic and inorganic chemicals sub-sector (*i.e.* the 35110 manufacturing code) was updated into nine sub-sectors, namely inorganic chloral and alkaline (the 35111 code), industrial gas (35112), inorganic pigment (35113), inorganic chemicals not else classified (35114), organic chemicals from woods and gum (35115), organic pigment (35116), organic chemicals from oil and gases (35117), special organic chemicals (35118), and organic chemicals that not else classified (35119).

The second reclassification was published in 1998 to follow the change in ISIC, from ISIC Revision 2 to ISIC Revision 3 (the KKI-1990 was changed into KKI-1998). In this reclassification, the BPS changed completely the manufacturing code. For example, the code for bakeries was 31179 in KKI-1990, but it was changed to 15410 in KKI-1998.

As a supplementary for the SI, this study also utilizes data from several sources when constructing the final panel dataset. The types and sources of the supplementary data are presented in Table 1. The wholesale price index (WPI) is used as a monetary deflator for output and material. Similarly, the machinery price index and the electricity price index are used as a deflator for capital and electricity, respectively. To deflate the monetary value of fuel, the fuel price index is calculated from the OPEC fuel basket price from *DX for Windows*.[4] The input-output tables are used for calculating spillover variables for downstream and upstream industries (*i.e.* variables of backward and forward spillovers).

Table 1. Sources and Descriptions of Data

No.	Data	Source	Description
Primary Data			
1	Survey of Industries (SI)	The Indonesian Central Board of Statistics (BPS)	The SI is an annual survey of medium and large manufacturing establishments, which cover up to 21,671 establishments with at least 20 employees and consist of more than 160 variables.
Supplementary Data			
2	Wholesale Price Index (WPI)	The Indonesian Central Board of Statistics (BPS)	The WPI used in this study is a WPI of 150 commodities categorized by ISIC four-digit.
3	WPI of Machinery	The Indonesian Central Board of Statistics (BPS)	The machinery price index covers prices of all machinery, except electricity machinery, used by manufacturing industries.
4	WPI of Electricity	The Indonesian Central Board of Statistics (BPS)	The electricity price index is calculated from the price of electricity supplied by the state energy company (*Perusahaan Listrik Negara* or PLN) and published by the BPS as a part of the WPI.
5	Fuel Price Index	*DX* for Windows	The fuel price index is calculated from the OPEC fuel basket prices.
6	Input-Output Table	The Indonesian Central Board of Statistics (BPS)	The Indonesian input-output table consists of the value of inputs used by sector i from sector j and value of output sold to sector j by sector i at a certain year. It captures 161 sectors of all industries in Indonesia. For the purpose of this study, only input-output values of manufacturing industries (88 sectors) are used.

Source: Author's compilation

2 Procedure for Constructing a Consistent Balanced Panel Set

Constructing a consistent and integrated dataset is necessary for obtaining reliable and unbiased empirical analysis. In this study, the possible inconsistency and other problems in the SI data are identified. A consistent and integrated balance panel set is then constructed by following several steps of adjustment. The steps of adjustment are described as follow:

Step 1: Adjustment for industrial code.

As noted above, the BPS reclassified the industrial codes twice: in 1990 and 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

[4] The OPEC fuel prices are converted from US$ values to Indonesia rupiah (IDR) using average yearly exchange rates published by the central Bank of Indonesia in Statistics of Economic and Finance Indonesia (*Statistik Ekonomi dan Keuangan Indonesia* or SEKI).

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 1,346 out of the original 29,340 establishments. Second, the data from 1998 to 2000 (which use KKI-1998) are adjusted to KKI-1990 by following the 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.[5] 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 3,078 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 applies 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 is 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 is 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 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

[5] 1,732 out of 22,175 establishments are removed since they are only assigned with two- and three digit industrial codes.

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). The replacement values of fixed capitals are regressed against the one-year lagged output in order to obtain the estimated coefficient of capital. The estimated coefficient is then used to calculate the predicted values of fixed capital for the missing data.

Step 5: Matching firms for a balanced panel

A balanced panel dataset 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 4-digit ISIC industries); the machinery price index is used for deflating the value of capital; the nominal values of energy are a sum of electricity and fuel expenditures, which are deflated using the electricity price index and the fuel price index. All price indexes are at a constant price of 1993.

By following the steps of adjustment, the final balanced panel dataset consists of 3,218 establishments with 43,134 observations.

Definition and Measurement of Variables

A crucial part in empirical studies is the measurement of variables. The reliability of empirical results depends heavily on the accuracy of measures of variables. From the available SI data, supported by the most up-to-date information from the literature, this study constructs variables for the empirical model in Equations (3) and (4). The variables are divided into two groups based on the two simultaneous equations: a stochastic production frontier and an inefficiency function. The variables for the inefficiency function are divided further into two, namely FDI variables and other variables. The constructions of the variables are discussed below and the definitions are given in Table 2.

Table 2. Definitions of Variables

Variables	Definition
Production Function	
Y	Output (in million rupiah), which is deflated using a wholesale price index (WPI) at a constant price of 1993
L	Labor (number of workers) is the total number of employees directly and indirectly engaged in productions
K	Capital (million rupiah), which is deflated using WPI for machinery at a constant price of 1993
M	Material (million rupiah), which is deflated using a wholesale price index at a constant price of 1993
E	Energy (million rupiah) is the sum of electricity and fuel expenditures, which are deflated using a WPI for electricity and fuel price index at a constant price of 1993
Inefficiency Function	
FDI	Foreign ownership, which is measured by a dummy variable: 1 if the share of foreign ownership is greater than 0 percent; and 0 if otherwise.

FDIHorisontal	Spillovers of FDI on domestic firms in the same industries, which is measured by the share of foreign firms' output over total output of the five-digit industry
FDIBackward	Spillovers of FDI on upstream industries, which is calculated from the share of the total output of an industry that is sold to foreign buyers across all five-digit industries.
FDIForward	Spillovers of FDI on downstream industries, which is calculated from the share of the total output of an industry that is bought from foreign suppliers across all five-digit industries.
Age	Age of firms is measured by the different between year of survey and year of starting production
Crisis	Economic crisis is measured by a dummy variable: 1 if the year of observation is 1997 onward, and 0 if the year of observation is before 1997.

Results and Interpretation

1 Testing For Model Specification

Given the general *translog* frontier, as specified in Equations (3), this study tests a number of null hypotheses for finding the appropriate model for the dataset. The results of the relevant null hypotheses tests are presented in Table 4. The first null hypothesis is to confirm whether the Cobb-Douglas production frontier is an appropriate specification for the dataset, by imposing the following restrictions: $\beta_{LL} = \beta_{LK} = \beta_{LM} = \beta_{LE} = \beta_{KK} = \beta_{KM} = \beta_{KE} = \beta_{MM} = \beta_{ME} = \beta_{EE} = 0$, on Equation (1). The result of the log-likelihood test shows a strong rejection of the null hypothesis at the 1% level of significance, suggesting that the Cobb-Douglas model is an inappropriate specification, given the *translog* model.

Table 4. Log-Likelihood Tests for Model Specification of the Stochastic Production Frontier

Restrictions	Full Samples	Critical Values (α=0.10)	Critical Values (α=0.05)	Critical Values (α=0.01)
Cobb-Douglas ($\beta_{LL}=\beta_{LK}=\beta_{LM}=\beta_{LE}=\beta_{KK}=\beta_{KM}=\beta_{KE}=\beta_{MM}=\beta_{ME}=\beta_{EE}=0$)	9801.42***	22.31	25	30.58
Hicks-Neutral ($\beta_{Lt}= \beta_{Kt} = \beta_{Mt} = \beta_{Et} =0$)	266.34***	7.78	9.49	13.28
No TP ($\beta_{t}=\beta_{tt}= \beta_{Lt}= \beta_{Kt} = \beta_{Mt} = \beta_{Et} =0$)	69.22***	10.64	12.59	16.81
No Inefficiency Effect ($\gamma=\delta_0=\delta_1= \ldots =\delta_6=0$)	1403.86***	7.09	8.76	12.48

Source: Author's calculations. Note: the log-likelihood ratio statistics are calculated from Equation (3) based on the restricted and unrestricted models for horizontal spillovers. The log-likelihood ratio statistics on models for backward spillovers or forward spillovers provide similar conclusions. ***, **, and * denote significance at 1%, 5%, and 10%, respectively. The critical values are based on Chi-squared distribution. For the null hypothesis of no-inefficiency effect, the critical value is based on a mixed chi-squared distribution provided by Kodde and Palm (1986).

The second null hypothesis test, for Hicks-neutral technical progress (TP) under a restriction: $\beta_{Lt} = \beta_{Kt} = \beta_{Mt} = \beta_{Et} = 0$, also rejects the null hypothesis, but the levels of significance vary between 1% and 10%. Similarly, when imposing a restriction: $\beta_t = \beta_{tt} = \beta_{Lt} = \beta_{Kt} = \beta_{Mt} = \beta_{Et} = 0$, for a null hypothesis of no-technological progress (TP), the statistical results suggest that the no-TP specification is inappropriate, given the *translog* specification. The last null hypothesis for no inefficiency effect, which imposes the restriction: $\gamma = \delta_0 = \delta_1 = ... = \delta_6 = 0$, shows also a rejection of null hypothesis at the 1% level of significance.

Given these statistical results, one can conclude that the flexible *translog* model, as specified in Equation (1), appears to be the appropriate specification for the firms in the analysis. Therefore, the estimations of the stochastic frontiers in this study follows the *translog* production frontier.

2 FDI Spillover Effects on Manufacturing Firms

Using the *translog* stochastic frontier and the inefficiency function specified in Equations (3) and (4), this study begins the estimation of FDI spillover effects for all manufacturing firms in the dataset. Three spillover variables, as constructed above, are used for testing the spillover hypothesis. These three variables are estimated separately because the partial correlation tests shows that these variables are moderately correlated each other, particularly between *FDIHorizontal* and *FDIForward*, which have a 0.82 correlation coefficient. Estimating them together in one equation may result in a near multicollinearity problem, with a consequence of insignificance in estimated coefficients (Gujarati, 2003). The selected parameter estimates for the manufacturing firms are presented in Table 5.

The first three columns of Table 5 display estimation results for all manufacturing establishments using three different spillover variables. The coefficients of the *translog* stochastic production frontier (the upper part of the table) has no immediate economic implication, as the impacts of each input to output depend on the combination of the coefficients of all terms involving the input (first and second orders). Therefore, output elasticity with respect to labour, capital, material and energy, along with return to scale coefficients, has been calculated.[6] The annual average industry-wise elasticities and return to scale (RTS) coefficients are presented in Appendix 1. The firm-specific results are not presented due to space limitation but can be obtained from the author upon request.

From the calculated elasticity scores, it is apparent that the average output elasticity with respect to labour is positive for all the observed years, ranging from 0.20 to 0.23 (Appendix 2). Similarly, the elasticity to capital and elasticity to material are also positive, with the average scores of 0.09 for the former and 0.69 for the latter. The same is also true for energy, as the average scores of output elasticity are positive. Furthermore, the four output elasticity scores sum up to return to scale (RTS) coefficient. The annual average score of RTS is 1.06 between 1988 and 2000, suggesting an increasing return to scale (IRTS) of the Indonesian manufacturing industry.[7] This average RTS increases steadily during the observed years, from 1.03 in 1988 to 1.14 in 2000, indicating that the benefits of operating on a larger scale have been increased over time.

The finding of increasing returns to scale is consistent with the rejection of the Cobb-Douglas function, which basically assumes constant return to scale. The increasing

[6] The output elasticity of each input is obtained by taking a partial derivative of the *translog* model and evaluating them at particulate values of variables. Based on the *translog* model in Equation (3), the output elasticity of labour is defined as $\varepsilon_L = \beta_L + 2\beta_{LL}[lnL] + \beta_{LK}[lnK] + \beta_{LM}[lnM] + \beta_{LE}[lnE] + \beta_{LT}T$. Similarly, the output elasticity of capital, material, and energy are obtained by the partial derivatives of output to capital, output to material, and output to energy, respectively.

[7] The slightly larger than one of average RTS also suggests that larger firms might have slight cost advantages relative to smaller firms.

returns to scale are mostly contributed by the output elasticity of material (ranging from 0.62 to 0.80 during the observed years), which is not surprising given the heavy reliance on raw material and the nature of the industry. As argued by Aswicahyono (1998), Indonesian manufacturing products are mostly either natural resource based or simple assembly processed, which make the industry rely heavily on material input. In contrast, the output elasticity of capital is relatively low, suggesting a low capital intensity. This result may need to be interpreted with caution as capital is a key factor for output growth. However, this result is somehow unsurprising as the share of capital in total industry outputs is usually low in labour-intensive environment, such as the Indonesian manufacturing industry. High elasticity of capital, as argued by Wacker *et al.* (2006), is usually observed only in manufacturing industries that rely heavily on advanced technologies. Nevertheless, the results are consistent with findings in previous studies on Indonesian manufacturing firms that use more than two factor inputs (Amiti and Konings, 2005; Ikhsan, 2007).

Moving to the inefficiency function (the lower part of Table 5), the estimated coefficients of *FDI* (which take the value of one if the firm is a foreign-owned firm and zero if the firm is a domestic firm) are negative and highly significant at the 1% level, suggesting that foreign-owned firms are, on average, less inefficient than domestic firms, keeping other variables constant. This result supports the mainstream premise that foreign firms generally possess more updated knowledge and have more experience in serving markets, so that they are more efficient than domestic firms.

As expected, the coefficient of *FDIHorizontal* has a negative sign and is statistically significant at the 1% level, meaning that the presence of FDI reduces inefficiency of firms in the same five-digit industries. Similarly, *FDIBackward* and *FDIForward* have also negative and highly significant coefficients, which indicate negative effects of FDI on technical inefficiency (or positive technical efficiency spillovers) on suppliers and buyers, respectively. Although this study uses a longer time period by including the period of crisis, the findings are in line with Blalock and Gertler (2008) and Takii (2005) on the ground that FDI at the industrial level generates positive spillovers to firms in the same industries, firms in upstream industries, and firms in downstream industries.

With regard to variables not associated with foreign ownership, the coefficient of Age is positive for the three spillover models but it is significant only for the horizontal spillover model (the first column of Table 5). This is not a surprise since the impact of age to firms' efficiencies is still a matter of debate in the literature, as noted in Section 5.4.3.1. An older firm could have a higher efficiency due to knowledge accumulation through learning experience, while a younger firm might be more efficient because of possessing up-dated knowledge. Nevertheless, the result is consistent with findings in Lundvall and Battese (2000) for Kenya and Kathuria (2001) for India. Similarly, the coefficients of crisis also show inconclusive findings, with positive and significant effects on inefficiency in horizontal and backward spillover models, but with negative insignificant effects in the forward spillover model. This demonstrates the argument in literature that the impacts of crisis on firms are uneven and depend on heterogeneous characteristics of firms (for example, Narjoko and Hill, 2007).

Table 5. Estimates of Stochastic Production Frontiers on the FDI Spillover Effects in the Indonesian Manufacturing Firms

Variable	Horisontal Spillovers 1 (All firms)	Backward Spillovers 1 (All firms)	Forward Spillovers 1 (All firms)
Production Frontier (Dependent Variable: lnY)			
Constant	1.144***	1.214***	1.117***
	(37.08)	(37.58)	(37.01)
lnL	0.601***	0.608***	0.614***
	(32.87)	(30.65)	(31.07)
lnK	0.180***	0.177***	0.175***
	(17.34)	(16.01)	(15.86)
lnM	0.212***	0.198***	0.192***
	(19.41)	(18.03)	(17.16)
lnE	0.244***	0.253***	0.255***
	(26.16)	(27.08)	(27.42)
$[\ln L]^2$	0.014**	0.011*	0.011**
	(2.42)	(1.84)	(1.96)
lnL*lnK	0.043***	0.041***	0.040***
	(9.73)	(8.65)	(8.38)
lnL*lnM	-0.174***	-0.171***	-0.171***
	(-39.88)	(-38.12)	(-3.82)
lnL*lnE	0.067***	0.067***	0.066**
	(13.93)	(13.81)	(13.76)
$[\ln K]^2$	-0.003**	-0.002*	-0.002*
	(-2.38)	(-1.74)	(-1.70)
lnK*lnM	-0.071***	-0.073***	-0.073***
	(-28.17)	(-28.54)	(-28.28)
lnK*lnE	0.057***	0.058***	0.059***
	(22.86)	(21.32)	(21.86)
$[\ln M]^2$	0.164***	0.165***	0.165***
	(98.82)	(99.87)	(100.50)
lnM*lnE	-0.143***	-0.143***	-0.143***
	(51.52)	(-51.12)	(-51.64)
$[\ln E]^2$	0.023***	0.022***	0.021***
	(17.69)	(14.76)	(10.59)
T	0.006***	0.006***	0.005***
	(3.79)	(2.88)	(2.96)
lnL*T	-0.001	-0.000	0.001
	(0.54)	(-0.60)	(0.76)
lnK*T	-0.000	-0.000	-0.002
	(-0.26)	(-0.14)	(-0.51)
lnM*T	0.001*	0.001	0.001***
	(1.83)	(1.37)	(3.41)
lnE*T	-0.004	-0.000***	-0.001**
	(-1.05)	(-3.69)	(-2.02)
T^2	-0.001***	-0.000***	-0.001***
	(-5.81)	(-3.69)	(-8.78)
Inefficiency Function (Dependent Variable: u)			
Constant	0.078***	0.124***	0.062***
	(21.59)	(16.05)	(23.09)
FDI	**-0.008*****	**-0.011*****	**-0.010*****
	(-6.56)	(-8.82)	(-10.76)
FDIHorizontal	**-0.126*****	-	-
	(-88.00)		
FDIBackward	-	**-0.085*****	-
		(-18.88)	
FDIForward	-	-	**-0.124*****
			(-25.00)
Age	0.002***	0.000	0.000
	(3.30)	(0.49)	(0.37)
Crisis	0.015***	0.017***	-0.002
	(6.91)	(4.67)	(-1.00)
Sigma-squared	0.033***	0.033***	0.033***
	(195.31)	(144.52)	(140.34)
Gamma	0.005***	0.024***	0.001***
	(20.78)	(10.66)	(8.32)

Source: Author's Calculation using the model specified in Equations (3) and (4). Notes: The t-statistics are in parenthesis. *** denotes 1% significance level, ** denotes 5% significance level, and * denotes 10% significance level.

Table 6. Output Elasticity of Inputs and Return to Scale (RTS) for the Indonesian Manufacturing Sector

Year	Labour	Capital	Material	Energy	RTS
1988	0.22	0.09	0.62	0.10	1.03
1989	0.22	0.09	0.63	0.09	1.03
1990	0.21	0.08	0.66	0.08	1.03
1991	0.22	0.09	0.63	0.09	1.03
1992	0.20	0.08	0.67	0.08	1.03
1993	0.21	0.09	0.66	0.08	1.04
1994	0.21	0.09	0.67	0.07	1.05
1995	0.20	0.09	0.69	0.07	1.06
1996	0.20	0.09	0.72	0.06	1.07
1997	0.20	0.09	0.73	0.06	1.08
1998	0.21	0.10	0.73	0.06	1.10
1999	0.21	0.10	0.76	0.06	1.12
2000	0.20	0.09	0.80	0.05	1.14
1998-1992	0.22	0.09	0.64	0.09	1.03
1993-1996	0.21	0.09	0.68	0.07	1.05
1997-2000	0.21	0.09	0.75	0.06	1.11
1988-2000	0.21	0.09	0.69	0.07	1.06

Source: Author's calculation from the estimates of stochastic production frontier for all firms under the horizontal spillover model (second column of Table 5)

3 FDI Spillovers to R&D and Non-R&D Firms

Research and development (R&D) is a key absorptive capacity for domestic firms to gain FDI spillover benefits. Firms with R&D are likely to receive higher spillover benefits than those without R&D. Incorporating this argument and testing whether it applies in the Indonesian manufacturing sector, this study estimates Equations (3) and (4) on a group of R&D firms and non-R&D firms, separately. Table 7 presents the estimates of these two groups. Interestingly, the estimates show that both R&D and non-R&D firms receive positive horizontal, backward, and forward spillovers from FDI, as suggested by the negative sign and statistical significance of estimates for the three spillover measures. However, coefficients of spillover variables for the first group are greater than those for the second group, indicating that the magnitude of spillovers is larger for the R&D firms than for the non-R&D firms. This finding is not a surprise since R&D firms are generally having up-to-date knowledge. The finding confirms the argument that R&D expenditure increases firms' ability to absorb FDI spillover benefits, which are in line with findings by Kathuria (2002) for India and Marcin (2008) for Poland. This finding justifies that firms with larger absorptive capacities, such as those with R&D expenditure, will receive higher spillover effects from FDI if compared to firms with smaller, which have no R&D expenditure.

Table 6 Estimates of Stochastic Production Frontiers on the FDI Spillover Effects: The Importance of Research and Development (R&D)

Variable	Horisontal Spillovers (R&D Firms)	Backward Spillovers (R&D Firms)	Forward Spillovers (R&D Firms)	Horisontal Spillovers (Non-R&D)	Backward Spillovers (Non-R&D)	Forward Spillovers (Non-R&D)
Production Frontier (Dependent Variable: lnY)						
Constant	0.575***	0.741***	0.816***	1.072***	1.20***	1.178***
	(6.21)	(8.69)	(7.18)	(33.98)	(35.00)	(33.03)
lnL	0.582***	0.641***	0.608***	0.535***	0.571***	0.574***
	(9.49)	(17.30)	(9.91)	(25.06)	(25.76)	(26.32)
lnK	0.216***	0.183**	0.186***	0.234***	0.206***	0.207***
	(6.16)	(2.42)	(5.30)	(20.27)	(17.17)	(17.20)
lnM	0.321***	0.289***	0.269***	0.208***	0.167***	0.169***
	(9.57)	(6.03)	(7.45)	(17.63)	(13.06)	(13.62)
lnE	0.334***	0.321***	0.335***	0.248***	0.256***	0.257***
	(8.58)	(10.63)	(8.49)	(25.22)	(26.05)	(26.04)
$[\ln L]^2$	0.016	0.031***	0.148	0.017***	0.012*	0.014**
	(1.04)	(3.64)	(0.96)	(2.70)	(1.89)	(2.17)
lnL*lnK	0.016	0.016***	0.019	0.060***	0.052***	0.054***
	(1.30)	(11.48)	(1.55)	(11.67)	(9.98)	(10.36)
lnL*lnM	-0.131***	-0.160*	-0.139***	-0.179***	-0.173***	-0.176***
	(-11.21)	(-1.95)	(-11.93)	(-36.31)	(-34.55)	(-34.92)
lnL*lnE	0.054***	0.065	0.055***	0.063***	0.062***	0.061***
	(3.60)	(1.12)	(3.57)	(12.37)	(12.11)	(12.04)
$[\ln K]^2$	0.014***	0.011	0.010***	-0.009***	-0.007***	-0.008***
	(4.99)	(0.69)	(3.12)	(-7.14)	(-5.32)	(-6.14)
lnK*lnM	-0.080***	-0.079***	-0.070***	-0.070***	-0.073***	-0.072***
	(-11.96)	(-4.94)	(-9.79)	(-25.03)	(-25.46)	(-24.98)
lnK*lnE	0.031***	0.031	0.033***	0.053***	0.060***	0.060***
	(3.53)	(1.64)	(3.73)	(18.74)	(20.15)	(20.66)
$[\ln M]^2$	0.150***	0.148***	0.149***	0.162***	0.167***	0.167***
	(35.88)	(78.40)	(34.51)	(90.57)	(81.65)	(89.88)
lnM*lnE	-0.143***	-0.132***	-0.138***	-0.139***	-0.142***	-0.143***
	(17.48)	(-76.61)	(-16.63)	(-46.56)	(-44.89)	(-47.69)
$[\ln E]^2$	0.033***	0.024	0.030***	0.023***	0.021***	0.021***
	(5.48)	(1.36)	(4.91)	(15.45)	(13.75)	(14.14)
T	0.014**	0.020***	0.016***	0.011***	0.006***	0.006***
	(2.34)	(5.49)	(2.69)	(6.05)	(2.90)	(2.90)
lnL*T	-0.001	-0.001	-0.001***	0.001*	-0.002**	-0.002**
	(-0.65)	(-0.40)	(-0.29)	(-1.74)	(-1.99)	(-1.98)
lnK*T	0.002	0.001	0.002	-0.001**	-0.001*	-0.001*
	(1.27)	(1.23)	(1.48)	(-2.31)	(-1.73)	(-1.71)
lnM*T	-0.004***	-0.004***	-0.003**	0.002***	0.002***	0.003***
	(-3.00)	(-3.26)	(-2.28)	(3.34)	(5.06)	(5.39)
lnE*T	0.002	0.002***	0.001	-0.000	-0.001	-0.001*
	(1.56)	(3.39)	(0.71)	(-0.46)	(1.58)	(-1.66)
T^2	-0.000***	-0.001	-0.001***	-0.001***	-0.001***	-0.001***
	(2.50)	(-0.98)	(-3.61)	(-7.44)	(-4.06)	(-5.30)
Inefficiency Function (Dependent Variable: u)						
Constant	0.104***	0.092***	0.117***	0.066***	0.059***	0.049***
	(14.97)	(10.66)	(11.13)	(15.46)	(15.72)	(8.76)
FDI	-0.078***	-0.148**	-0.186***	-0.419***	-0.264***	-0.201***
	(-2.60)	(-2.40)	(-12.96)	(-44.33)	(-29.84)	(-18.33)
FDIHorizontal	-0.107***	-	-	-0.049***	-	-
	(-13.73)			(-3.18)		
FDIBackward	-	-0.114***	-	-	-0.065***	-
		(-28.24)			(-17.30)	
FDIForward	-	-	-0.125***	-		-0.069***
			(-5.25)			(-4.50)
Age	0.001***	0.000	0.000	0.001***	0.001**	0.000**
	(5.09)	(1.34)	(0.034)	(16.75)	(1.99)	(1.98)
Crisis	0.028***	0.027	-0.013	-0.004*	0.022***	0.020***
	(6.49)	(0.17)	(-0.97)	(-1.92)	(7.30)	(4.49)
Sigma-squared	0.042***	0.042**	0.041***	0.030***	0.031***	0.031***
	(65.25)	(2.14)	(59.85)	(266.13)	(126.89)	(130.61)
Gamma	0.006***	0.045**	0.005***	0.070***	0.025***	0.015***
	(2.63)	(2.36)	(4.21)	(17.99)	(16.12)	(9.13)

Source: Author's Calculation using the model specified in Equations (3) and (4). Notes: The t-statistics are in parenthesis. *** denotes 1% significance level, ** denotes 5% significance level, and * denotes 10% significance level.

Conclusions

This study has examined the spillover effects of FDI on firm-level productivity in Indonesian manufacturing industry. Utilizing data from Annual Survey of Indonesian manufacturing firms and employing the Battese and Coelli (1995) stochastic production frontier model, this study finds that FDI generates positive spillover effects on firm-level productivity. An interesting finding emerges when the samples are divided into two groups: firms with R&D spending and firms without R&D spending. The results show that the group of firms with R&D spending receives larger magnitude of spillovers than the group of firms without R&D spending. These findings justify the argument of the importance of absorptive capacity in gaining the productivity spillovers from FDI.

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