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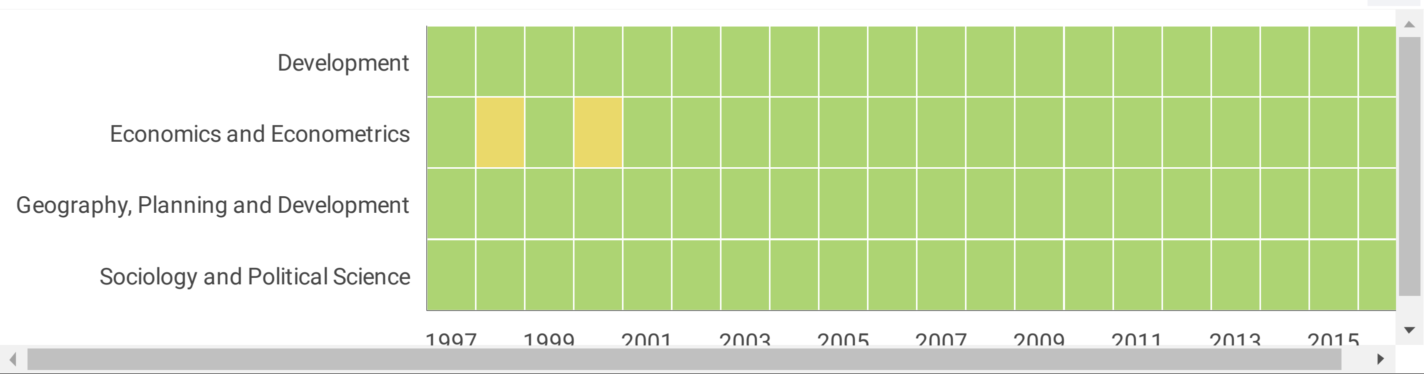

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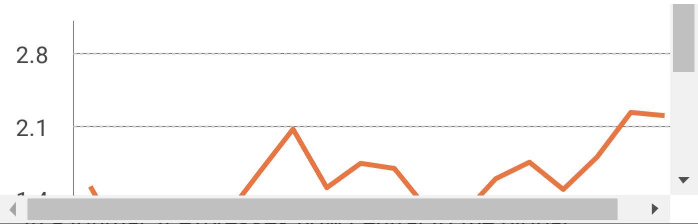

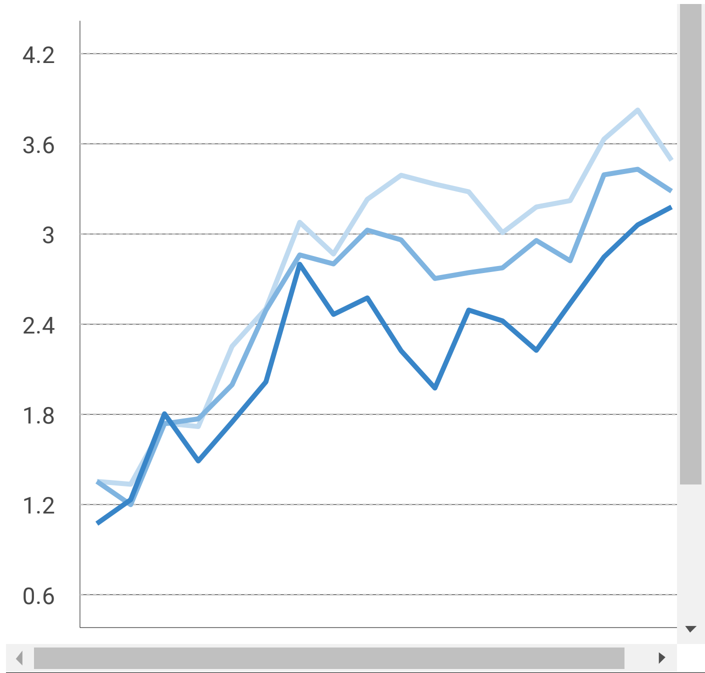

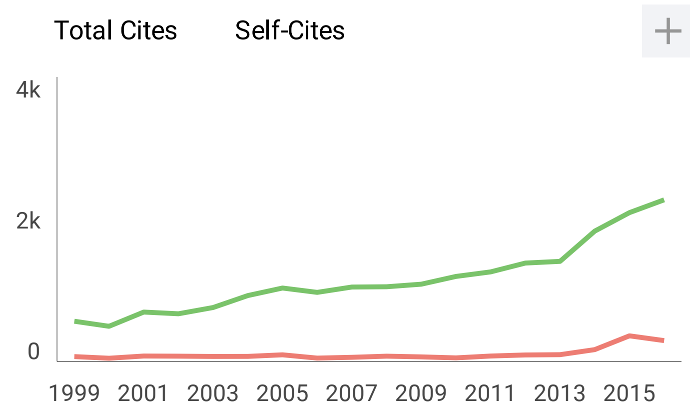

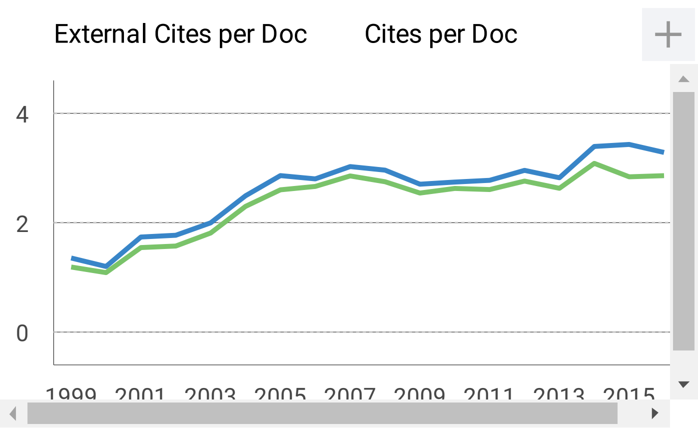

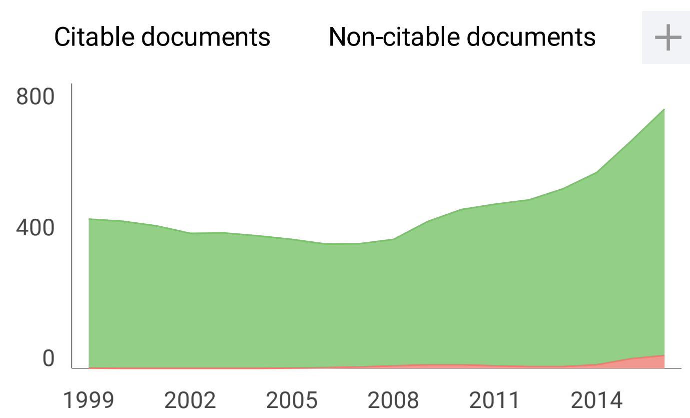

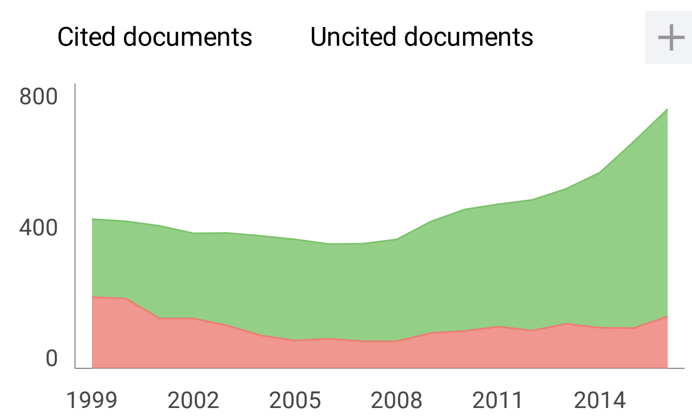

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Does Foreign Direct Investment Lead to Productivity Spillovers? Firm Level Evidence from Indonesia

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Summary. — This paper examines whether spillovers from foreign direct investment (FDI) make any contribution to productivity growth in the Indonesian chemical and pharmaceutical firms using plant-level panel data. The spillover effects from FDI are analyzed using a stochastic frontier approach and productivity growth is decomposed using a generalized *Malmquist* output-oriented index. The results show positive productivity spillovers from FDI; higher competition is associated with larger spillovers; and domestic firms with R&D gain more spillover benefits compared to those without R&D. FDI spillovers are found to be positive and significant for technological progress and positive, but not significant, for technical and scale efficiency change.

Key words — FDI spillovers, frontier production function, *Malmquist* index, total factor productivity growth

1. INTRODUCTION

Foreign direct investment (FDI) is believed to provide recipient countries with knowledge [1] transfer as well as capital. The argument is that multinational corporations (MNCs) establish subsidiaries in overseas and transfer knowledge to their subsidiaries. The transferred knowledge has a certain public good quality and may spread through non-market mechanisms over the entire economy leading to productivity gains (hereafter productivity spillovers) in domestic firms (Blomstrom, 1989).

Expectation of productivity spillovers from knowledge transfers has been a major impetus to policy makers in many countries to provide FDI-friendly regime. [2] In developing countries, policies in favor of FDI have been introduced since the early 1980s. Since then, net inflows of FDI have increased dramatically and FDI has been the most significant part of private capital inflows to developing countries. From 1985 to 2006, for example, the net FDI inflows to developing countries have increased from US$ 14 billion to US$ 379 billion, rising more than 25-folds (UNCTAD, 2007). In recent years, FDI inflows have accounted for more than half of the total private capital inflows in developing countries (Ng, 2006).

Now an important question is whether these huge FDI inflows indeed bring about productivity spillovers for recipient countries, particularly for developing economies. The evidence is fairly mixed so far. Some empirical studies confirm positive productivity spillovers from FDI (e.g., Caves, 1974; Chakraborty & Nunnenkamp, 2008; Gorg & Strobl, 2005; Javorcik, 2004; Schiff & Wang, 2008), but others find negative or no spillovers (e.g., Aitken & Harrison, 1999; Barry, Gorg, & Strobl, 2005; Djankov & Hoekman, 2000; Haddad & Harrison, 1993). The mixed evidence intuitively implies that there is no universal relationship between FDI and domestic firms' productivity. Some studies, however, argue that the mixed findings may be attributed to domestic firms' characteristics or host countries' ability to absorb productivity spillovers (Gorg & Greenaway, 2004; Smeets, 2008). Nevertheless, differences in findings depend significantly on research design, methodological approach, types of data used, estimation strategy, and even on the construction of the spillover variable.

The present paper extends the current empirical literature to determine whether the FDI leads to productivity gains in the Indonesian chemical and pharmaceutical industries during 1988–2000. These two industries have been chosen as they continuously attracted the highest inflow of annual FDI since 1975 (Table 2). They belong to the group of the most productive sectors in the Indonesian manufacturing industries in terms of value added per worker (around 1.5 times of the manufacturing average), [3] while registering a consistent growth of an annual average of 17.71% during 1988–2000). [4] An overwhelming presence of MNCs in this sector provides a good basis to examine the role of firm-specific characteristics in determining the productivity spillovers.

We estimate FDI productivity spillovers using the Stochastic Frontier Approach (SFA). With this method we also address the importance of competition and firms' absorptive capacity for gaining productivity spillovers. Furthermore, we identify the sources of productivity growth in the presence of FDI in these two major industries of the Indonesian economy. A generalized *Malmquist index* is used to decompose total factor productivity (TFP) growth into technical efficiency change (TEC), technological progress (TP), and scale efficiency change (SEC). We then test the impact of FDI spillover effects on each of these components of productivity growth. The authors know of no other study that addresses the issue of decomposing the productivity effects of FDI using a generalized *Malmquist index*. [5]

The rest of this paper proceeds as follows: Section 2 provides an overview of the Indonesian manufacturing sector and the inflow of FDI, which is followed by a critical review of the theoretical and empirical studies on productivity spillovers in Section 3. Section 4 discusses estimation techniques followed by data sources and variable construction. Section 6 presents the results for model selection and estimation,

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followed by an analysis of empirical results. The summary of findings and policy implications is given in the final section.

2. AN OVERVIEW OF THE INDONESIAN MANUFACTURING AND FDI FLOWS

Indonesian manufacturing has been demonstrating spectacular growth and unprecedented transformation since the second half of 1970s. This transformation is evident not only in rapid output and in employment growth, but also in the transition to modern capital and skill-intensive industries, strong productivity and wage growth, and broadening the industrial base outside the capital city, along with a probable reduction in concentration levels (Hill, 1996). Decisive liberalization reforms have been introduced since the mid 1980s. These included reduction in tariff and non-tariff barriers,[6] privatization of public enterprises, relaxation of foreign investment rules, and lessening other restrictions. The reform package also included fiscal reform, financial liberalization, and the maintenance of a realistic and flexible exchange rate, together with trade liberalization, reduction in government intervention and improved management of public enterprises. The industrial development policies were focused on the priority industries and the creation of industrial zones. The reforms of the 1980s were designed to improve the productivity performance of manufacturing industries by encouraging competition from within the economy as well as from outside.

The change of policy direction from interventionist to liberalization encourages the expansion of export-oriented sub-sectors, such as chemicals and pharmaceuticals (ISIC 35), and woods and wood products (ISIC 33). As a result, since 1987 Indonesia has experienced a surge in manufactured exports, for example, during the period 1989–93 manufactured exports grew at an average annual rate of 27%, while manufacturing value added (MVA) grew at an average annual rate of 22% (UNIDO, 2000). Export-oriented manufacturing firms witnessed a higher growth than non-export firms, and at the same time, manufacturing firms experienced a substantial productivity growth.

Studies reveal that manufacturing sector experienced higher TFP (total factor productivity) growth at around 6% per annum in the post liberalization period (Ikhsan, 2007; Vial, 2006) compared to a negative growth of −4.9% during 1981–83 (Aswicahyono, 1988). One of the important factors contributing to these positive outcomes in the manufacturing sector during the post-liberalization period was a massive inflow of FDI.[7] The huge increase in FDI inflows, from a meager US$ 0.2 billion in 1983 to US$ 5.9 billion in 2006,[8] facilitated the high growth of manufacturing industries in terms of output, employment, and value added. Moreover, the growing FDI inflows helped create backward and forward linkages in the economy. Although there was a decrease in manufacturing growth during the East Asian crisis in 1997, this sector revived quickly and demonstrated further growth since 2000.

The manufacturing sector received a large proportion of total FDI inflows in the Indonesian economy. The share of approved FDI to this sector accounts for more than 50% of total approved FDI over the last three decades (Table 1). Although the total approved FDI decreased steadily after the economic crisis, the share of manufacturing FDI remains the largest part of the total FDI. Furthermore, within the manufacturing sector over the years (Table 2), the highest share of manufacturing FDI flowed to chemicals and pharmaceuticals (44.56%), followed by metal products (13.13%) and papers and paper products (11.96%). Food products have received an increasing share of manufacturing FDI, particularly after the deregulation in 1984. However, the average percentage of FDI to this sector remains relatively small of the total approved manufacturing FDI.

Based on the high level of FDI, the present study focuses on chemical and pharmaceutical firms in examining the productivity spillovers of FDI. Another reason to focus on this sector rather than on pooling data for the whole Indonesian manufacturing is to reduce heterogeneity in data, as suggested by Bartelsman and Doms (2000). Firms in the chemical and pharmaceutical sectors have different characteristics, in terms of size and technology, compared to, for example, firms in food processing sector. Pooling firms from both industries together may give rise to persistent heterogeneity in data.

The chemical and pharmaceutical sectors (ISIC 35) represent about 18% of Indonesian manufacturing output and around 12% of the manufacturing employment in 2005. This sector employs some 540 thousand people with wages of around IDR 8,445 billions per year. Its contribution to the manufacturing value added (MVA) was the third highest of all industries after the food industry and textiles. During 1975–2005, this sector expanded rapidly, increasing in value added by more than 35 times.[9] It is a diverse industry ranging from large-scale petrochemical complexes to medium-sized establishments that simply mix chemicals to produce paint, pesticide, and traditional medicines. In the Annual Survey of Manufacturing Industries, the BPS divides this sector into six sub-sectors: industrial chemicals (ISIC 351), pharmaceutical and other chemicals (352), oil and gas refining (353 and 354), rubber and products (355), and plastic products (356). Among these sub-sectors, the oil and gas refining sub-sectors have only been surveyed since 1990 and cover only a few establishments. The other four sub-sectors have been surveyed since 1975.

In this study, the focus is on the sub-sectors industrial chemicals (ISIC 351) and pharmaceuticals and other chemicals (ISIC 352), as these two sub-sectors represent more than 70% of the sector value added. The trend and key indicators of the two sub-sectors (hereafter, chemical firms and pharmaceutical firms refer to firms in these two sub-sectors, respectively) during the studied periods are presented in Table 3. From the table, one might note that the combined sub-sectors expanded rapidly during 1988–98, which can be observed from an increase in output and value added by more than 10 times. Labor productivity, which is measured by value added per labor (VA/L), also increased considerably by almost eight times during the years.

Interestingly, the number of foreign firms, as a percentage of total firms across the two sub-sectors combined, increased quite significantly from 12.92% in 1988 to 18.65% in 1998. A similar pattern is also observed for foreign share (as a percentage of value added), as it rose drastically from 27% in 1988 to 61.23% in 1998, suggesting an important contribution of foreign firms to the value added in this sector. The exported outputs of the combined sub-sectors were less than 7% during 1988–98. In contrast, there was heavy reliance on imported materials, with 55.18% and 44.75% of total material was imported in 1988 and 1998, respectively.

3. RELATED LITERATURE AND HYPOTHESIS DEVELOPMENT

(a) *MNCs, superior knowledge, and productivity spillovers*

When MNCs establish subsidiaries overseas, they come across disadvantages in the form of access to resources

Table 1. *Share of approved manufacturing FDI 1975–2006*

Year	Total approved FDI (million USD)	Approved manufacturing FDI (million USD)	Share of manufacturing FDI to total FDI (percentages)
1975–79	5,322.10	3,666.40	68.89
1980–84	7,765.70	6,346.10	81.72
1985–89	12,300.20	10,150.10	82.52
1990–94	57,996.50	37,507.10	64.67
1995–99	126,919.20	81,092.60	63.89
2000–04	57,495.20	31,735.20	55.20
2005–06	29,203.20	14,336.10	49.09
1975–2006	297,002.10	184,833.60	62.23

Sources: Calculated from Indonesian Financial Statistics, Central Bank of Indonesia, various years.

Table 2. *The distribution of approved manufacturing FDI (as % of total approved manufacturing FDI) in two-digit ISIC industries for the period 1975–2006*

Year	Food (31)	Textile and leather (32)	Wood and wood product (33)	Paper and paper product (34)	Chemical and pharmaceutical (35)	Non metal mineral (36)	Basic metal (37)	Metal products (38)	Others (39)
1975–79	4.96	8.81	0.77	2.87	15.84	9.97	47.99	8.59	0.19
1980–84	2.63	6.21	2.41	12.21	18.12	5.67	24.60	28.13	0.01
1985–89	5.40	9.14	2.83	18.69	48.25	4.61	2.74	7.92	0.42
1990–94	5.29	11.54	1.50	15.79	35.13	5.35	7.35	17.01	1.05
1995–99	5.10	2.50	0.88	14.36	58.62	3.36	3.74	11.12	0.33
2000–04	7.62	4.27	1.34	7.37	54.83	2.96	6.29	6.12	9.21
2005	10.66	2.31	1.70	3.78	47.76	6.11	0.00	11.53	16.16
2006	12.47	1.88	1.66	14.09	18.40	9.45	0.00	35.13	6.91
1975–2006	6.31	5.99	1.40	11.96	44.56	4.71	8.11	13.13	3.83

Source: Calculated from Indonesian Financial Statistics, Central Bank of Indonesia, various years.

Table 3. *Trend and key indicators of the chemical and pharmaceutical sectors*

Key indicators	Chemicals and pharmaceuticals (ISIC 351 and 352)			Industrial chemicals (ISIC 351)			Pharmaceuticals and other chemicals (ISIC 352)		
	1988	1993	1998	1988	1993	1998	1988	1993	1998
Output (billion rupiah)	4,133	11,071	42,948	2,142	5,637	27,793	1,991	5,434	15,155
Value-added (billion rupiah)	1,451	4,376	16,712	784	2,401	10,983	667	1,975	5,729
Labor (person)	114,565	160,673	192,618	39,495	60,241	81,914	75,070	100,432	110,704
VA/L (thousand rupiah)	12,668	27,236	86,760	19,850	39,853	134,074	8,889	19,669	51,751
No of establishments	743	892	1,035	218	325	431	525	567	604
Foreign firm (% of total establishments)	12.92	14.01	18.65	11.93	16.92	22.97	13.33	13.35	15.56
Domestic firm (% of total establishments)	81.16	81.28	77.10	75.23	76.00	71.69	83.81	83.30	80.96
SOEs (% of total establishments)	5.92	4.71	4.25	12.84	7.08	5.34	2.86	3.35	3.48
Foreign share (% of VA)	27.00	42.85	61.23	17.12	39.97	67.90	38.61	46.35	48.42
Export (% of output)	5.09[a]	6.56	1.42	8.09[a]	10.88	4.62	3.46[a]	4.08	1.29
Imported-material (% of total material)	55.18	44.48	44.75	57.01	46.02	43.05	52.97	42.83	48.15

Source: Authors' calculation from the Annual Survey of Large and Medium Manufacturing Industries.
Foreign firms are defined as firms with any foreign ownership, domestic firms are firms those 100% owned by domestic private individual or companies, and state-owned enterprises (SOEs) are firms owned by the central or district government.
[a] The figure was calculated based on the data in 1990 because it was the first year the information on export was published.

and domestic demand, when compared to their local counterparts. Domestic firms have more experience in serving domestic markets and possess more information regarding the type of products, consumer preferences, and distributional networks relative to MNCs. In order to compete with the domestic firms, MNCs need to possess superior knowledge (Caves, 1971). The superior knowledge, which is often known as special intangible assets in the industrial organizational theory of FDI, takes the form of process and product, managerial and organizational, and scale efficiency knowledge (Kokko & Kravtsova, 2008). With this superior knowledge, MNCs are often assumed to have higher performance levels than domestic firms, in particular being more efficient and productive. To test whether this is the case in the Indonesian chemical and pharmaceutical sectors, this study hypothesizes that

H1a. Foreign-owned firms are more efficient (or productive) than domestic firms.

If MNCs indeed possess superior knowledge relative to domestic firms, there is a possibility that MNCs may generate positive productivity spillovers (Blomstrom & Kokko, 1998). When MNCs transfer knowledge to their subsidiaries, the transferred knowledge may spill, through non-market mechanisms, over the entire economy that may then lead to productivity growth in domestic firms. However, MNCs would prevent their knowledge seeping to domestic firms by raising the cost of spillovers, such as patenting their products and ideas.

A large number of empirical studies examine the productivity spillovers hypothesis of FDI in the literature. The pioneering empirical research in this area was conducted by Caves (1974) on Australia, followed by Globerman (1979) on Canada, and Blomstrom and Persson (1983) on Mexico. The empirical literature then developed in many directions in a number of country-specific and cross-country investigations. However, the findings of these studies are diverse and inconclusive.[10] The relationship between FDI spillovers and firms' productivity gains still remains to be an empirical issue. Being the top recipients of FDI, the higher *per capita* productivity in Indonesian chemical and pharmaceutical industries than the manufacturing average therefore suggests a test for the following hypothesis:

H1b. There is a positive productivity spillover from FDI in the Indonesian chemical and pharmaceutical sectors.

(b) *Productivity spillovers and competition*

Most of the previous studies on FDI spillovers treat the specific mechanisms of productivity spillovers as occurring in a "black box" (Gorg & Strobl, 2005). These studies often assume that productivity spillovers from FDI occur automatically as a consequence of foreign firms' presence in domestic markets. The channels of productivity spillovers are not explicitly taken into account in such studies.

However, some studies try to consider explicitly the channels of productivity spillovers from FDI. There are three fundamental mechanisms for productivity spillovers to take place. First, the entry of MNCs may lead to greater competition in domestic markets, which then forces domestic firms to utilize their resources and technology in more efficient ways, leading to productivity gains (Wang & Blomstrom, 1992). Second, knowledge may spill over to domestic firms *via* labor turnover, that is, when workers trained by MNCs move to domestic firms and bring with them the knowledge and other crucial intangible assets (Fosfuri, Motta, & Ronde, 2001). Third, foreign firms in domestic markets may create demonstration effects to domestic firms through direct imitation and reverse engineering (Das, 1987), or new innovation through R&D (Cheung & Lin, 2004).

Of these three channels of productivity spillovers, the first channel is of particular interest in this study. Competition may result in either positive or negative productivity spillovers for domestic firms. Aitken and Harrison (1999) argue that, in the short-run, the presence of foreign firms in an imperfect competition domestic market may raise the average cost of production of domestic firms through the "market stealing" phenomenon. Foreign firms with a lower marginal cost have an incentive to increase production relative to their domestic competitors. The productivity of domestic firms will fall as they have to spread fixed costs over a smaller amount of output. However, in the long-run, when all costs can be treated as variable costs, there is a possibility for domestic firms to reduce their costs by allocating their resources more efficiently and imitating foreign firms' knowledge (Wang & Blomstrom, 1992). If the efficiency effect from foreign presence is larger than the competition effect, there can be positive productivity spillovers. Following these arguments, this study tests the following hypothesis:

H2. Higher competition is associated with larger spillovers from foreign presence in the industry, that is, positive productivity spillover through competition.

(c) *Productivity spillovers and absorptive capacity*

The mixed evidence of productivity spillovers leads to the celebrated argument that firm-specific characteristics (or absorptive capacity) may influence the ability of domestic firms in gaining productivity spillovers from FDI (Findlay, 1978; Glass & Saggi, 1998; Wang & Blomstrom, 1992). The most commonly used measure of absorptive capacity is the extent of research and development (R&D) expenditure. In a study of the Indian manufacturing firms, Kathuria (2000) shows that local firms that invest in learning, or R&D activities receive high productivity spillovers, whereas the non-R&D local firms do not gain much from the presence of foreign firms. This result indicates that the productivity spillovers are not automatic consequences of the presence of foreign firms; rather they depend on the efforts of local firms' investment in R&D activities. Kinoshita (2001) finds similar evidence in a study on Czech manufacturing firms during 1995–98. By focusing on electrical machinery and radio & TV sectors, she finds that R&D is a necessary condition for technology spillovers from FDI. In a more recent study on twelve OECD countries, Griffith, Redding, and van Reenen (2004) also confirm that R&D plays an important role in knowledge transfer, besides its role as a medium of innovation. To capture a firm-specific characteristic of Indonesian chemical and pharmaceutical firms in determining the productivity spillovers from FDI, this study also tests the following hypothesis:

H3. Domestic firms with R&D expenditure gain more productivity spillovers from FDI than those without R&D expenditure.

(d) *Sources of productivity advantage from FDI*

Technical and scale efficiencies are hardly studied in the literature in relation to productivity gains from FDI. While the theoretical literature provides little guidance to these two sources of productivity growth, the empirical studies also tend to ignore the decomposition issue (Girma & Gorg, 2007). The empirical studies usually assume that productivity advantage from FDI is exclusively contributed by technology transfers as is consistent with the use of conventional approach of production function.[11]

The stochastic productivity frontier literature, such as Orea (2002), offer a parametric decomposition of productivity growth into three components: technical efficiency change (TEC), technological progress (TP), and scale efficiency change (SEC). By decomposing productivity growth using this analysis, it is possible to examine the productivity advantage from FDI to technical and scale efficiencies as well as technological progress. In a recent survey, Smeets (2008) argues that the productivity spillovers from FDI should be defined broadly, as it arises from new knowledge rather not only from new technology. Further, he defines knowledge as including technology; managerial, and production skills, which may contribute to technical efficiency and ability to exploit scale efficiency. Therefore, the final hypothesis to test sources of productivity gains from FDI can be stated as follows:

H4. There are positive FDI spillovers to each component of productivity growth (TEC, TP, and SEC).

4. MODEL SPECIFICATION AND ESTIMATION TECHNIQUES

(a) *Productivity spillovers from FDI: a stochastic frontier approach*

When measuring efficiencies and productivity at the firm level, researchers face the choice of alternative approaches, such as conventional production (cost) functions, data envelopment analysis (DEA), and stochastic frontier production (cost) function. Each of these approaches has its merits and demerits. The debate over which approach is appropriate continues (Coelli, Rao, O'Donnell, & Battese, 2005).

We apply the stochastic frontier production function to test the spillover hypothesis from FDI. Following Battese and Coelli (1995) the stochastic frontier approach (SFA) is used to estimate a production function and an inefficiency function simultaneously.[12] The Battese–Coelli model can be expressed as follows:[13]

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

where y_{it} implies 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, and β represents the $(k \times 1)$ vector of parameters to be estimated. The error term consists of two components: v_{it} and u_{it}, which are independent of each other. In addition, the v_{it} denotes the time-specific and stochastic part, with *iid* $N(0, \sigma_v^2)$, and the u_{it} represents technical inefficiency, which is normal distribution, but truncated at zero with mean $z_{it}\delta$ and variance σ_u^2.

The technical inefficiency effects, u_{it}, are 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. In a linear equation, the technical inefficiency effects can be specified as follows:

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

where w_{it} is an unobservable random variable, which is defined by the truncation of the normal distribution with zero mean and variance, σ_u^2, such that the point of truncation is $-z_{it}\delta$.

Eqn. (1) shows the stochastic production function in terms of the original production value, and Eqn. (2) represents the technical inefficiency effects. The parameters of both equations can be estimated simultaneously by the maximum-likelihood method. The likelihood function is expressed in terms of variance parameters $\sigma_s^2 \equiv \sigma_v^2 + \sigma_u^2$ and $\gamma \equiv \sigma_u^2/\sigma_s^2$.[14] If γ equals zero, then the model reduces to a traditional mean response function in which z_{it} can be directly included into the production function.

Based on the theoretical model in Eqns. (1) and (2), we start with a flexible functional form, namely, a *translog* production function. By adopting a flexible functional form, the risk of errors in the model specification can be reduced. Moreover, the *translog* form is useful for decomposing the total factor productivity growth. The functional form of the *translog* production function is as follows:

$$\ln y_{it} = \beta_0 + \sum_{n=1}^{N} \beta_n \ln x_{nit} + \frac{1}{2} \sum_{n=1}^{N} \sum_{k=1}^{N} \beta_{nk} \ln x_{nit} \ln x_{kit} + \beta_t t + \frac{1}{2}\beta_{tt} t^2 + \sum_{n=1}^{N} \beta_{nt} \ln x_{nit} t + v_{it} - u_{it}, \tag{3}$$

where y implies output, x represents variables that explain output (labor and capital, so $N = 2$), t is time, i is firm. And u_{it} is defined as:

$$u_{it} = \delta_0 + \sum_{j=1}^{J} \delta_j z_{jit} + w_{it}, \tag{4}$$

where z is the set of explanatory variables that explain technical inefficiency.

Hypotheses H1a, H1b, H2, and H3 are tested by estimating three alternative technical inefficiency functions to avoid the possibility of multicollinearity. A test of H1 includes only a spillover variable; a test of H2 involves an interacting variable of spillover and competition; and a test of H3 involves an interacting variable of spillover and R&D. The interacting variables in H2 and H3 are likely to have a high correlation with each other. A simple possible way to deal with this issue in a stochastic frontier model is to estimate the hypotheses separately.

To test H1, the subscript j in Eqn. (4) represents the dummy variable of foreign ownership (to test H1a) and FDI spillovers (to test H1b). These hypotheses are tested by controlling the age of the firm. z_j in Eqn. (4) includes an interacting variable of competition and spillovers when testing H2, while it represents an interacting variable of R&D and spillovers when testing H3. Details of definition and construction of each variable used in Eqns. (3) and (4) are presented in Table A1.

Given the specifications in Eqns. (3) and (4), the technical efficiency of production for the ith firm at the tth year is defined as the ratio of the actual output of firm i, $\ln y_{it}$, to its potential output, $\ln y_{it}^p$:

$$TE = \frac{\ln y_{it}}{\ln y_{it}^p} = E[-u_{it} | (v_{it} - u_{it})] = E[(-z_{it}\delta - w_{it}) | (v_{it} - u_{it})], \tag{5}$$

where

$$\ln y_{it}^p = \beta_0 + \sum_{n=1}^{N} \beta_n \ln x_{nit} + \frac{1}{2} \sum_{n=1}^{N} \sum_{k=1}^{K} \beta_{nk} \ln x_{nit} \ln x_{kit} + \beta_t t + \frac{1}{2}\beta_{tt} t^2 + \sum_{n=1}^{N} \beta_{nt} \ln x_{nit} t + v_{it}. \tag{6}$$

(b) *Decomposing productivity growth: a generalized Malmquist index*

Orea (2002) shows that if firm i's technology in time t can be represented by a *translog* output-oriented distance function $D_O(y_{it}, x_{it}, t)$ where y_{it}, x_{it}, and t are defined as above, then the logarithm of a generalized output-oriented *Malmquist* productivity growth index, $G_{Oi}^{t,t+1}$, can be decomposed into TEC, TP, and SEC between time periods t and $t + 1$:

$$G_{Oi}^{t,t+1} = \mathrm{TEC}_i^{t,t+1} + \mathrm{TP}_i^{t,t+1} + \mathrm{SEC}_i^{t,t+1}, \tag{7}$$

where

$$\mathrm{TEC}_i^{t,t+1} = \ln D_O(y_{i,t+1}, x_{i,t+1}, t+1) - \ln D_O(y_{it}, x_{it}, t), \tag{8}$$

$$\mathrm{TP}_i^{t,t+1} = \frac{1}{2}\left[\frac{\partial \ln D_O(y_{i,t+1}, x_{i,t+1}, t+1)}{\partial (t+1)} + \frac{\partial \ln D_O(y_{it}, x_{it}, t)}{\partial t}\right], \tag{9}$$

$$\mathrm{SEC}_i^{t,t+1} = \frac{1}{2}\sum_{n=1}^{N}\left[\frac{\varepsilon_{i,t+1} - 1}{\varepsilon_{i,t+1}}\varepsilon_{i,t+1,n} + \frac{\varepsilon_{it} - 1}{\varepsilon_{it}}\varepsilon_{itn}\right] \cdot \ln\left[\frac{x_{i,t+1,n}}{x_{itn}}\right], \tag{10}$$

Table A1. *Definitions of variables*

Variables	Definition
Production function	
Y	Value-added (in million rupiah), which is deflated using a wholesale price index of four-digit ISIC industries at a constant price of 1993
L	Labor (number of workers)
K	Capital (million rupiah), which is deflated using a wholesale price index of four-digit ISIC industries at a constant price of 1993
Inefficiency function	
Foreign	Foreign ownership, which is measured by a dummy variable: 1 if the share of foreign ownership is greater than 0%; and 0 if otherwise
Spillover	Spillover variable, is measured by the share of foreign firms' output over total output in three-digit ISIC industry
Age	Age of firms, is measured by the difference between year of survey and year of starting production
HHI	Herfindahl–Hirschman index for a measure of concentration, which is calculated from $H = \sum_{i=1}^{m} S_i^2$, for S_i^2 is market share of each firms
R&D	Expenditure on research and development (R&D) is measured by dummy variable: 1 if firm spends on research and development activities during the observed years, and 0 otherwise
Spillover * HHI	An interacting variable of spillover and HHI, which is a measure of productivity spillovers through concentration
Spillover * R&D	An interacting variable of spillover and R&D dummy, which is a measure whether R&D firms receive more or less spillovers

where $\varepsilon_{it} = \sum_{n=1}^{N} \varepsilon_{itn}$ is the scale elasticity such that $\varepsilon_{itn} = \frac{\partial \ln D_O(y_{it}, x_{it}, t)}{\partial \ln x_{itn}}$.

If the output is only one, then a *translog* output-oriented distance function can be defined as

$$\ln D_O(y_{it}, x_{it}, t) = \ln y_{it} - \ln y_{it}^p - v_{it}. \tag{11}$$

Given the technical efficiency measure in Eqn. (5), the technical efficiency change (TEC) between periods $t+1$ and t can be estimated by following Coelli *et al.* (2005):

$$\mathrm{TEC}_i^{t,t+1} = \ln TE_{i,t+1} - \ln TE_{it}. \tag{12}$$

The technical progress (TP) index can be obtained from Eqns. (6), (9), and (11) as follows:

$$\mathrm{TP}_{i,t+1,t} = \frac{1}{2}\left[\sum_{n=1}^{N} \beta_{tn} \ln x_{i,t+1,n} + \sum_{n=1}^{N} \beta_{tn} \ln x_{itn} + 2\beta_t + 2\beta_{tt}[(t+1)+t]\right]. \tag{13}$$

From Eqn. (3), the scale elasticity can be written as

$$\varepsilon_{nit} = \beta_n + \frac{1}{2}\sum_{k=1}^{K} \beta_{nk} x_{nit} + \beta_{nt} t. \tag{14}$$

The index of scale efficiency change then can be calculated by using Eqns. (10) and (14).

(c) *Estimating FDI spillovers on sources of productivity growth*

After obtaining the indices of *Malmquist* productivity growth (G_O), TEC, TP, SEC, the next step is to estimate the contribution of FDI spillovers on total factor productivity growth and its sources. A panel regression is employed to estimate the spillover effects. The linear panel data regression can be written as

$$Y_{i,j,t+1,t} = \alpha_0 + \alpha_1 Foreign_{ijt} + \alpha_2 Spillover_{jt} + \alpha_3 Age_{ijt} + \alpha_4 HHI_{jt} + \alpha_5 Spillover_{jt} * HHI_{jt} + \alpha_6 RD_{ijt} + \alpha_7 Spillover_{jt} * RD_{ijt} + \zeta_{it}, \tag{15}$$

where $Y = (G_O$, TEC, TP, SEC), i denotes firm, j implies sub-sector (in this case is three-digit ISIC industries), and ζ is the disturbance term.

5. DATA SOURCES

Data used in this study come from 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).[15] Other supplementary data are wholesale price index (WPI) published by BPS, which are used as deflators for monetary variables in Eqns. (3) and (4).

To construct a unique balanced panel data covering the selected period (1988–2000) and only for chemical and pharmaceutical firms, this study follows several adjustment steps. A detailed explanation about data sources and the adjustment process is given at the beginning of the Appendix A. The original observations for chemical and pharmaceutical firms (ISIC 35) in the selected period are 29,234 observations. After the adjustment process and the construction of a balanced panel, the observations are reduced to 7,384 (consisting of 568 firms for 13 years). Some observations are removed during the adjustment of industrial codes and the cleaning of data from nonsense, noise, and missing values (Step 1 and Step 3 of the adjustments presented in Appendix A), some are dropped when choosing only ISIC 351 and 352 (Step 5), and some others are removed during the construction of a balanced panel (Step 6).[16] The largest numbers of observations are removed when choosing only ISIC 351 and 352 (17,962 out of 29,234 observations or 61.44%). Oil and gas refining sub-sectors (ISIC 353 and 354) are excluded from the dataset as these sub-sectors were not surveyed in 1988 and 1989. In addition, information regarding research and development (R&D) expenditure are available in the dataset since 1994. For the years 1988–93, the R&D dummy variable is defined as equal to that for the year 1994. The summary statistics for the main variables used in the econometric analysis are presented in Table A2.

6. ALTERNATIVE MODEL ESTIMATION AND ANALYSIS OF RESULTS

(a) *Choosing the functional form*

The first step in the SFA is to find an appropriate functional form that represents the data. Given the specifications of the *translog* model in Eqn. (3), various sub-models of the *translog*

Table A2. *Summary statistics*

Variables	Unit	Minimum	Maximum	Mean	Std. dev.
Y	Million of 1993 rupiah	7.80	1,038,731.76	14,221.62	37,635.65
L	Persons	16	6,961	265.10	486.85
K	Million of 1993 rupiah	1.54	916,035.13	5,309.84	23,948.88
Foreign	Binary dummy	0	1	0.14	0.35
Spillover	Ratio	0.14	0.76	0.34	0.14
Age	Years	0	100	20.47	14.87
HHI	Ratio	0.12	0.77	0.27	0.14
R&D	Binary dummy	0	1	0.25	0.43

are considered and tested under a number of null hypotheses. A null hypothesis of $\beta_{nt} = 0$ is to confirm whether Hicks-neutral technological progress is an appropriate specification for the dataset, while a null hypothesis of $\beta_t = \beta_{tt} = \beta_{nt} = 0$ is for no-technological progress in the production frontier. In addition, a null hypothesis of $\beta_{tt} = \beta_{nt} = \beta_{nk} = 0$, for all n and k, is to test for Cobb-Douglas production frontier and a null hypothesis of $\gamma = \delta_0 = \delta_j = 0$ is to confirm the no-inefficiency effect. For performing tests of the relevant null hypotheses, the generalized likelihood ratio statistic $\lambda = -2[l(H_0) - l(H_1)]$ is employed, 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 *translog* model defined in Eqn. (3). If the null hypothesis is true, the test statistic has approximately a χ^2 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 χ^2 distribution, and the critical value for this test is taken from Table 1 of Kodde and Palm (1986).[17] The estimation results for *translog* and the sub-models under the Battese and Coelli's (1995) SFA are presented in Table 4.

The last row of Table 4 presents log-likelihood values for each functional form. These log-likelihood values are used to calculate the generalized likelihood ratio statistic, λ. The results of the null hypotheses tests are presented in Table A3. From the results, it is apparent that various sub-models of the *translog* are found to be an inadequate representation of the data, given the specification of *translog* model. Therefore, the estimation results from Model 1 in Table 4 are used in the interpretation of productivity spillovers.

(b) *Foreign firms and productivity spillovers*

The estimation results of a *translog* stochastic production frontier show that the coefficients of labor and capital have expected positive signs. The positive and highly significant coefficients confirm the expected positive and significant output effects of labor and capital. In contrast, the squared variable of labor $[(\ln L)^2]$ is negative and statistically significant at a 1% level, which indicates a diminishing return to labor. The same is not true of the squared capital. Its estimated coefficient, while negative, turns out to be statistically insignificant. Furthermore, the estimated coefficient of the interacting variable between labor and capital ($\ln L * \ln K$) is positive and significant at a 1% level, suggesting a substitution effect between labor and capital.

For time variables, both coefficients of time (T) and its square are negative and statistically significant. A non-neutral technological progress toward capital is indicated by a positive and statistically significant (at 1% level) coefficient of the interacting variable between time and capital ($T * \ln K$). The combination of the various coefficients of variables that involve T determines the movement of the production frontier over time, with this movement being positive (technological progress) or negative (technological regress) depending on values of K, L, and T.[18] The results in Table 7 below show that, when evaluated at the particular values of K, L, and T for each firm and time period, technological progress has been the dominant factor contributing to productivity growth of both foreign and domestic firms in the Indonesian chemical and pharmaceutical industries over the full sample period.

A particular interest of this study is on the estimated coefficients of the inefficiency function in the second part of Model 1 in Table 4. The negative and statistically significant (at 1% level) coefficient of the dummy foreign ownership (Foreign) indicates that, on average, foreign firms achieve higher efficiency than their domestic counterparts do. Similarly, the average technical efficiency indices for both foreign and domestic firms confirm that foreign firms have higher technical efficiency than domestic firms during the observed years (Figure 1). The higher average efficiency indices of foreign firms compared to domestic firms also indicate that foreign firms are indeed premiers in the chemical and pharmaceutical sectors and operate on the technology frontier. This result supports one of the classic hypotheses of the early literature in industrial organization, namely, that MNCs possess superior knowledge and efficiency, in the form of intangible assets, compared to their domestic counterparts.

The negative and significant coefficient on the spillover variable (spillover) in Model 1 in Table 4 implies a positive and significant efficiency spillover in the chemical and pharmaceutical sectors. This result suggests that in the Indonesian chemical and pharmaceutical sectors higher foreign share results in domestic firms utilizing their resources in a more efficient way, which then leads to productivity gains. The evidence of positive efficiency spillovers from FDI in this study is consistent with previous empirical studies on the Indonesian manufacturing sector which use a conventional approach of production function and focus on all manufacturing firms (e.g., Blalock & Gertler 2008; Sjoholm, 1999a).

The coefficient of a controlling variable, Age, is positive and statistically significant at a 1% level, indicating that older firms have higher inefficiency. This finding may not be a surprise, younger firms are likely to possess modern technology and capital equipment compared to older firms due to technology diffusion.

To ensure that the inclusion of foreign firms in the estimation on FDI spillovers does not introduce bias, this study estimates also the frontier for only domestic firms. The results are presented in Table A4. Interestingly, all coefficients have similar signs and levels of significance as those for the sample of all firms. This is not a surprise given a fact that foreign firms are only 14.98% of the total sample (1,106 out of 7,384 observations). The negative and highly significant coefficient of the key variable, spillovers, is consistent with the result for the

Table 4. *Maximum likelihood estimates of stochastic production frontier*

Variables	Parameters	Model 1	Model 2	Model 3	Model 4	Model 5
Production function						
Constant	β_0	1.25***	1.33***	1.47***	2.138***	1.938***
		(0.22)	(0.21)	(0.23)	(0.043)	(0.042)
Ln(*L*)	β_1	2.47***	2.36***	2.38***	0.804***	0.725***
		(0.10)	(0.11)	(0.12)	(0.012)	(0.015)
Ln(*K*)	β_2	0.24***	0.196***	0.175**	0.4920***	0.49438***
		(0.07)	(0.071)	(0.097)	(0.0081)	(0.0087)
$[\text{Ln}(L)]^2$	β_{11}	−0.521***	−0.534***	0.542***	–	–
		(0.027)	(0.027)	(0.031)		
$\text{Ln}(L) * \text{Ln}(K)$	β_{12}	0.106***	0.132***	0.133***	–	–
		(0.024)	(0.024)	(0.031)		
$[\text{Ln}(K)]^2$	β_{22}	−0.0058	−0.0017	0.001	–	–
		(0.0073)	(0.0076)	(0.013)		
T	β_t	−0.016*	0.0306***	–	–	–
		(0.012)	(0.0068)			
$\text{Ln}(L) * T$	β_{1t}	0.0015	–	–	–	–
		(0.0038)				
$\text{Ln}(K) * T$	β_{2t}	0.0083***	–	–	–	–
		(0.0022)				
T^2	β_{tt}	−0.00157***	−0.00104***	–	–	–
		(0.00045)	(0.00046)			
Inefficiency function						
Constant	δ_0	−0.267***	−0.238***	−0.276***	−0.483***	–
		(0.083)	(0.052)	(0.090)	(0.097)	
Foreign	δ_F	−0.0546***	−0.053	−0.05	−0.058***	–
		(0.0070)	(0.060)	(0.15)	(0.005)	
Spillover	δ_S	−0.119***	−0.010	−0.006	−0.059*	–
		(0.087)	(0.018)	(0.024)	(0.024)	
Age	δ_A	0.01247***	0.01198***	0.0112***	0.0147***	–
		(0.00099)	(0.00088)	(0.0016)	(0.0012)	
Gamma	γ	0.558***	0.540***	0.543***	0.622***	–
		(0.033)	(0.045)	(0.057)	(0.029)	
Log-likelihood		−4937.56	−4953.21	−5010.35	−5271.82	−5443.96

Note: Model 1 is a *translog* production function. Models 2 and Model 3 represent a Hicks-neutral and a no-technological progress production functions, respectively. Model 4 is a Cobb–Douglas production function and Model 5 represents a no-inefficiency production function. Standard errors are in parentheses and presented until two significant digits, and the corresponding coefficients are presented up to the same number of digits behind the decimal points as the standard errors.
* Denotes significance at 10%.
** Denotes significance at 5%.
*** Denotes significance at 1%.

Table A3. *Tests of hypothesis of stochastic production frontier*

Test	H_0	λ	χ^2 1%	Conclusion
Hicks neutral	$\beta_{nt} = 0$	31.30	9.210	Hicks neutral rejected
No-technological progress	$\beta_t = \beta_{nt} = \beta_{tt} = 0$	145.58	13.277	No-technological progress rejected
Cobb–Douglas	$\beta_{nk} = \beta_t = \beta_{nt} = \beta_{tt} = 0$	668.52	18.475	Cobb–Douglas rejected
No-inefficiency	$\gamma = \delta_0 = \delta_j = 0$	1012.80	17.755	No-inefficiency rejected

Source: Authors' calculation from log-likelihood functions.

sample of all firms, suggesting that the finding of positive FDI spillovers on technical efficiency of domestic firms in Table 3 is not simply a result of biased estimation. Following Kathuria (2000), this study chooses to proceed with the sample of all firms since it measures inefficiency from a distance to the most efficient firms, which can be either foreign or domestic firms. Hence, the inefficiency indexes are measured relative to the best-practice foreign or domestic firms.

Considering that the shock in the economic environment, such as economic crisis, might be affecting FDI spillovers, this study also estimates the samples for the period before the crisis (1988–96) and for the period after the crisis (1997–2000). The estimation results for these two periods are presented in Table A5. In both periods, the coefficients of spillovers are negative. However, the significance levels are different; it is significant at the 1% level for the before-crisis period but it is marginally significant at the 10% level for the crisis period. In addition, the coefficient is smaller for the crisis period compared to the before-crisis period, suggesting that the magnitude of spillovers is smaller during the crisis period. However, the short time

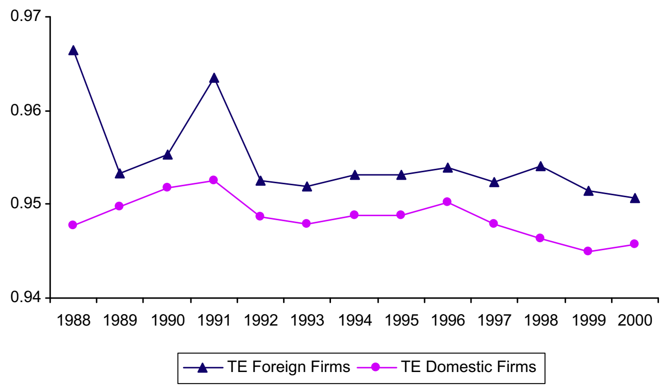

Figure 1. *Average technical efficiency indexes of foreign and domestic firms.*

span for the sample of the crisis period means that the results need to be treated with caution as there are substantially fewer observations than for the full period or the pre-crisis period.

(c) *Productivity spillovers and competition*

This section tests H2 that productivity spillovers are affected by the degree of competition. The *Herfindahl–Hirschman Index* (HHI) is used as a measure of the degree of competition within three-digit ISIC industries (a higher value of HHI indicates greater concentration of sales among producers). Higher concentration is an inverse measure of static competition that can protect inefficient firms. However, higher concentration can also be the result of dynamic competition among firms of differential efficiency that removes inefficient firms from the industry as argued by Demsetz (1973) and Peltzman (1977). The first argument suggests that HHI is associated with greater inefficiency, while the latter argument suggests that HHI is associated with lower inefficiency. The estimated maximum likelihood parameters of a stochastic production function for productivity and competition are presented in Table 5. The spillover variable without interacting with HHI is excluded from the estimation because of multicollinearity with the interacting variable.

Each estimated parameter of production functions shown in Table 5 has a similar sign and significance as in the baseline model shown in Table 4. Therefore, there is no need to explain the estimated parameters of production function further. In the inefficiency function, the negative coefficient of competition (HHI) indicates that concentration among firms in the Indonesian chemical and pharmaceutical sectors decreases the inefficiency of firms, which is consistent with the argument

Table A4. *Maximum likelihood estimates of stochastic production frontier for domestic firms*

Variables	Parameters	Model 1	Model 2	Model 3	Model 4	Model 5
Production function						
Constant	β_0	1.48***	1.37***	1.59***	2.119***	2.107***
		(0.22)	(0.21)	(0.21)	(0.036)	0.044
Ln(L)	β_1	1.92***	1.95***	1.95***	0.858***	0.760***
		(0.11)	(0.11)	(0.11)	(0.014)	0.016
Ln(K)	β_2	0.314***	0.317***	0.274***	0.4474***	0.4435***
		(0.072)	(0.071)	(0.070)	(0.0082)	0.0095
$[\text{Ln}(L)]^2$	β_{11}	−0.569***	−0.556***	−0.607***	–	–
		(0.027)	(0.028)	(0.023)		
Ln(L) * Ln(K)	β_{12}	0.232***	0.223***	0.259***	–	–
		(0.023)	(0.023)	(0.020)		
$[\text{Ln}(K)]^2$	β_{22}	−0.0339***	−0.0311***	−0.0326***	–	–
		(0.0074)	(0.0074)	(0.0069)		
T	β_t	0.005	0.0317***	–	–	–
		(0.013)	(0.0067)			
Ln(L) * T	β_{1t}	0.0043	–	–	–	–
		(0.0039)				
Ln(K) * T	β_{2t}	0.0031	–	–	–	–
		(0.0024)				
T^2	β_{tt}	−0.00147***	−0.00127***	–	–	–
		(0.00047)	(0.00047)			
Inefficiency function						
Constant	δ_0	−0.562***	−0.565***	−1.05***	−1.28***	–
		(0.096)	(0.077)	(0.19)	(0.26)	
Spillover	δ_S	−0.44***	−0.49***	−0.53***	−0.62***	–
		(0.15)	(0.12)	(0.15)	(0.21)	
Age	δ_A	0.1611***	0.0164***	0.0208***	0.0247***	–
		(0.0015)	(0.0012)	(0.0023)	(0.0031)	
Gamma	γ	0.552***	0.615***	0.679***	0.754***	–
		(0.043)	(0.029)	(0.036)	(0.029)	
Log-likelihood		−3979.40	−3983.45	−4023.07	−4235.33	−4419.20
No. of observations		6,278	6,278	6,278	6,278	6,278

Note: Model 1 is a *translog* production function. Models 2 and Model 3 represent a Hicks-neutral and a no-technological progress production function, respectively. Model 4 is a Cobb–Douglas production function and Model 5 represents a no-inefficiency production function. Standard errors are in parentheses and presented until two significant digits, and the corresponding coefficients are presented up to the same number of digits behind the decimal points as the standard errors.
*** Denotes significance at 1%.

Table A5. *Estimates for the periods before crisis and after crisis*

Variables	Parameters	Before crisis (1988–96)		After Crisis (1997–2000)	
		Coefficient	SE	Coefficient	SE
Production function					
Constant	β_0	0.30	0.33	4.62***	1.22
Ln(*L*)	β_1	2.53***	1.41	2.51***	0.43
Ln(*K*)	β_2	0.53***	0.12	0.44**	0.23
[Ln(*L*)]	β_{11}	−0.516***	0.043	−0.619***	0.050
Ln(*L*) * Ln(*K*)	β_{12}	0.077*	0.042	0.318***	0.040
[Ln(*K*)]^2	β_{22}	−0.020	0.016	−0.031	0.018
T	β_t	0.001	0.021	−0.23	0.20
Ln(*L*) * *T*	β_{1t}	0.0231***	0.0074	−0.083	0.026
Ln(*K*) * *T*	β_{2t}	−0.0073*	0.0042	0.053	0.012
T^2	β_{tt}	0.0019	0.0012	0.003	0.008
Inefficiency function					
Constant	δ_0	−0.188***	0.066	−0.271***	0.050
Foreign	δ_F	−0.052***	0.0073	−0.098***	−0.012
Spillover	δ_S	−0.052***	0.021	−0.0074*	0.0040
Age	δ_A	0.01174***	0.00094	0.0047***	0.0013
Gamma	γ	0.541***	0.076	0.304***	0.112
Log-likelihood		−3420.79		−2381.85	
No. of observations		5,112		2,272	

Note: Standard errors are presented until two significant digits and the corresponding coefficients are presented up to the same number of digits behind the decimal points as the standard errors.
* Denotes significance at 10%.
** Denotes significance at 5%.
*** Denotes significance at 1%.

Table 5. *Maximum likelihood estimates of stochastic production frontier with inefficiency coefficients as a function of HHI and Spillover * HHI*

Variable	Parameter	Coefficient	Standard error	Asymptotic *t*-ratio
Production function				
Constant	β_0	1.45	0.22	6.71***
Ln(*L*)	β_1	2.48	0.10	24.64***
Ln(*K*)	β_2	0.155	0.070	2.203**
[Ln(*L*)]^2	β_{11}	−0.544	0.025	−21.349***
Ln(*L*) * Ln(*K*)	β_{12}	0.119	0.022	5.461***
[Ln(*K*)]^2	β_{22}	−0.0010	0.0069	−0.1359
T	β_t	−0.033	0.012	−2.811***
Ln(*L*) * *T*	β_{1t}	−0.0011	0.0038	−0.2949
Ln(*K*) * *T*	β_{2t}	0.0098	0.0022	4.3782***
T^2	β_{tt}	−0.00115	0.00046	−2.50830**
Inefficiency function				
Constant	δ_0	−1.66	0.30	−5.61***
HHI	δ_H	−7.08	1.11	−6.37***
Spillover * HHI	δ_{SH}	−1.59	0.25	−6.22***
Gamma	γ	0.846	0.017	48.693***

Note: Figures are rounded. Standard errors are presented until two significant digits and the corresponding coefficients and *t*-ratio are also presented up to the same number of digits behind the decimal points as the standard errors.
** Denotes significance at 5%.
*** Denotes significance at 1%.

that concentration is a result of dynamic competition that removes inefficient firms.

The negative coefficient of the interacting variable between concentration and spillovers (HHI * Spillovers) suggests that higher concentration is associated with larger spillovers from foreign presence. From these findings, it may be inferred that domestic firms operating in a concentrated sub-sectors of the Indonesian chemical and pharmaceutical sectors may gain spillover benefits from foreign firms. This finding is consistent with the findings by Blomstrom and Sjoholm (1999) and Sjoholm (1999b) on the overall Indonesian manufacturing. Although the present study differs with those two previous studies in terms of the methodology, data techniques, and period of observations, the findings of this present study can be seen as a support and update evidence of those two previous studies.

(d) *Productivity spillovers and absorptive capacity*

The estimated parameters of productivity spillovers and absorptive capacity are presented in Table 6. The focus of analysis is on the estimated parameters of the inefficiency

Table 6. *Maximum likelihood estimates of stochastic production frontier with inefficiency coefficient as a function of R&D and Spillover ∗ R&D*

Variable	Parameter	Coefficient	Standard error	Asymptotic t-ratio
Production function				
Constant	β_0	1.24	0.21	5.92***
Ln(L)	β_1	2.392	0.097	2.454**
Ln(K)	β_2	0.278	0.065	4.244***
[Ln(L)]	β_{11}	−0.559	0.026	−21.179***
Ln(L) ∗ Ln(K)	β_{12}	0.140	0.022	6.348***
$[\text{Ln}(K)]^2$	β_{22}	−0.0163	0.0066	−2.4354**
T	β_t	−0.024	0.012	−1.975*
Ln(L) ∗ T	β_{1t}	−0.0017	0.0037	−0.4709
Ln(K) ∗ T	β_{2t}	0.0100	0.0021	4.7205***
T^2	β_{tt}	−0.00157	0.00045	−3.50424***
Inefficiency function				
Constant	δ_0	−0.45	0.17	−2.63***
R&D	δ_R	−0.466	0.063	−7.418***
Spillover ∗ R&D	δ_{SR}	−0.46	0.19	−2.40**
Gamma	γ	0.588	0.044	13.284***

Note: Figures are rounded. Standard errors are presented until two significant digits and the corresponding coefficients and t-ratio are also presented up to the same number of digits behind the decimal points as the standard errors.
* Denotes significance at 10%.
** Denotes significance at 5%.
*** Denotes significance at 1%.

Table 7. *Sources of productivity growth*

Year	Full sample				Foreign firms				Domestic firms			
	TEC	TP	SEC	G_O	TEC	TP	SEC	G_O	TEC	TP	SEC	G_O
1989	−0.01	3.17	0.59	3.76	−1.37	2.27	0.30	1.21	0.22	3.31	0.64	4.17
1990	0.22	3.00	0.99	4.21	1.57	2.19	−0.26	3.50	−0.01	3.13	1.19	4.32
1991	−0.02	2.83	0.40	3.21	0.65	1.62	0.32	2.59	−0.13	3.03	6.25	9.14
1992	−0.69	2.68	0.38	2.36	−2.00	1.92	−0.15	−0.23	−0.48	2.80	0.46	2.78
1993	0.41	2.52	0.35	3.29	1.09	1.77	0.63	3.48	0.30	2.64	0.31	3.25
1994	0.19	2.34	0.06	2.59	0.18	1.59	0.22	1.99	0.19	2.46	0.03	2.68
1995	−0.09	2.15	0.21	2.27	−0.13	1.40	0.57	1.84	−0.09	2.27	2.64	4.82
1996	0.12	1.93	0.40	2.45	0.08	1.17	−0.52	0.72	0.13	2.05	0.07	2.26
1997	−0.36	1.78	−0.01	1.40	−0.24	1.05	−0.52	0.29	−0.38	1.89	0.07	1.58
1998	0.11	1.61	0.25	1.97	0.33	0.91	0.35	1.60	0.08	1.72	0.24	2.03
1999	−0.06	1.35	−0.31	0.99	−0.44	0.66	−0.15	0.07	0.01	1.46	−0.34	1.13
2000	0.24	1.16	0.45	1.85	0.19	0.50	0.31	1.00	0.24	1.27	0.02	1.53
1989–92	−0.10	2.34	0.47	2.71	−0.23	1.60	0.04	1.41	−0.08	2.45	1.71	4.08
1993–96	0.16	2.23	0.26	2.65	0.30	1.48	0.22	2.01	0.14	2.35	0.76	3.25
1997–2000	−0.02	1.47	0.10	1.55	−0.04	0.78	0.00	0.74	−0.01	1.59	0.00	1.57
1988–2000	0.01	2.04	0.29	2.33	−0.01	1.31	0.08	1.39	0.01	2.16	0.89	3.06

Note: Arithmetic average of annual rate in percentage.
Source: Authors' calculation using Eqns. (7)–(14).

function (the middle part of Table 6). The coefficient of the research and development dummy (R&D) is negative and significant at the 1% level, suggesting that firms with R&D expenditure, on average, have higher efficiencies compared to those without R&D expenditure. This finding is similar to that of Todo and Miyamoto's (2006) study of the overall Indonesian manufacturing sector.

The negative coefficient of the interacting variable between R&D and spillovers (R&D ∗ Spillover) suggests that firms with R&D expenditure gain more spillovers from foreign firms. Given this result, it is possible to infer that firms with R&D expenditure can reap benefits from foreign firms' presence by upgrading their knowledge and creating new innovation. This finding confirms that firms' absorptive capacity (or firms' specific characteristic) determines productivity spillovers from FDI, as argued in some previous studies, for example, by Kathuria (2000, 2001). This finding is also in line with the finding by Takii (2005) for the whole Indonesian manufacturing firms, even though this present study includes also the period of economic crisis in the estimation.

(e) *Sources of productivity growth and FDI spillovers*

The indices of TEC, TP, SEC and G_O are calculated using Eqns. (7)–(14) and the average of these indices for the selected period is presented in Table 7. It is apparent from Table 7 that TEC, TP, SEC and G_O for domestic firms are on average higher than those for foreign firms. These results suggest that domestic firms are catching up the foreign firms in terms of technical efficiency, technology, and scale efficiency. With larger TEC indices of some domestic firms than those of foreign firms, all domestic firms are likely to approach the same level of technical efficiency as achieved by foreign firms in the long run. The same result would also turn out to be for technology level and scale efficiency. As the indices of TP for domestic firms are, on average, larger than those for foreign firms therefore domestic firms may eventually approach to the same level of technology as achieved by foreign firms. Scale efficiency may also be approaching the same level for domestic and foreign firms.

Table 7 also shows that the major contribution to productivity growth in the Indonesian chemical and pharmaceutical firms is from technological progress. This is not surprising as chemical and pharmaceutical sectors are capital- and technology-intensive. Furthermore, when the sample is divided into domestic and foreign firms, technological progress is the major driver of productivity growth in both groups. In contrast, the TEC and SEC indices are relatively constant, suggesting that these two components do not contribute much to productivity growth.

Using the indexes of TEC, TP, SEC, and G_O obtained from the decomposition, we then estimate the impact of FDI spillovers on total factor productivity (TFP) growth and its sources. The estimated parameters are presented in Table 8. We perform both random effect (RE) and fixed effect (FE) panel data models for TFP growth and its sources. The Hausman specification test is used to choose which of the two models is better at representing the data. It can be seen from the probability for χ^2-statistic of the Hausman test (Table 8) that the RE model is preferred for TEC and SEC, but the FE model is better for TP and G_O in all samples. For the sample of domestic firms only, RE model turns out to be a better model for TEC and FE model is well suited for TP, TEC, and G_O. Therefore, the interpretation of the estimated parameters for TFP growth and its sources is based on the best-suited model in each case.

Table 8 reveals that FDI spillovers contribute significantly to technological progress (as shown by a positive and significant estimate of spillover variable in the regression on technological progress). However, spillovers do not contribute much to technical efficiency and scale efficiency (as shown by a statistically insignificant estimate of spillover variable on technical efficiency change and scale efficiency change). These results indicate the role of technology transfers in generating productivity spillovers. Hence, one may argue that the spillover effects of productivity growth in the Indonesia chemical and pharmaceutical firms are predominantly due to enhancing technological progress and not as a result of technical efficiency and scale efficiency improvements.

Moreover, a positive and statistically significant estimate of concentration on technological progress suggests that a more competitive environment may reduce technological progress. A positive and significant estimate is also found for R&D dummy, which indicates that firms with R&D expenditure have higher technological progress than those without R&D expenditure. The positive and statistically significant estimate of interacting variable between spillover and R&D indicates

Table 8. *Sources of productivity growth and FDI spillovers*

	TEC		TP		SEC		G_O	
	FE	RE	FE	RE	FE	RE	FE	RE
	Full sample							
Foreign	0.0015	−0.000093	0.0012**	0.0033***	0.058	−0.0071	0.062	0.0018
Spillover	0.013	0.0037	0.0057***	0.036***	0.068	−0.035	0.088*	0.047*
Age	−0.000095	−0.000013	−0.0018***	−0.00093***	−0.0043**	0.00092	−0.0065***	0.00087***
HHI	−0.0060	−0.010	0.0083***	−0.038***	0.26	0.043	0.28	0.010
Spillover * HHI	−0.0052	0.0071	−0.011***	0.029***	−0.12	0.0052	−0.14	0.062
RD	0.0012	−0.000043	0.00031*	0.0022***	0.12***	0.11***	0.13***	0.12***
Spillover * RD	−0.0017	0.00050	0.00057*	0.0076***	−0.27***	−0.26***	0.29***	−0.27***
R^2	0.001	0.001	0.006	0.048	0.001	0.005	0.001	0.005
Hausman test	Prob $\chi^2 = 0.847$: RE		Prob $\chi^2 = 0.000$: FE		Prob $\chi^2 = 0.267$: RE		Prob $\chi^2 = 0.016$: FE	
Observations	6,816		6,816		6,816		6,816	
	Domestic firms							
Foreign	–	–	–	–	–	–	–	–
Spillover	0.012	0.0036	0.0063***	0.038***	0.040	−0.035	0.059*	0.050*
Age	−0.000083	−0.000011	−0.0019***	−0.00095***	−0.0050	0.0010	−0.0072***	0.00096***
HHI	−0.0085	−0.011	0.0076***	−0.039***	0.28	0.052	0.30	0.00063
Spillover * HHI	−0.0026	0.0086	−0.011***	0.030***	−0.085	−0.0012	−0.10	0.055
RD	0.0016	0.00017	0.000057*	0.0021***	0.14***	0.13***	0.15***	0.14***
Spillover * RD	−0.0028	0.000026	0.0010*	0.0067***	−0.31**	−0.31***	−0.33***	0.32***
R^2	0.001	0.001	0.004	0.041	0.001	0.005	0.001	0.005
Hausman test	Prob $\chi^2 = 0.808$: RE		Prob $\chi^2 = 0.000$: FE		Prob $\chi^2 = 0.000$: FE		Prob $\chi^2 = 0.016$: FE	
Observations	5,856		5,856		5,856		5,856	

Source: Authors' estimation using STATA10. FE is fixed-effect model and RE is random-effect model. Coefficients are presented until two significant digits.
* Denotes significant at 10% level.
** Denotes significant at 5% level.
*** Denotes significant at 1% level.

Table 9. *Sources of productivity growth and FDI spillovers: dealing with endogeneity*

	TEC	TP	SEC	G_O
Strategy 1: Replacing spillover with a lagged-spillover				
	Full sample			
Spillover_{t-1}	0.00079	0.0010***	0.027	0.0031*
R^2	0.001	0.007	0.005	0.001
Hausman test	Prob $\chi^2 = 0.456$: RE	Prob $\chi^2 = 0.000$: FE	Prob $\chi^2 = 0.282$: RE	Prob $\chi^2 = 0.023$: RE
Observation	6,816	6,816	6,816	6,816
	Domestic firms			
Spillover_{t-1}	0.00020	0.00018***	0.026	0.0030*
R^2	0.001	0.004	0.005	0.001
Hausman test	Prob $\chi^2 = 0.849$: RE	Prob $\chi^2 = 0.000$: FE	Prob $\chi^2 = 0.157$: RE	Prob $\chi^2 = 0.010$: FE
Observation	5,856	5,856	5,856	5,856
Strategy 2: Arellano–Bond GMM estimations				
	Full sample			
Spillover	0.031	0.0033*	0.012	0.015*
Wald-χ^2	Prob $\chi^2 = 0.000$	Prob $\chi^2 = 0.000$	Prob $\chi^2 = 0.064$	Prob $\chi^2 = 0.000$
Observation	5,680	5,680	5,680	5,680
	Domestic firms			
Spillover	0.035	0.00097*	0.037	0.039*
Wald-χ^2	Prob $\chi^2 = 0.000$	Prob $\chi^2 = 0.000$	Prob $\chi^2 = 0.073$	Prob $\chi^2 = 0.017$
Observation	4,859	4,859	4,859	4,859

Source: Authors' estimation using STATA10.
Note: FE is fixed-effect model and RE is random-effect model. The estimation for all sample includes Foreign, Age, HHI, HHI ∗ Spillover, RD, and RD ∗ Spillover variables; the estimation for domestic firms includes Age, HHI, HHI ∗ Spillover, RD, and RD ∗ Spillover variables. Coefficients are presented until two significant digits.
* Denotes significant at 10% level.
*** Denotes significant at 1% level.

that firms with R&D expenditure tend to gain more technological spillovers. However, the estimate for an interacting variable between spillover and concentration is negative and statistically significant, suggesting that competition is associated with higher spillovers on technological progress.

Endogeneity is a particularly important issue for the key variable, spillover. The OLS coefficients shown in Table 8 are estimated under an assumption that the variation in the spillover variable is exogenous to the productivity growth of domestic firms. If this assumption is not fulfilled then OLS may yield biased estimates. In the case where FDI is attracted to industries (or sub-sectors) with high productivity growth, the estimates shown in Table 8 could be biased upward. Alternatively, foreign firms may be attracted to slow-growing industries in order to gain a greater competitive advantage, which in this case, the OLS estimates shown in Table 8 may bias downward.

In dealing with this possible endogeneity bias, this study pursues two strategies, following Haskel, Pereira, and Slaughter (2007). The first strategy is to use lagged measures of spillover instead of spillover at time t. Lags may be appropriate because spillovers may take time to materialize. The second strategy is to adopt an instrumental variable estimation, as an alternative to OLS. This study employs the Arellano-Bond GMM estimator, which adds a lagged dependent variable and once-lagged independent variables as instrumental variables.

The estimation results for the first and the second strategies of addressing endogeneity bias are presented in Table 9. For the first strategy, we present the results of the best-suited model. As the results show, the signs and significances of the lagged spillover (Spillover_{t-1}) on productivity growth (and its sources) are similar to those of spillover at time t shown in Table 8. The only notable difference is the value of the coefficients, which are larger for the lagged spillover. The positive and significant coefficient Spillover_{t-1} on G_O is consistent with the spillover-taking-time argument. The positive and significant coefficient Spillover_{t-1} on TP, and positive and insignificant on TEC and SEC, suggest that the presence of FDI contributes significantly to technological progress but not to technical efficiency change and scale efficiency change.

The results for the second strategy are presented in the lower part of Table 9. The Arellano–Bond GMM estimates on spillover present similar conclusions as those of Table 8. By adding a lagged dependent variable and once-lagged variables as instruments, the results show a positive and significant affect of spillover on productivity growth and technological progress. However, the level of significance of the coefficient on technological progress in this model is lower than those shown in Table 8, which may be due to the lack of good instruments.

7. CONCLUSION AND POLICY IMPLICATIONS

This study examines the productivity spillovers from FDI in the Indonesian chemical and pharmaceutical sectors by using a unique and extensive firm-level panel data covering the period 1988–2000. Unlike most of the previous studies on FDI productivity spillovers, this paper uses the stochastic frontier production function following Battese and Coelli (1995) and a generalized *Malmquist* output-oriented index to decompose productivity growth. The intra-industry productivity spillovers are examined through the spillover variable, and the roles of competition and R&D in extending spillovers from FDI are evaluated to test a channel of productivity spillovers.

The empirical results show that intra-industry productivity spillovers are present in the Indonesian chemical and pharmaceutical sectors. It also shows that competition facilitates spillovers from a foreign presence in the industry. Firms with R&D expenditure receive more productivity spillovers than those without R&D expenditure. Furthermore, technological progress is the major driver of productivity growth in the Indonesian chemical and pharmaceutical firms. FDI spillovers have been found to be positive and significant for technological progress; however, positive but not significant for technical and scale efficiency change.

Despite the presence of positive spillovers from FDI, the policy implications of these findings are not straightforward. These results may support the continuing fiscal and investment incentives provided by the Indonesian government for FDI. However, with many countries competing for FDI, particularly in the presence of an asymmetric competition among countries, there are undesirable welfare effects for a developing country, such as Indonesia (Bjorvata & Eckel, 2006). This suggests policies for strengthening the absorptive capacity of domestic firms through investing in knowledge and human capital formation may be superior to policies that provide concessions for FDI. There is also a need for further institutional reforms including political system, economic management and government administration, and trade policies in order to develop a more competitive environment in the manufacturing sector. More general policies should be pursued, which not only attract FDI but also benefit domestic firms, for example, build modern infrastructure, increasing and strengthening the institutions for accelerating and sustaining economic growth.

NOTES

1. Following Smeets (2008), knowledge is defined broadly as managerial know-how, superior technology, and the ability to exploit scale efficiency.

2. UNCTAD (2003) reported that of the 1,641 national regulatory changes to FDI from 1991 to 2001, 94% provide more favorable incentives for FDI.

3. The figure is calculated from the Annual Survey of Large and Medium Manufacturing Industry conducted by Indonesian Central Bureau of Statistics (Badan Pusat Statistik, BPS) for the period 1975–2000. During this period, chemical and pharmaceutical sectors are the second most productive sector in manufacturing industry (among nine sectors) in terms of value added per labor, just slightly below metal products (which is around 1.58 times of the manufacturing average). Please see Appendix A for the explanation about the Annual Survey.

4. The figure is calculated from the Annual Survey of Large and Medium Manufacturing Industry.

5. One recent study decomposes productivity spillover of FDI (Girma & Gorg, 2007), but it only decomposes productivity growth into two components (TP and SE) by using a deterministic approach called Divisia index, which has some severe limitations. For example, no allowance is made for measurement error and other statistical noise, so that the resulting productivity measures from this index are likely to be contaminated.

6. For example, the effective rate of protection (ERP) was reduced from 133% in 1984 to 19% in 1987 (Fane & Philips, 1991; Sjoholm, 1999a).

7. Since the liberalization in 1988, the government had provided a range of incentives for FDI through a set of consecutive reforms (which were undertaken in 1992, October 1993, and June 1994). The incentives included permission for foreign ownership up to 100% in priority sectors and targeted areas, a reduction in capital requirement from US$ 1 million to US$ 250,000, an open-up for export-oriented FDI, an automatic renew of foreign license for next 30 years, and a relaxation of domestic-material requirement (Pangestu, 1996). During the crisis and after, the provided incentives have been more extensive. The government simplified the administration procedure and granted income tax facilities. The enactment of the Law no. 25/2007 and the Government Regulation no. 1/2007 on investment provide non-discriminatory treatment for both foreign and domestic investors and income-tax dispensation to 15 sectors, including chemicals (Adiningsih, Lestari, Rahutami, & Wijaya, 2009).

8. The figures are obtained from Indonesian Economic and Financial Statistics (Statistik Ekonomi dan Keuangan Indonesia or SEKI) published by Central Bank of Indonesia, various years.

9. Figures are calculated from the Annual Survey of Large and Medium Manufacturing Industries.

10. For a comprehensive survey, please see Cuyveys, Soeng, Plasmans, and Van den Bulcke (2008).

11. As is widely known, the conventional approach of the production function assumes that all firms are fully efficient, which is unlikely to happen in reality. This means a productivity improvement is exclusively related to a shift of a production frontier. Hence, the productivity advantage from FDI under this conventional approach is determined solely by technological progress.

12. In the literature of stochastic frontiers, a simultaneous estimation of a production function and an efficiency function is known as a one-stage estimation procedure. This procedure is preferable since a two-stage estimation procedure is inconsistent in its assumption regarding the independently and identically distributed technical inefficiency effects (Kumbhakar, Ghosh, & McGuckin, 1991). Moreover, the two-stage estimation procedure is unlikely to provide estimates that are as efficient as those obtained using the single-stage estimation procedure. For more details, see Kumbhakar and Lovell (2000).

13. Battese and Coelli (1995) model is commonly classified as an extension of random-effect model in the panel data stochastic frontier analysis. An excellent discussion on the classification of panel-data stochastic frontier models into fixed-effect and random-effect is provided in chapter 4 of Kuenzle (2005).

14. The mathematical derivation of the maximum likelihood function and its related variance parameters are discussed in Battese and Coelli (1993).

15. The data are available in an electronic format (*d*-base file) and obtained under a license.

16. This study uses a balanced panel data for the purpose of decomposing total factor productivity growth into its components (efficiency change, technological change, and scale efficiency change), which are then used as dependent variables for the analysis of FDI spillovers on sources of productivity growth. In the original data, some firms appeared only in certain years and some others even appeared only in one year, which made calculations of the growth variables for these firms impossible. Therefore, this study excludes these firms from the final dataset since they might not provide a consistent growth data for the observed years. The authors are aware of the possibility of neglecting the relatively new foreign and

domestic firms which might be on the frontier. However, since the objective is also to decompose total factor productivity (TFP) growth, this study proceeds by using the balanced data.

17. For explanation regarding a mixed chi-squared and a test for no inefficiency effect, see Battese and Coelli (1988).

18. A simpler picture emerges in Model 2, where neutrality of technical change is imposed. Here the coefficient of time is positive and statistically significant, suggesting technological progress. However, the coefficient of time squared is negative and statistically significant, suggesting technological progress is falling over the sample period.

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APPENDIX A

A.1. *Sources of data and construction of dataset*

The annual surveys of medium and large manufacturing establishments (*Survey Tahunan Statistik Industri* or SI hereafter) cover 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 labor 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 number of establishments surveyed varies depending on 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 have been conducted since 1975, and the most recent available data are for the year 2005. However, this study uses only the period of data from 1988 to 2000. The year 1988 is chosen as a starting year because the data on the replacement value of capital is not available before 1988. The 2002–05 period is excluded because the BPS does not present the specific identification code (SID from hereafter) in the years 2002–04 and the inclusion of 2001 data reduces the number of establishments by almost 50% of the total sample when a balanced panel is constructed.

In order to construct a unique balanced panel data covering the selected period and only for chemical and pharmaceutical firms, this study follows several steps:

Step 1: Adjustment for industrial code:

The BPS reclassifies the industrial code twice (in 1990 and 1998) to accommodate the growing number of manufacturing establishments as well as the revisions to International Standard Industrial Classification (ISIC). Fortunately, the BPS provides concordance tables for these reclassifications. The concordance tables and the SID are used to obtain a consistent industrial code for the selected period.

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 authors went through the survey questionnaires to obtain consistent variable 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 and/or labor are removed.
b. If a firm reported a missing value for a particular variable in a given time but reported 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% of the total observations.
c. Typographical errors (or key-punch error) in the raw data are adjusted for consistency. For example, if in the raw data, foreign share of a firm for the whole of the selected period is typed as a 100%, except for a certain year being typed as 0%, then the 0% share is adjusted to 100%.
d. Observations that are considered as outliers are removed from dataset by sorting the data based on output and removing 1.5% of the lowest values and 1.5% of the highest values, as suggested by Takii (2005).

Step 4: Back casting the missing values of capital.

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

Step 5: Choosing only chemical and pharmaceutical firms (ISIC 351 and 352).

Based on the industrial code, chemical and pharmaceutical firms are chosen. In this study, the chemical and pharmaceutical sectors are defined as ISIC 351 (industrial chemicals) and ISIC 352 (pharmaceuticals and other chemicals).

Step 6: Balanced panel dataset is constructed for the selected period by matching firms based on the specific identification code (SID).

Step 7: All monetary variables (output and material) are deflated using a wholesale price index provided by the BPS at a constant price of 1993.

View Item: Does Foreign Direct Investment Lead to Productivity Spillovers? Firm Level Evidence from Indonesia

., Suyanto and SALIM, RUHUL A. and BLOCH, HARRY (2009) *Does Foreign Direct Investment Lead to Productivity Spillovers? Firm Level Evidence from Indonesia.* World Development, 37 (12). pp. 1861-1876. ISSN 0305-750X

Abstract

Whether spillovers from foreign direct investment (FDI) make any contribution to host countries' productivity growth, remains a contentious issue in the literature. This paper aims to contribute to this debate by empirically examining the specific contribution of FDI to productivity growth in the Indonesian chemical and pharmaceutical firms using plant-level survey data from the Indonesia's Central Board of Statistics (BPS). A unique balanced panel dataset is constructed that covers 568 firms for the period of 1988-2000. The spillover effects from FDI are analyzed using a stochastic frontier approach and productivity growth is decomposed using a generalized Malmquist output-oriented index. The results show positive productivity spillovers from FDI in the chemical and pharmaceutical sector; higher competition is associated with larger spillovers; and domestic firms with R&D gain more spillover benefits compared to those without R&D. Furthermore, technological progress is the major driver of productivity growth in the chemical and pharmaceutical firms. FDI spillovers are found to be positive and significant for technological progress. FDI is also positive, but not significant, for technical and scale efficiency change. These findings provide rationale for policies that attract FDI and support R&D in the manufacturing sector in Indonesia and elsewhere.

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Surabaya, 13 Mei 2016
Reviewer 1

Prof. Dr. R. Wilopo, Ak., CA, CFE

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LEMBAR
HASIL PENILAIAN SEJAWAT SEBIDANG ATAU *PEER REVIEW*
KARYA ILMIAH : JURNAL ILMIAH

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Surabaya, 14 Juni 2016
Reviewer 2

Prof. Dr. Munawar Ismail, SE, DEA

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Unit Kerja ...(4) : FEB Universitas Brawijaya

Does Foreign Direct Investment Lead to Productivity Spillovers?

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Does Foreign Direct Investment Lead to Productivity Spillovers? Firm Level Evidence from Indonesia

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Summary. — This paper examines whether spillovers from foreign direct investment (FDI) make any contribution to productivity growth in the Indonesian chemical and pharmaceutical firms using plant-level panel data. The spillover effects from FDI are analyzed using a stochastic frontier approach and productivity growth is decomposed using a generalized *Malmquist* output-oriented index. The results show positive productivity spillovers from FDI; higher competition is associated with larger spillovers; and domestic firms with R&D gain more spillover benefits compared to those without R&D. FDI spillovers are found to be positive and significant for technological progress and positive, but not significant, for technical and scale efficiency change.

Key words — FDI spillovers, frontier production function, *Malmquist* index, total factor productivity growth

1. INTRODUCTION

Foreign direct investment (FDI) is believed to provide recipient countries with knowledge [1] transfer as well as capital. The argument is that multinational corporations (MNCs) establish subsidiaries in overseas and transfer knowledge to their subsidiaries. The transferred knowledge has a certain public good quality and may spread through non-market mechanisms over the entire economy leading to productivity gains (hereafter productivity spillovers) in domestic firms (Blomstrom, 1989).

Expectation of productivity spillovers from knowledge transfers has been a major impetus to policy makers in many countries to provide FDI-friendly regime. [2] In developing countries, policies in favor of FDI have been introduced since the early 1980s. Since then, net inflows of FDI have increased dramatically and FDI has been the most significant part of private capital inflows to developing countries. From 1985 to 2006, for example, the net FDI inflows to developing countries have increased from US$ 14 billion to US$ 379 billion, rising more than 25-folds (UNCTAD, 2007). In recent years, FDI inflows have accounted for more than half of the total private capital inflows in developing countries (Ng, 2006).

Now an important question is whether these huge FDI inflows indeed bring about productivity spillovers for recipient countries, particularly for developing economies. The evidence is fairly mixed so far. Some empirical studies confirm positive productivity spillovers from FDI (e.g., Caves, 1974; Chakraborty & Nunnenkamp, 2008; Gorg & Strobl, 2005; Javorcik, 2004; Schiff & Wang, 2008), but others find negative or no spillovers (e.g., Aitken & Harrison, 1999; Barry, Gorg, & Strobl, 2005; Djankov & Hoekman, 2000; Haddad & Harrison, 1993). The mixed evidence intuitively implies that there is no universal relationship between FDI and domestic firms' productivity. Some studies, however, argue that the mixed findings may be attributed to domestic firms' characteristics or host countries' ability to absorb productivity spillovers (Gorg & Greenaway, 2004; Smeets, 2008). Nevertheless, differences in findings depend significantly on research design, methodological approach, types of data used, estimation strategy, and even on the construction of the spillover variable.

The present paper extends the current empirical literature to determine whether the FDI leads to productivity gains in the Indonesian chemical and pharmaceutical industries during 1988–2000. These two industries have been chosen as they continuously attracted the highest inflow of annual FDI since 1975 (Table 2). They belong to the group of the most productive sectors in the Indonesian manufacturing industries in terms of value added per worker (around 1.5 times of the manufacturing average), [3] while registering a consistent growth of an annual average of 17.71% during 1988–2000). [4] An overwhelming presence of MNCs in this sector provides a good basis to examine the role of firm-specific characteristics in determining the productivity spillovers.

We estimate FDI productivity spillovers using the Stochastic Frontier Approach (SFA). With this method we also address the importance of competition and firms' absorptive capacity for gaining productivity spillovers. Furthermore, we identify the sources of productivity growth in the presence of FDI in these two major industries of the Indonesian economy. A generalized *Malmquist index* is used to decompose total factor productivity (TFP) growth into technical efficiency change (TEC), technological progress (TP), and scale efficiency change (SEC). We then test the impact of FDI spillover effects on each of these components of productivity growth. The authors know of no other study that addresses the issue of decomposing the productivity effects of FDI using a generalized *Malmquist index*. [5]

The rest of this paper proceeds as follows: Section 2 provides an overview of the Indonesian manufacturing sector and the inflow of FDI, which is followed by a critical review of the theoretical and empirical studies on productivity spillovers in Section 3. Section 4 discusses estimation techniques followed by data sources and variable construction. Section 6 presents the results for model selection and estimation,

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followed by an analysis of empirical results. The summary of findings and policy implications is given in the final section.

2. AN OVERVIEW OF THE INDONESIAN MANUFACTURING AND FDI FLOWS

Indonesian manufacturing has been demonstrating spectacular growth and unprecedented transformation since the second half of 1970s. This transformation is evident not only in rapid output and in employment growth, but also in the transition to modern capital and skill-intensive industries, strong productivity and wage growth, and broadening the industrial base outside the capital city, along with a probable reduction in concentration levels (Hill, 1996). Decisive liberalization reforms have been introduced since the mid 1980s. These included reduction in tariff and non-tariff barriers,[6] privatization of public enterprises, relaxation of foreign investment rules, and lessening other restrictions. The reform package also included fiscal reform, financial liberalization, and the maintenance of a realistic and flexible exchange rate, together with trade liberalization, reduction in government intervention and improved management of public enterprises. The industrial development policies were focused on the priority industries and the creation of industrial zones. The reforms of the 1980s were designed to improve the productivity performance of manufacturing industries by encouraging competition from within the economy as well as from outside.

The change of policy direction from interventionist to liberalization encourages the expansion of export-oriented sub-sectors, such as chemicals and pharmaceuticals (ISIC 35), and woods and wood products (ISIC 33). As a result, since 1987 Indonesia has experienced a surge in manufactured exports, for example, during the period 1989–93 manufactured exports grew at an average annual rate of 27%, while manufacturing value added (MVA) grew at an average annual rate of 22% (UNIDO, 2000). Export-oriented manufacturing firms witnessed a higher growth than non-export firms, and at the same time, manufacturing firms experienced a substantial productivity growth.

Studies reveal that manufacturing sector experienced higher TFP (total factor productivity) growth at around 6% per annum in the post liberalization period (Ikhsan, 2007; Vial, 2006) compared to a negative growth of −4.9% during 1981–83 (Aswicahyono, 1988). One of the important factors contributing to these positive outcomes in the manufacturing sector during the post-liberalization period was a massive inflow of FDI.[7] The huge increase in FDI inflows, from a meager US$ 0.2 billion in 1983 to US$ 5.9 billion in 2006,[8] facilitated the high growth of manufacturing industries in terms of output, employment, and value added. Moreover, the growing FDI inflows helped create backward and forward linkages in the economy. Although there was a decrease in manufacturing growth during the East Asian crisis in 1997, this sector revived quickly and demonstrated further growth since 2000.

The manufacturing sector received a large proportion of total FDI inflows in the Indonesian economy. The share of approved FDI to this sector accounts for more than 50% of total approved FDI over the last three decades (Table 1). Although the total approved FDI decreased steadily after the economic crisis, the share of manufacturing FDI remains the largest part of the total FDI. Furthermore, within the manufacturing sector over the years (Table 2), the highest share of manufacturing FDI flowed to chemicals and pharmaceuticals (44.56%), followed by metal products (13.13%) and papers and paper products (11.96%). Food products have received an increasing share of manufacturing FDI, particularly after the deregulation in 1984. However, the average percentage of FDI to this sector remains relatively small of the total approved manufacturing FDI.

Based on the high level of FDI, the present study focuses on chemical and pharmaceutical firms in examining the productivity spillovers of FDI. Another reason to focus on this sector rather than on pooling data for the whole Indonesian manufacturing is to reduce heterogeneity in data, as suggested by Bartelsman and Doms (2000). Firms in the chemical and pharmaceutical sectors have different characteristics, in terms of size and technology, compared to, for example, firms in food processing sector. Pooling firms from both industries together may give rise to persistent heterogeneity in data.

The chemical and pharmaceutical sectors (ISIC 35) represent about 18% of Indonesian manufacturing output and around 12% of the manufacturing employment in 2005. This sector employs some 540 thousand people with wages of around IDR 8,445 billions per year. Its contribution to the manufacturing value added (MVA) was the third highest of all industries after the food industry and textiles. During 1975–2005, this sector expanded rapidly, increasing in value added by more than 35 times.[9] It is a diverse industry ranging from large-scale petrochemical complexes to medium-sized establishments that simply mix chemicals to produce paint, pesticide, and traditional medicines. In the Annual Survey of Manufacturing Industries, the BPS divides this sector into six sub-sectors: industrial chemicals (ISIC 351), pharmaceutical and other chemicals (352), oil and gas refining (353 and 354), rubber and products (355), and plastic products (356). Among these sub-sectors, the oil and gas refining sub-sectors have only been surveyed since 1990 and cover only a few establishments. The other four sub-sectors have been surveyed since 1975.

In this study, the focus is on the sub-sectors industrial chemicals (ISIC 351) and pharmaceuticals and other chemicals (ISIC 352), as these two sub-sectors represent more than 70% of the sector value added. The trend and key indicators of the two sub-sectors (hereafter, chemical firms and pharmaceutical firms refer to firms in these two sub-sectors, respectively) during the studied periods are presented in Table 3. From the table, one might note that the combined sub-sectors expanded rapidly during 1988–98, which can be observed from an increase in output and value added by more than 10 times. Labor productivity, which is measured by value added per labor (VA/L), also increased considerably by almost eight times during the years.

Interestingly, the number of foreign firms, as a percentage of total firms across the two sub-sectors combined, increased quite significantly from 12.92% in 1988 to 18.65% in 1998. A similar pattern is also observed for foreign share (as a percentage of value added), as it rose drastically from 27% in 1988 to 61.23% in 1998, suggesting an important contribution of foreign firms to the value added in this sector. The exported outputs of the combined sub-sectors were less than 7% during 1988–98. In contrast, there was heavy reliance on imported materials, with 55.18% and 44.75% of total material was imported in 1988 and 1998, respectively.

3. RELATED LITERATURE AND HYPOTHESIS DEVELOPMENT

(a) *MNCs, superior knowledge, and productivity spillovers*

When MNCs establish subsidiaries overseas, they come across disadvantages in the form of access to resources

Table 1. *Share of approved manufacturing FDI 1975–2006*

Year	Total approved FDI (million USD)	Approved manufacturing FDI (million USD)	Share of manufacturing FDI to total FDI (percentages)
1975–79	5,322.10	3,666.40	68.89
1980–84	7,765.70	6,346.10	81.72
1985–89	12,300.20	10,150.10	82.52
1990–94	57,996.50	37,507.10	64.67
1995–99	126,919.20	81,092.60	63.89
2000–04	57,495.20	31,735.20	55.20
2005–06	29,203.20	14,336.10	49.09
1975–2006	297,002.10	184,833.60	62.23

Sources: Calculated from Indonesian Financial Statistics, Central Bank of Indonesia, various years.

Table 2. *The distribution of approved manufacturing FDI (as % of total approved manufacturing FDI) in two-digit ISIC industries for the period 1975–2006*

Year	Food (31)	Textile and leather (32)	Wood and wood product (33)	Paper and paper product (34)	Chemical and pharmaceutical (35)	Non metal mineral (36)	Basic metal (37)	Metal products (38)	Others (39)
1975–79	4.96	8.81	0.77	2.87	15.84	9.97	47.99	8.59	0.19
1980–84	2.63	6.21	2.41	12.21	18.12	5.67	24.60	28.13	0.01
1985–89	5.40	9.14	2.83	18.69	48.25	4.61	2.74	7.92	0.42
1990–94	5.29	11.54	1.50	15.79	35.13	5.35	7.35	17.01	1.05
1995–99	5.10	2.50	0.88	14.36	58.62	3.36	3.74	11.12	0.33
2000–04	7.62	4.27	1.34	7.37	54.83	2.96	6.29	6.12	9.21
2005	10.66	2.31	1.70	3.78	47.76	6.11	0.00	11.53	16.16
2006	12.47	1.88	1.66	14.09	18.40	9.45	0.00	35.13	6.91
1975–2006	6.31	5.99	1.40	11.96	44.56	4.71	8.11	13.13	3.83

Source: Calculated from Indonesian Financial Statistics, Central Bank of Indonesia, various years.

Table 3. *Trend and key indicators of the chemical and pharmaceutical sectors*

Key indicators	Chemicals and pharmaceuticals (ISIC 351 and 352)			Industrial chemicals (ISIC 351)			Pharmaceuticals and other chemicals (ISIC 352)		
	1988	1993	1998	1988	1993	1998	1988	1993	1998
Output (billion rupiah)	4,133	11,071	42,948	2,142	5,637	27,793	1,991	5,434	15,155
Value-added (billion rupiah)	1,451	4,376	16,712	784	2,401	10,983	667	1,975	5,729
Labor (person)	114,565	160,673	192,618	39,495	60,241	81,914	75,070	100,432	110,704
VA/L (thousand rupiah)	12,668	27,236	86,760	19,850	39,853	134,074	8,889	19,669	51,751
No of establishments	743	892	1,035	218	325	431	525	567	604
Foreign firm (% of total establishments)	12.92	14.01	18.65	11.93	16.92	22.97	13.33	13.35	15.56
Domestic firm (% of total establishments)	81.16	81.28	77.10	75.23	76.00	71.69	83.81	83.30	80.96
SOEs (% of total establishments)	5.92	4.71	4.25	12.84	7.08	5.34	2.86	3.35	3.48
Foreign share (% of VA)	27.00	42.85	61.23	17.12	39.97	67.90	38.61	46.35	48.42
Export (% of output)	5.09[a]	6.56	1.42	8.09[a]	10.88	4.62	3.46[a]	4.08	1.29
Imported-material (% of total material)	55.18	44.48	44.75	57.01	46.02	43.05	52.97	42.83	48.15

Source: Authors' calculation from the Annual Survey of Large and Medium Manufacturing Industries.
Foreign firms are defined as firms with any foreign ownership, domestic firms are firms those 100% owned by domestic private individual or companies, and state-owned enterprises (SOEs) are firms owned by the central or district government.
[a]The figure was calculated based on the data in 1990 because it was the first year the information on export was published.

and domestic demand, when compared to their local counterparts. Domestic firms have more experience in serving domestic markets and possess more information regarding the type of products, consumer preferences, and distributional networks relative to MNCs. In order to compete with the domestic firms, MNCs need to possess superior knowledge (Caves, 1971). The superior knowledge, which is often known as special intangible assets in the industrial organizational theory of FDI, takes the form of process and product, managerial and organizational, and scale efficiency knowledge (Kokko & Kravtsova, 2008). With this superior knowledge, MNCs are often assumed to have higher performance levels than domestic firms, in particular being more efficient and productive. To test whether this is the case in the Indonesian chemical and pharmaceutical sectors, this study hypothesizes that

H1a. Foreign-owned firms are more efficient (or productive) than domestic firms.

If MNCs indeed possess superior knowledge relative to domestic firms, there is a possibility that MNCs may generate positive productivity spillovers (Blomstrom & Kokko, 1998). When MNCs transfer knowledge to their subsidiaries, the transferred knowledge may spill, through non-market mechanisms, over the entire economy that may then lead to productivity growth in domestic firms. However, MNCs would prevent their knowledge seeping to domestic firms by raising the cost of spillovers, such as patenting their products and ideas.

A large number of empirical studies examine the productivity spillovers hypothesis of FDI in the literature. The pioneering empirical research in this area was conducted by Caves (1974) on Australia, followed by Globerman (1979) on Canada, and Blomstrom and Persson (1983) on Mexico. The empirical literature then developed in many directions in a number of country-specific and cross-country investigations. However, the findings of these studies are diverse and inconclusive.[10] The relationship between FDI spillovers and firms' productivity gains still remains to be an empirical issue. Being the top recipients of FDI, the higher *per capita* productivity in Indonesian chemical and pharmaceutical industries than the manufacturing average therefore suggests a test for the following hypothesis:

H1b. There is a positive productivity spillover from FDI in the Indonesian chemical and pharmaceutical sectors.

(b) *Productivity spillovers and competition*

Most of the previous studies on FDI spillovers treat the specific mechanisms of productivity spillovers as occurring in a "black box" (Gorg & Strobl, 2005). These studies often assume that productivity spillovers from FDI occur automatically as a consequence of foreign firms' presence in domestic markets. The channels of productivity spillovers are not explicitly taken into account in such studies.

However, some studies try to consider explicitly the channels of productivity spillovers from FDI. There are three fundamental mechanisms for productivity spillovers to take place. First, the entry of MNCs may lead to greater competition in domestic markets, which then forces domestic firms to utilize their resources and technology in more efficient ways, leading to productivity gains (Wang & Blomstrom, 1992). Second, knowledge may spill over to domestic firms *via* labor turnover, that is, when workers trained by MNCs move to domestic firms and bring with them the knowledge and other crucial intangible assets (Fosfuri, Motta, & Ronde, 2001). Third, foreign firms in domestic markets may create demonstration effects to domestic firms through direct imitation and reverse engineering (Das, 1987), or new innovation through R&D (Cheung & Lin, 2004).

Of these three channels of productivity spillovers, the first channel is of particular interest in this study. Competition may result in either positive or negative productivity spillovers for domestic firms. Aitken and Harrison (1999) argue that, in the short-run, the presence of foreign firms in an imperfect competition domestic market may raise the average cost of production of domestic firms through the "market stealing" phenomenon. Foreign firms with a lower marginal cost have an incentive to increase production relative to their domestic competitors. The productivity of domestic firms will fall as they have to spread fixed costs over a smaller amount of output. However, in the long-run, when all costs can be treated as variable costs, there is a possibility for domestic firms to reduce their costs by allocating their resources more efficiently and imitating foreign firms' knowledge (Wang & Blomstrom, 1992). If the efficiency effect from foreign presence is larger than the competition effect, there can be positive productivity spillovers. Following these arguments, this study tests the following hypothesis:

H2. Higher competition is associated with larger spillovers from foreign presence in the industry, that is, positive productivity spillover through competition.

(c) *Productivity spillovers and absorptive capacity*

The mixed evidence of productivity spillovers leads to the celebrated argument that firm-specific characteristics (or absorptive capacity) may influence the ability of domestic firms in gaining productivity spillovers from FDI (Findlay, 1978; Glass & Saggi, 1998; Wang & Blomstrom, 1992). The most commonly used measure of absorptive capacity is the extent of research and development (R&D) expenditure. In a study of the Indian manufacturing firms, Kathuria (2000) shows that local firms that invest in learning, or R&D activities receive high productivity spillovers, whereas the non-R&D local firms do not gain much from the presence of foreign firms. This result indicates that the productivity spillovers are not automatic consequences of the presence of foreign firms; rather they depend on the efforts of local firms' investment in R&D activities. Kinoshita (2001) finds similar evidence in a study on Czech manufacturing firms during 1995–98. By focusing on electrical machinery and radio & TV sectors, she finds that R&D is a necessary condition for technology spillovers from FDI. In a more recent study on twelve OECD countries, Griffith, Redding, and van Reenen (2004) also confirm that R&D plays an important role in knowledge transfer, besides its role as a medium of innovation. To capture a firm-specific characteristic of Indonesian chemical and pharmaceutical firms in determining the productivity spillovers from FDI, this study also tests the following hypothesis:

H3. Domestic firms with R&D expenditure gain more productivity spillovers from FDI than those without R&D expenditure.

(d) *Sources of productivity advantage from FDI*

Technical and scale efficiencies are hardly studied in the literature in relation to productivity gains from FDI. While the theoretical literature provides little guidance to these two sources of productivity growth, the empirical studies also tend to ignore the decomposition issue (Girma & Gorg, 2007). The empirical studies usually assume that productivity advantage from FDI is exclusively contributed by technology transfers as is consistent with the use of conventional approach of production function.[11]

The stochastic productivity frontier literature, such as Orea (2002), offer a parametric decomposition of productivity growth into three components: technical efficiency change (TEC), technological progress (TP), and scale efficiency change (SEC). By decomposing productivity growth using this analysis, it is possible to examine the productivity advantage from FDI to technical and scale efficiencies as well as technological progress. In a recent survey, Smeets (2008) argues that the productivity spillovers from FDI should be defined broadly, as it arises from new knowledge rather not only from new technology. Further, he defines knowledge as including technology; managerial, and production skills, which may contribute to technical efficiency and ability to exploit scale efficiency. Therefore, the final hypothesis to test sources of productivity gains from FDI can be stated as follows:

H4. There are positive FDI spillovers to each component of productivity growth (TEC, TP, and SEC).

4. MODEL SPECIFICATION AND ESTIMATION TECHNIQUES

(a) *Productivity spillovers from FDI: a stochastic frontier approach*

When measuring efficiencies and productivity at the firm level, researchers face the choice of alternative approaches, such as conventional production (cost) functions, data envelopment analysis (DEA), and stochastic frontier production (cost) function. Each of these approaches has its merits and demerits. The debate over which approach is appropriate continues (Coelli, Rao, O'Donnell, & Battese, 2005).

We apply the stochastic frontier production function to test the spillover hypothesis from FDI. Following Battese and Coelli (1995) the stochastic frontier approach (SFA) is used to estimate a production function and an inefficiency function simultaneously.[12] The Battese–Coelli model can be expressed as follows:[13]

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

where y_{it} implies 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, and β represents the $(k \times 1)$ vector of parameters to be estimated. The error term consists of two components: v_{it} and u_{it}, which are independent of each other. In addition, the v_{it} denotes the time-specific and stochastic part, with $iid\ N(0, \sigma_v^2)$, and the u_{it} represents technical inefficiency, which is normal distribution, but truncated at zero with mean $z_{it}\delta$ and variance σ_u^2.

The technical inefficiency effects, u_{it}, are 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. In a linear equation, the technical inefficiency effects can be specified as follows:

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

where w_{it} is an unobservable random variable, which is defined by the truncation of the normal distribution with zero mean and variance, σ_u^2, such that the point of truncation is $-z_{it}\delta$.

Eqn. (1) shows the stochastic production function in terms of the original production value, and Eqn. (2) represents the technical inefficiency effects. The parameters of both equations can be estimated simultaneously by the maximum-likelihood method. The likelihood function is expressed in terms of variance parameters $\sigma_s^2 \equiv \sigma_v^2 + \sigma_u^2$ and $\gamma \equiv \sigma_u^2/\sigma_s^2$.[14] If γ equals zero, then the model reduces to a traditional mean response function in which z_{it} can be directly included into the production function.

Based on the theoretical model in Eqns. (1) and (2), we start with a flexible functional form, namely, a *translog* production function. By adopting a flexible functional form, the risk of errors in the model specification can be reduced. Moreover, the *translog* form is useful for decomposing the total factor productivity growth. The functional form of the *translog* production function is as follows:

$$\ln y_{it} = \beta_0 + \sum_{n=1}^{N} \beta_n \ln x_{nit} + \frac{1}{2}\sum_{n=1}^{N}\sum_{k=1}^{N} \beta_{nk} \ln x_{nit} \ln x_{kit} + \beta_t t + \frac{1}{2}\beta_{tt}t^2 + \sum_{n=1}^{N} \beta_{nt} \ln x_{nit} t + v_{it} - u_{it}, \tag{3}$$

where y implies output, x represents variables that explain output (labor and capital, so $N = 2$), t is time, i is firm. And u_{it} is defined as:

$$u_{it} = \delta_0 + \sum_{j=1}^{J} \delta_j z_{jit} + w_{it}, \tag{4}$$

where z is the set of explanatory variables that explain technical inefficiency.

Hypotheses H1a, H1b, H2, and H3 are tested by estimating three alternative technical inefficiency functions to avoid the possibility of multicollinearity. A test of H1 includes only a spillover variable; a test of H2 involves an interacting variable of spillover and competition; and a test of H3 involves an interacting variable of spillover and R&D. The interacting variables in H2 and H3 are likely to have a high correlation with each other. A simple possible way to deal with this issue in a stochastic frontier model is to estimate the hypotheses separately.

To test H1, the subscript j in Eqn. (4) represents the dummy variable of foreign ownership (to test H1a) and FDI spillovers (to test H1b). These hypotheses are tested by controlling the age of the firm. z_j in Eqn. (4) includes an interacting variable of competition and spillovers when testing H2, while it represents an interacting variable of R&D and spillovers when testing H3. Details of definition and construction of each variable used in Eqns. (3) and (4) are presented in Table A1.

Given the specifications in Eqns. (3) and (4), the technical efficiency of production for the ith firm at the tth year is defined as the ratio of the actual output of firm i, ln y_{it}, to its potential output, ln y_{it}^p:

$$TE = \frac{\ln y_{it}}{\ln y_{it}^p} = E[-u_{it}|(v_{it} - u_{it})] = E[(-z_{it}\delta - w_{it})|(v_{it} - u_{it})], \tag{5}$$

where

$$\ln y_{it}^p = \beta_0 + \sum_{n=1}^{N} \beta_n \ln x_{nit} + \frac{1}{2}\sum_{n=1}^{N}\sum_{k=1}^{K} \beta_{nk} \ln x_{nit} \ln x_{kit} + \beta_t t + \frac{1}{2}\beta_{tt}t^2 + \sum_{n=1}^{N} \beta_{nt} \ln x_{nit} t + v_{it}. \tag{6}$$

(b) *Decomposing productivity growth: a generalized Malmquist index*

Orea (2002) shows that if firm i's technology in time t can be represented by a *translog* output-oriented distance function $D_O(y_{it}, x_{it}, t)$ where y_{it}, x_{it}, and t are defined as above, then the logarithm of a generalized output-oriented *Malmquist* productivity growth index, $G_{Oi}^{t,t+1}$, can be decomposed into TEC, TP, and SEC between time periods t and $t+1$:

$$G_{Oi}^{t,t+1} = \mathrm{TEC}_i^{t,t+1} + \mathrm{TP}_i^{t,t+1} + \mathrm{SEC}_i^{t,t+1}, \tag{7}$$

where

$$\mathrm{TEC}_i^{t,t+1} = \ln D_O(y_{i,t+1}, x_{i,t+1}, t+1) - \ln D_O(y_{it}, x_{it}, t), \tag{8}$$

$$\mathrm{TP}_i^{t,t+1} = \frac{1}{2}\left[\frac{\partial \ln D_O(y_{i,t+1}, x_{i,t+1}, t+1)}{\partial(t+1)} + \frac{\partial \ln D_O(y_{it}, x_{it}, t)}{\partial t}\right], \tag{9}$$

$$\mathrm{SEC}_i^{t,t+1} = \frac{1}{2}\sum_{n=1}^{N}\left[\frac{\varepsilon_{i,t+1} - 1}{\varepsilon_{i,t+1}}\varepsilon_{i,t+1,n} + \frac{\varepsilon_{it} - 1}{\varepsilon_{it}}\varepsilon_{itn}\right] \cdot \ln\left[\frac{x_{i,t+1,n}}{x_{itn}}\right], \tag{10}$$

Table A1. *Definitions of variables*

Variables	Definition
Production function	
Y	Value-added (in million rupiah), which is deflated using a wholesale price index of four-digit ISIC industries at a constant price of 1993
L	Labor (number of workers)
K	Capital (million rupiah), which is deflated using a wholesale price index of four-digit ISIC industries at a constant price of 1993
Inefficiency function	
Foreign	Foreign ownership, which is measured by a dummy variable: 1 if the share of foreign ownership is greater than 0%; and 0 if otherwise
Spillover	Spillover variable, is measured by the share of foreign firms' output over total output in three-digit ISIC industry
Age	Age of firms, is measured by the difference between year of survey and year of starting production
HHI	Herfindahl–Hirschman index for a measure of concentration, which is calculated from $H=\sum_{i=1}^{m} S_i^2$, for S_i^2 is market share of each firms
R&D	Expenditure on research and development (R&D) is measured by dummy variable: 1 if firm spends on research and development activities during the observed years, and 0 otherwise
Spillover * HHI	An interacting variable of spillover and HHI, which is a measure of productivity spillovers through concentration
Spillover * R&D	An interacting variable of spillover and R&D dummy, which is a measure whether R&D firms receive more or less spillovers

where $\varepsilon_{it}=\sum_{n=1}^{N}\varepsilon_{itn}$ is the scale elasticity such that $\varepsilon_{itn}=\frac{\partial \ln D_O(y_{it},x_{it},t)}{\partial \ln x_{itn}}$.

If the output is only one, then a *translog* output-oriented distance function can be defined as

$$\ln D_O(y_{it},x_{it},t)=\ln y_{it}-\ln y_{it}^{\rho}-v_{it}. \tag{11}$$

Given the technical efficiency measure in Eqn. (5), the technical efficiency change (TEC) between periods $t+1$ and t can be estimated by following Coelli *et al.* (2005):

$$\mathrm{TEC}_i^{t,t+1}=\ln TE_{i,t+1}-\ln TE_{it}. \tag{12}$$

The technical progress (TP) index can be obtained from Eqns. (6), (9), and (11) as follows:

$$\mathrm{TP}_{i,t+1,t}=\frac{1}{2}\left[\sum_{n=1}^{N}\beta_{tn}\ln x_{i,t+1,n}+\sum_{n=1}^{N}\beta_{tn}\ln x_{itn}+2\beta_t\right.$$
$$\left.+2\beta_{tt}[(t+1)+t]\right]. \tag{13}$$

From Eqn. (3), the scale elasticity can be written as

$$\varepsilon_{nit}=\beta_n+\frac{1}{2}\sum_{k=1}^{K}\beta_{nk}x_{nit}+\beta_{nt}t. \tag{14}$$

The index of scale efficiency change then can be calculated by using Eqns. (10) and (14).

(c) *Estimating FDI spillovers on sources of productivity growth*

After obtaining the indices of *Malmquist* productivity growth (G_O), TEC, TP, SEC, the next step is to estimate the contribution of FDI spillovers on total factor productivity growth and its sources. A panel regression is employed to estimate the spillover effects. The linear panel data regression can be written as

$$Y_{i,j,t+1,t}=\alpha_0+\alpha_1 Foreign_{ijt}+\alpha_2 Spillover_{jt}+\alpha_3 Age_{ijt}$$
$$+\alpha_4 HHI_{jt}+\alpha_5 Spillover_{jt}*HHI_{jt}+\alpha_6 RD_{ijt}$$
$$+\alpha_7 Spillover_{jt}*RD_{ijt}+\zeta_{it}, \tag{15}$$

where $Y=(G_O$, TEC, TP, SEC), i denotes firm, j implies sub-sector (in this case is three-digit ISIC industries), and ζ is the disturbance term.

5. DATA SOURCES

Data used in this study come from 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).[15] Other supplementary data are wholesale price index (WPI) published by BPS, which are used as deflators for monetary variables in Eqns. (3) and (4).

To construct a unique balanced panel data covering the selected period (1988–2000) and only for chemical and pharmaceutical firms, this study follows several adjustment steps. A detailed explanation about data sources and the adjustment process is given at the beginning of the Appendix A. The original observations for chemical and pharmaceutical firms (ISIC 35) in the selected period are 29,234 observations. After the adjustment process and the construction of a balanced panel, the observations are reduced to 7,384 (consisting of 568 firms for 13 years). Some observations are removed during the adjustment of industrial codes and the cleaning of data from nonsense, noise, and missing values (Step 1 and Step 3 of the adjustments presented in Appendix A), some are dropped when choosing only ISIC 351 and 352 (Step 5), and some others are removed during the construction of a balanced panel (Step 6).[16] The largest numbers of observations are removed when choosing only ISIC 351 and 352 (17,962 out of 29,234 observations or 61.44%). Oil and gas refining sub-sectors (ISIC 353 and 354) are excluded from the dataset as these sub-sectors were not surveyed in 1988 and 1989. In addition, information regarding research and development (R&D) expenditure are available in the dataset since 1994. For the years 1988–93, the R&D dummy variable is defined as equal to that for the year 1994. The summary statistics for the main variables used in the econometric analysis are presented in Table A2.

6. ALTERNATIVE MODEL ESTIMATION AND ANALYSIS OF RESULTS

(a) *Choosing the functional form*

The first step in the SFA is to find an appropriate functional form that represents the data. Given the specifications of the *translog* model in Eqn. (3), various sub-models of the *translog*

Table A2. *Summary statistics*

Variables	Unit	Minimum	Maximum	Mean	Std. dev.
Y	Million of 1993 rupiah	7.80	1,038,731.76	14,221.62	37,635.65
L	Persons	16	6,961	265.10	486.85
K	Million of 1993 rupiah	1.54	916,035.13	5,309.84	23,948.88
Foreign	Binary dummy	0	1	0.14	0.35
Spillover	Ratio	0.14	0.76	0.34	0.14
Age	Years	0	100	20.47	14.87
HHI	Ratio	0.12	0.77	0.27	0.14
R&D	Binary dummy	0	1	0.25	0.43

are considered and tested under a number of null hypotheses. A null hypothesis of $\beta_{nt} = 0$ is to confirm whether Hicks-neutral technological progress is an appropriate specification for the dataset, while a null hypothesis of $\beta_t = \beta_{tt} = \beta_{nt} = 0$ is for no-technological progress in the production frontier. In addition, a null hypothesis of $\beta_{tt} = \beta_{nt} = \beta_{nk} = 0$, for all n and k, is to test for Cobb-Douglas production frontier and a null hypothesis of $\gamma = \delta_0 = \delta_j = 0$ is to confirm the no-inefficiency effect. For performing tests of the relevant null hypotheses, the generalized likelihood ratio statistic $\lambda = -2[l(H_0) - l(H_1)]$ is employed, 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 *translog* model defined in Eqn. (3). If the null hypothesis is true, the test statistic has approximately a χ^2 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 χ^2 distribution, and the critical value for this test is taken from Table 1 of Kodde and Palm (1986).[17] The estimation results for *translog* and the sub-models under the Battese and Coelli's (1995) SFA are presented in Table 4.

The last row of Table 4 presents log-likelihood values for each functional form. These log-likelihood values are used to calculate the generalized likelihood ratio statistic, λ. The results of the null hypotheses tests are presented in Table A3. From the results, it is apparent that various sub-models of the *translog* are found to be an inadequate representation of the data, given the specification of *translog* model. Therefore, the estimation results from Model 1 in Table 4 are used in the interpretation of productivity spillovers.

(b) *Foreign firms and productivity spillovers*

The estimation results of a *translog* stochastic production frontier show that the coefficients of labor and capital have expected positive signs. The positive and highly significant coefficients confirm the expected positive and significant output effects of labor and capital. In contrast, the squared variable of labor $[(\ln L)^2]$ is negative and statistically significant at a 1% level, which indicates a diminishing return to labor. The same is not true of the squared capital. Its estimated coefficient, while negative, turns out to be statistically insignificant. Furthermore, the estimated coefficient of the interacting variable between labor and capital ($\ln L * \ln K$) is positive and significant at a 1% level, suggesting a substitution effect between labor and capital.

For time variables, both coefficients of time (T) and its square are negative and statistically significant. A non-neutral technological progress toward capital is indicated by a positive and statistically significant (at 1% level) coefficient of the interacting variable between time and capital ($T * \ln K$). The combination of the various coefficients of variables that involve T determines the movement of the production frontier over time, with this movement being positive (technological progress) or negative (technological regress) depending on values of K, L, and T.[18] The results in Table 7 below show that, when evaluated at the particular values of K, L, and T for each firm and time period, technological progress has been the dominant factor contributing to productivity growth of both foreign and domestic firms in the Indonesian chemical and pharmaceutical industries over the full sample period.

A particular interest of this study is on the estimated coefficients of the inefficiency function in the second part of Model 1 in Table 4. The negative and statistically significant (at 1% level) coefficient of the dummy foreign ownership (Foreign) indicates that, on average, foreign firms achieve higher efficiency than their domestic counterparts do. Similarly, the average technical efficiency indices for both foreign and domestic firms confirm that foreign firms have higher technical efficiency than domestic firms during the observed years (Figure 1). The higher average efficiency indices of foreign firms compared to domestic firms also indicate that foreign firms are indeed premiers in the chemical and pharmaceutical sectors and operate on the technology frontier. This result supports one of the classic hypotheses of the early literature in industrial organization, namely, that MNCs possess superior knowledge and efficiency, in the form of intangible assets, compared to their domestic counterparts.

The negative and significant coefficient on the spillover variable (spillover) in Model 1 in Table 4 implies a positive and significant efficiency spillover in the chemical and pharmaceutical sectors. This result suggests that in the Indonesian chemical and pharmaceutical sectors higher foreign share results in domestic firms utilizing their resources in a more efficient way, which then leads to productivity gains. The evidence of positive efficiency spillovers from FDI in this study is consistent with previous empirical studies on the Indonesian manufacturing sector which use a conventional approach of production function and focus on all manufacturing firms (e.g., Blalock & Gertler 2008; Sjoholm, 1999a).

The coefficient of a controlling variable, Age, is positive and statistically significant at a 1% level, indicating that older firms have higher inefficiency. This finding may not be a surprise, younger firms are likely to possess modern technology and capital equipment compared to older firms due to technology diffusion.

To ensure that the inclusion of foreign firms in the estimation on FDI spillovers does not introduce bias, this study estimates also the frontier for only domestic firms. The results are presented in Table A4. Interestingly, all coefficients have similar signs and levels of significance as those for the sample of all firms. This is not a surprise given a fact that foreign firms are only 14.98% of the total sample (1,106 out of 7,384 observations). The negative and highly significant coefficient of the key variable, spillovers, is consistent with the result for the

Table 4. *Maximum likelihood estimates of stochastic production frontier*

Variables	Parameters	Model 1	Model 2	Model 3	Model 4	Model 5
Production function						
Constant	β_0	1.25***	1.33***	1.47***	2.138***	1.938***
		(0.22)	(0.21)	(0.23)	(0.043)	(0.042)
Ln(L)	β_1	2.47***	2.36***	2.38***	0.804***	0.725***
		(0.10)	(0.11)	(0.12)	(0.012)	(0.015)
Ln(K)	β_2	0.24***	0.196***	0.175**	0.4920***	0.49438***
		(0.07)	(0.071)	(0.097)	(0.0081)	(0.0087)
$[\text{Ln}(L)]^2$	β_{11}	−0.521***	−0.534***	0.542***	–	–
		(0.027)	(0.027)	(0.031)		
Ln(L) * Ln(K)	β_{12}	0.106***	0.132***	0.133***	–	–
		(0.024)	(0.024)	(0.031)		
$[\text{Ln}(K)]^2$	β_{22}	−0.0058	−0.0017	0.001	–	–
		(0.0073)	(0.0076)	(0.013)		
T	β_t	−0.016*	0.0306***	–	–	–
		(0.012)	(0.0068)			
Ln(L) * T	β_{1t}	0.0015	–	–	–	–
		(0.0038)				
Ln(K) * T	β_{2t}	0.0083***	–	–	–	–
		(0.0022)				
T^2	β_{tt}	−0.00157***	−0.00104***	–	–	–
		(0.00045)	(0.00046)			
Inefficiency function						
Constant	δ_0	−0.267***	−0.238***	−0.276***	−0.483***	–
		(0.083)	(0.052)	(0.090)	(0.097)	
Foreign	δ_F	−0.0546***	−0.053	−0.05	−0.058***	–
		(0.0070)	(0.060)	(0.15)	(0.005)	
Spillover	δ_S	−0.119***	−0.010	−0.006	−0.059*	–
		(0.087)	(0.018)	(0.024)	(0.024)	
Age	δ_A	0.01247***	0.01198***	0.0112***	0.0147***	–
		(0.00099)	(0.00088)	(0.0016)	(0.0012)	
Gamma	γ	0.558***	0.540***	0.543***	0.622***	–
		(0.033)	(0.045)	(0.057)	(0.029)	
Log-likelihood		−4937.56	−4953.21	−5010.35	−5271.82	−5443.96

Note: Model 1 is a *translog* production function. Models 2 and Model 3 represent a Hicks-neutral and a no-technological progress production functions, respectively. Model 4 is a Cobb–Douglas production function and Model 5 represents a no-inefficiency production function. Standard errors are in parentheses and presented until two significant digits, and the corresponding coefficients are presented up to the same number of digits behind the decimal points as the standard errors.

* Denotes significance at 10%.

** Denotes significance at 5%.

*** Denotes significance at 1%.

Table A3. *Tests of hypothesis of stochastic production frontier*

Test	H_0	λ	χ^2 1%	Conclusion
Hicks neutral	$\beta_{nt} = 0$	31.30	9.210	Hicks neutral rejected
No-technological progress	$\beta_t = \beta_{nt} = \beta_{tt} = 0$	145.58	13.277	No-technological progress rejected
Cobb–Douglas	$\beta_{nk} = \beta_t = \beta_{nt} = \beta_{tt} = 0$	668.52	18.475	Cobb–Douglas rejected
No-inefficiency	$\gamma = \delta_0 = \delta_j = 0$	1012.80	17.755	No-inefficiency rejected

Source: Authors' calculation from log-likelihood functions.

sample of all firms, suggesting that the finding of positive FDI spillovers on technical efficiency of domestic firms in Table 3 is not simply a result of biased estimation. Following Kathuria (2000), this study chooses to proceed with the sample of all firms since it measures inefficiency from a distance to the most efficient firms, which can be either foreign or domestic firms. Hence, the inefficiency indexes are measured relative to the best-practice foreign or domestic firms.

Considering that the shock in the economic environment, such as economic crisis, might be affecting FDI spillovers, this study also estimates the samples for the period before the crisis (1988–96) and for the period after the crisis (1997–2000). The estimation results for these two periods are presented in Table A5. In both periods, the coefficients of spillovers are negative. However, the significance levels are different; it is significant at the 1% level for the before-crisis period but it is marginally significant at the 10% level for the crisis period. In addition, the coefficient is smaller for the crisis period compared to the before-crisis period, suggesting that the magnitude of spillovers is smaller during the crisis period. However, the short time

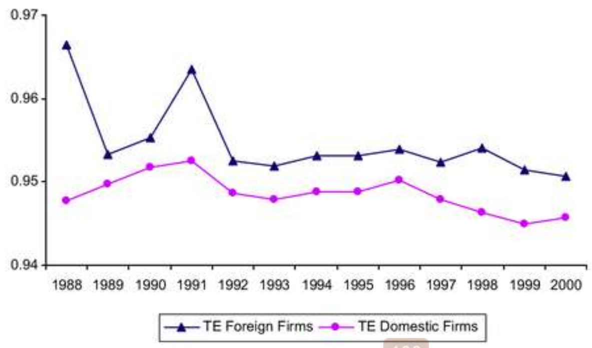

Figure 1. *Average technical efficiency indexes of foreign and domestic firms.*

span for the sample of the crisis period means that the results need to be treated with caution as there are substantially fewer observations than for the full period or the pre-crisis period.

(c) *Productivity spillovers and competition*

This section tests H2 that productivity spillovers are affected by the degree of competition. The *Herfindahl–Hirschman Index* (HHI) is used as a measure of the degree of competition within three-digit ISIC industries (a higher value of HHI indicates greater concentration of sales among producers). Higher concentration is an inverse measure of static competition that can protect inefficient firms. However, higher concentration can also be the result of dynamic competition among firms of differential efficiency that removes inefficient firms from the industry as argued by Demsetz (1973) and Peltzman (1977). The first argument suggests that HHI is associated with greater inefficiency, while the latter argument suggests that HHI is associated with lower inefficiency. The estimated maximum likelihood parameters of a stochastic production function for productivity and competition are presented in Table 5. The spillover variable without interacting with HHI is excluded from the estimation because of multicollinearity with the interacting variable.

Each estimated parameter of production functions shown in Table 5 has a similar sign and significance as in the baseline model shown in Table 4. Therefore, there is no need to explain the estimated parameters of production function further. In the inefficiency function, the negative coefficient of competition (HHI) indicates that concentration among firms in the Indonesian chemical and pharmaceutical sectors decreases the inefficiency of firms, which is consistent with the argument

Table A4. *Maximum likelihood estimates of stochastic production frontier for domestic firms*

Variables	Parameters	Model 1	Model 2	Model 3	Model 4	Model 5
Production function						
Constant	β_0	1.48***	1.37***	1.59***	2.119***	2.107***
		(0.22)	(0.21)	(0.21)	(0.036)	0.044
Ln(L)	β_1	1.92***	1.95***	1.95***	0.858***	0.760***
		(0.11)	(0.11)	(0.11)	(0.014)	0.016
Ln(K)	β_2	0.314***	0.317***	0.274***	0.4474***	0.4435***
		(0.072)	(0.071)	(0.070)	(0.0082)	0.0095
[Ln(L)]^2	β_{11}	−0.569***	−0.556***	−0.607***	–	–
		(0.027)	(0.028)	(0.023)		
Ln(L) * Ln(K)	β_{12}	0.232***	0.223***	0.259***	–	–
		(0.023)	(0.023)	(0.020)		
[Ln(K)]^2	β_{22}	−0.0339***	−0.0311***	−0.0326***	–	–
		(0.0074)	(0.0074)	(0.0069)		
T	β_t	0.005	0.0317***	–	–	–
		(0.013)	(0.0067)			
Ln(L) * T	β_{1t}	0.0043	–	–	–	–
		(0.0039)				
Ln(K) * T	β_{2t}	0.0031	–	–	–	–
		(0.0024)				
T^2	β_{tt}	−0.00147***	−0.00127***	–	–	–
		(0.00047)	(0.00047)			
Inefficiency function						
Constant	δ_0	−0.562***	−0.565***	−1.05***	−1.28***	–
		(0.096)	(0.077)	(0.19)	(0.26)	
Spillover	δ_S	−0.44***	−0.49***	−0.53***	−0.62***	–
		(0.15)	(0.12)	(0.15)	(0.21)	
Age	δ_A	0.1611***	0.0164***	0.0208***	0.0247***	–
		(0.0015)	(0.0012)	(0.0023)	(0.0031)	
Gamma	γ	0.552***	0.615***	0.679***	0.754***	–
		(0.043)	(0.029)	(0.036)	(0.029)	
Log-likelihood		−3979.40	−3983.45	−4023.07	−4235.33	−4419.20
No. of observations		6,278	6,278	6,278	6,278	6,278

Note: Model 1 is a *translog* production function. Models 2 and Model 3 represent a Hicks-neutral and a no-technological progress production function, respectively. Model 4 is a Cobb–Douglas production function and Model 5 represents a no-inefficiency production function. Standard errors are in parentheses and presented until two significant digits, and the corresponding coefficients are presented up to the same number of digits behind the decimal points as the standard errors.

*** Denotes significance at 1%.

Table A5. *Estimates for the periods before crisis and after crisis*

Variables	Parameters	Before crisis (1988–96)		After Crisis (1997–2000)	
		Coefficient	SE	Coefficient	SE
Production function					
Constant	β_0	0.30	0.33	4.62***	1.22
Ln(*L*)	β_1	2.53***	1.41	2.51***	0.43
Ln(*K*)	β_2	0.53***	0.12	0.44**	0.23
[Ln(*L*)]	β_{11}	−0.516***	0.043	−0.619***	0.050
Ln(*L*) * Ln(*K*)	β_{12}	0.077*	0.042	0.318***	0.040
[Ln(*K*)]^2	β_{22}	−0.020	0.016	−0.031	0.018
T	β_t	0.001	0.021	−0.23	0.20
Ln(*L*) * *T*	β_{1t}	0.0231***	0.0074	−0.083	0.026
Ln(*K*) * *T*	β_{2t}	−0.0073*	0.0042	0.053	0.012
T^2	β_{tt}	0.0019	0.0012	0.003	0.008
Inefficiency function					
Constant	δ_0	−0.188***	0.066	−0.271***	0.050
Foreign	δ_F	−0.052***	0.0073	−0.098***	−0.012
Spillover	δ_S	−0.052***	0.021	−0.0074*	0.0040
Age	δ_A	0.01174***	0.00094	0.0047***	0.0013
Gamma	γ	0.541***	0.076	0.304***	0.112
Log-likelihood		−3420.79		−2381.85	
No. of observations		5,112		2,272	

Note: Standard errors are presented until two significant digits and the corresponding coefficients are presented up to the same number of digits behind the decimal points as the standard errors.
* Denotes significance at 10%.
** Denotes significance at 5%.
*** Denotes significance at 1%.

Table 5. *Maximum likelihood estimates of stochastic production frontier with inefficiency coefficients as a function of HHI and Spillover * HHI*

Variable	Parameter	Coefficient	Standard error	Asymptotic *t*-ratio
Production function				
Constant	β_0	1.45	0.22	6.71***
Ln(*L*)	β_1	2.48	0.10	24.64***
Ln(*K*)	β_2	0.155	0.070	2.203**
[Ln(*L*)]^2	β_{11}	−0.544	0.025	−21.349***
Ln(*L*) * Ln(*K*)	β_{12}	0.119	0.022	5.461***
[Ln(*K*)]^2	β_{22}	−0.0010	0.0069	−0.1359
T	β_t	−0.033	0.012	−2.811***
Ln(*L*) * *T*	β_{1t}	−0.0011	0.0038	−0.2949
Ln(*K*) * *T*	β_{2t}	0.0098	0.0022	4.3782***
T^2	β_{tt}	−0.00115	0.00046	−2.50830**
Inefficiency function				
Constant	δ_0	−1.66	0.30	−5.61***
HHI	δ_H	−7.08	1.11	−6.37***
Spillover * HHI	δ_{SH}	−1.59	0.25	−6.22***
Gamma	γ	0.846	0.017	48.693***

Note: Figures are rounded. Standard errors are presented until two significant digits and the corresponding coefficients and *t*-ratio are also presented up to the same number of digits behind the decimal points as the standard errors.
** Denotes significance at 5%.
*** Denotes significance at 1%.

that concentration is a result of dynamic competition that removes inefficient firms.

The negative coefficient of the interacting variable between concentration and spillovers (HHI * Spillovers) suggests that higher concentration is associated with larger spillovers from foreign presence. From these findings, it may be inferred that domestic firms operating in a concentrated sub-sectors of the Indonesian chemical and pharmaceutical sectors may gain spillover benefits from foreign firms. This finding is consistent with the findings by Blomstrom and Sjoholm (1999) and Sjoholm (1999b) on the overall Indonesian manufacturing. Although the present study differs with those two previous studies in terms of the methodology, data techniques, and period of observations, the findings of this present study can be seen as a support and update evidence of those two previous studies.

(d) *Productivity spillovers and absorptive capacity*

The estimated parameters of productivity spillovers and absorptive capacity are presented in Table 6. The focus of analysis is on the estimated parameters of the inefficiency

Table 6. *Maximum likelihood estimates of stochastic production frontier with inefficiency coefficient as a function of R&D and Spillover * R&D*

Variable	Parameter	Coefficient	Standard error	Asymptotic *t*-ratio
Production function				
Constant	β_0	1.24	0.21	5.92***
Ln(*L*)	β_1	2.392	0.097	2.454**
Ln(*K*)	β_2	0.278	0.065	4.244***
[Ln(*L*)]	β_{11}	−0.559	0.026	−21.179***
Ln(*L*) * Ln(*K*)	β_{12}	0.140	0.022	6.348***
$[\text{Ln}(K)]^2$	β_{22}	−0.0163	0.0066	−2.4354**
T	β_t	−0.024	0.012	−1.975*
Ln(*L*) * *T*	β_{1t}	−0.0017	0.0037	−0.4709
Ln(*K*) * *T*	β_{2t}	0.0100	0.0021	4.7205***
T^2	β_{tt}	−0.00157	0.00045	−3.50424***
Inefficiency function				
Constant	δ_0	−0.45	0.17	−2.63***
R&D	δ_R	−0.466	0.063	−7.418***
Spillover * R&D	δ_{SR}	−0.46	0.19	−2.40**
Gamma	γ	0.588	0.044	13.284***

Note: Figures are rounded. Standard errors are presented until two significant digits and the corresponding coefficients and *t*-ratio are also presented up to the same number of digits behind the decimal points as the standard errors.
* Denotes significance at 10%.
** Denotes significance at 5%.
*** Denotes significance at 1%.

Table 7. *Sources of productivity growth*

Year	Full sample				Foreign firms				Domestic firms			
	TEC	TP	SEC	G_O	TEC	TP	SEC	G_O	TEC	TP	SEC	G_O
1989	−0.01	3.17	0.59	3.76	−1.37	2.27	0.30	1.21	0.22	3.31	0.64	4.17
1990	0.22	3.00	0.99	4.21	1.57	2.19	−0.26	3.50	−0.01	3.13	1.19	4.32
1991	−0.02	2.83	0.40	3.21	0.65	1.62	0.32	2.59	−0.13	3.03	6.25	9.14
1992	−0.69	2.68	0.38	2.36	−2.00	1.92	−0.15	−0.23	−0.48	2.80	0.46	2.78
1993	0.41	2.52	0.35	3.29	1.09	1.77	0.63	3.48	0.30	2.64	0.31	3.25
1994	0.19	2.34	0.06	2.59	0.18	1.59	0.22	1.99	0.19	2.46	0.03	2.68
1995	−0.09	2.15	0.21	2.27	−0.13	1.40	0.57	1.84	−0.09	2.27	2.64	4.82
1996	0.12	1.93	0.40	2.45	0.08	1.17	−0.52	0.72	0.13	2.05	0.07	2.26
1997	−0.36	1.78	−0.01	1.40	−0.24	1.05	−0.52	0.29	−0.38	1.89	0.07	1.58
1998	0.11	1.61	0.25	1.97	0.33	0.91	0.35	1.60	0.08	1.72	0.24	2.03
1999	−0.06	1.35	−0.31	0.99	−0.44	0.66	−0.15	0.07	0.01	1.46	−0.34	1.13
2000	0.24	1.16	0.45	1.85	0.19	0.50	0.31	1.00	0.24	1.27	0.02	1.53
1989–92	−0.10	2.34	0.47	2.71	−0.23	1.60	0.04	1.41	−0.08	2.45	1.71	4.08
1993–96	0.16	2.23	0.26	2.65	0.30	1.48	0.22	2.01	0.14	2.35	0.76	3.25
1997–2000	−0.02	1.47	0.10	1.55	−0.04	0.78	0.00	0.74	−0.01	1.59	0.00	1.57
1988–2000	0.01	2.04	0.29	2.33	−0.01	1.31	0.08	1.39	0.01	2.16	0.89	3.06

Note: Arithmetic average of annual rate in percentage.
Source: Authors' calculation using Eqns. (7)–(14).

function (the middle part of Table 6). The coefficient of the research and development dummy (R&D) is negative and significant at the 1% level, suggesting that firms with R&D expenditure, on average, have higher efficiencies compared to those without R&D expenditure. This finding is similar to that of Todo and Miyamoto's (2006) study of the overall Indonesian manufacturing sector.

The negative coefficient of the interacting variable between R&D and spillovers (R&D * Spillover) suggests that firms with R&D expenditure gain more spillovers from foreign firms. Given this result, it is possible to infer that firms with R&D expenditure can reap benefits from foreign firms' presence by upgrading their knowledge and creating new innovation. This finding confirms that firms' absorptive capacity (or firms' specific characteristic) determines productivity spillovers from FDI, as argued in some previous studies, for example, by Kathuria (2000, 2001). This finding is also in line with the finding by Takii (2005) for the whole Indonesian manufacturing firms, even though this present study includes also the period of economic crisis in the estimation.

(e) *Sources of productivity growth and FDI spillovers*

The indices of TEC, TP, SEC and G_O are calculated using Eqns. (7)–(14) and the average of these indices for the selected period is presented in Table 7. It is apparent from Table 7 that TEC, TP, SEC and G_O for domestic firms are on average higher than those for foreign firms. These results suggest that domestic firms are catching up the foreign firms in terms of technical efficiency, technology, and scale efficiency. With larger TEC indices of some domestic firms than those of foreign firms, all domestic firms are likely to approach the same level of technical efficiency as achieved by foreign firms in the long run. The same result would also turn out to be for technology level and scale efficiency. As the indices of TP for domestic firms are, on average, larger than those for foreign firms therefore domestic firms may eventually approach to the same level of technology as achieved by foreign firms. Scale efficiency may also be approaching the same level for domestic and foreign firms.

Table 7 also shows that the major contribution to productivity growth in the Indonesian chemical and pharmaceutical firms is from technological progress. This is not surprising as chemical and pharmaceutical sectors are capital- and technology-intensive. Furthermore, when the sample is divided into domestic and foreign firms, technological progress is the major driver of productivity growth in both groups. In contrast, the TEC and SEC indices are relatively constant, suggesting that these two components do not contribute much to productivity growth.

Using the indexes of TEC, TP, SEC, and G_O obtained from the decomposition, we then estimate the impact of FDI spillovers on total factor productivity (TFP) growth and its sources. The estimated parameters are presented in Table 8. We perform both random effect (RE) and fixed effect (FE) panel data models for TFP growth and its sources. The Hausman specification test is used to choose which of the two models is better at representing the data. It can be seen from the probability for χ^2-statistic of the Hausman test (Table 8) that the RE model is preferred for TEC and SEC, but the FE model is better for TP and G_O in all samples. For the sample of domestic firms only, RE model turns out to be a better model for TEC and FE model is well suited for TP, TEC, and G_O. Therefore, the interpretation of the estimated parameters for TFP growth and its sources is based on the best-suited model in each case.

Table 8 reveals that FDI spillovers contribute significantly to technological progress (as shown by a positive and significant estimate of spillover variable in the regression on technological progress). However, spillovers do not contribute much to technical efficiency and scale efficiency (as shown by a statistically insignificant estimate of spillover variable on technical efficiency change and scale efficiency change). These results indicate the role of technology transfers in generating productivity spillovers. Hence, one may argue that the spillover effects of productivity growth in the Indonesia chemical and pharmaceutical firms are predominantly due to enhancing technological progress and not as a result of technical efficiency and scale efficiency improvements.

Moreover, a positive and statistically significant estimate of concentration on technological progress suggests that a more competitive environment may reduce technological progress. A positive and significant estimate is also found for R&D dummy, which indicates that firms with R&D expenditure have higher technological progress than those without R&D expenditure. The positive and statistically significant estimate of interacting variable between spillover and R&D indicates

Table 8. *Sources of productivity growth and FDI spillovers*

	TEC		TP		SEC		G_O	
	FE	RE	FE	RE	FE	RE	FE	RE
	Full sample							
Foreign	0.0015	−0.000093	0.0012**	0.0033***	0.058	−0.0071	0.062	0.0018
Spillover	0.013	0.0037	0.0057***	0.036***	0.068	−0.035	0.088*	0.047*
Age	−0.000095	−0.000013	−0.0018***	−0.00093***	−0.0043**	0.00092	−0.0065***	0.00087***
HHI	−0.0060	−0.010	0.0083***	−0.038***	0.26	0.043	0.28	0.010
Spillover * HHI	−0.0052	0.0071	−0.011***	0.029***	−0.12	0.0052	−0.14	0.062
RD	0.0012	−0.000043	0.00031*	0.0022***	0.12***	0.11***	0.13***	0.12***
Spillover * RD	−0.0017	0.00050	0.00057*	0.0076***	−0.27***	−0.26***	0.29***	−0.27***
R^2	0.001	0.001	0.006	0.048	0.001	0.005	0.001	0.005
Hausman test	Prob χ^2 = 0.847: RE		Prob χ^2 = 0.000: FE		Prob χ^2 = 0.267: RE		Prob χ^2 = 0.016: FE	
Observations	6,816		6,816		6,816		6,816	
	Domestic firms							
Foreign	–	–	–	–	–	–	–	–
Spillover	0.012	0.0036	0.0063***	0.038***	0.040	−0.035	0.059*	0.050*
Age	−0.000083	−0.000011	−0.0019***	−0.00095***	−0.0050	0.0010	−0.0072***	0.00096***
HHI	−0.0085	−0.011	0.0076***	−0.039***	0.28	0.052	0.30	0.00063
Spillover * HHI	−0.0026	0.0086	−0.011***	0.030***	−0.085	−0.0012	−0.10	0.055
RD	0.0016	0.00017	0.000057*	0.0021***	0.14***	0.13***	0.15***	0.14***
Spillover * RD	−0.0028	0.000026	0.0010*	0.0067***	−0.31**	−0.31***	−0.33***	0.32***
R^2	0.001	0.001	0.004	0.041	0.001	0.005	0.001	0.005
Hausman test	Prob χ^2 = 0.808: RE		Prob χ^2 = 0.000: FE		Prob χ^2 = 0.000: FE		Prob χ^2 = 0.016: FE	
Observations	5,856		5,856		5,856		5,856	

Source: Authors' estimation using STATA10. FE is fixed-effect model and RE is random-effect model. Coefficients are presented until two significant digits.

* Denotes significant at 10% level.

** Denotes significant at 5% level.

*** Denotes significant at 1% level.

Table 9. *Sources of productivity growth and FDI spillovers: dealing with endogeneity*

	TEC	TP	SEC	G_O
Strategy 1: Replacing spillover with a lagged-spillover				
	Full sample			
Spillover_{t-1}	0.00079	0.0010***	0.027	0.0031*
R^2	0.001	0.007	0.005	0.001
Hausman test	Prob $\chi^2 = 0.456$: RE	Prob $\chi^2 = 0.000$: FE	Prob $\chi^2 = 0.282$: RE	Prob $\chi^2 = 0.023$: RE
Observation	6,816	6,816	6,816	6,816
	Domestic firms			
Spillover_{t-1}	0.00020	0.00018***	0.026	0.0030*
R^2	0.001	0.004	0.005	0.001
Hausman test	Prob $\chi^2 = 0.849$: RE	Prob $\chi^2 = 0.000$: FE	Prob $\chi^2 = 0.157$: RE	Prob $\chi^2 = 0.010$: FE
Observation	5,856	5,856	5,856	5,856
Strategy 2: Arellano–Bond GMM estimations				
	Full sample			
Spillover	0.031	0.0033*	0.012	0.015*
Wald-χ^2	Prob $\chi^2 = 0.000$	Prob $\chi^2 = 0.000$	Prob $\chi^2 = 0.064$	Prob $\chi^2 = 0.000$
Observation	5,680	5,680	5,680	5,680
	Domestic firms			
Spillover	0.035	0.00097*	0.037	0.039*
Wald-χ^2	Prob $\chi^2 = 0.000$	Prob $\chi^2 = 0.000$	Prob $\chi^2 = 0.073$	Prob $\chi^2 = 0.017$
Observation	4,859	4,859	4,859	4,859

Source: Authors' estimation using STATA10.
Note: FE is fixed-effect model and RE is random-effect model. The estimation for all sample includes Foreign, Age, HHI, HHI * Spillover, RD, and RD * Spillover variables; the estimation for domestic firms includes Age, HHI, HHI * Spillover, RD, and RD * Spillover variables. Coefficients are presented until two significant digits.
* Denotes significant at 10% level.
*** Denotes significant at 1% level.

that firms with R&D expenditure tend to gain more technological spillovers. However, the estimate for an interacting variable between spillover and concentration is negative and statistically significant, suggesting that competition is associated with higher spillovers on technological progress.

Endogeneity is a particularly important issue for the key variable, spillover. The OLS coefficients shown in Table 8 are estimated under an assumption that the variation in the spillover variable is exogenous to the productivity growth of domestic firms. If this assumption is not fulfilled then OLS may yield biased estimates. In the case where FDI is attracted to industries (or sub-sectors) with high productivity growth, the estimates shown in Table 8 could be biased upward. Alternatively, foreign firms may be attracted to slow-growing industries in order to gain a greater competitive advantage, which in this case, the OLS estimates shown in Table 8 may bias downward.

In dealing with this possible endogeneity bias, this study pursues two strategies, following Haskel, Pereira, and Slaughter (2007). The first strategy is to use lagged measures of spillover instead of spillover at time t. Lags may be appropriate because spillovers may take time to materialize. The second strategy is to adopt an instrumental variable estimation, as an alternative to OLS. This study employs the Arellano-Bond GMM estimator, which adds a lagged dependent variable and once-lagged independent variables as instrumental variables.

The estimation results for the first and the second strategies of addressing endogeneity bias are presented in Table 9. For the first strategy, we present the results of the best-suited model. As the results show, the signs and significances of the lagged spillover (Spillover_{t-1}) on productivity growth (and its sources) are similar to those of spillover at time t shown in Table 8. The only notable difference is the value of the coefficients, which are larger for the lagged spillover. The positive and significant coefficient Spillover_{t-1} on G_O is consistent with the spillover-taking-time argument. The positive and significant coefficient Spillover_{t-1} on TP, and positive and insignificant on TEC and SEC, suggest that the presence of FDI contributes significantly to technological progress but not to technical efficiency change and scale efficiency change.

The results for the second strategy are presented in the lower part of Table 9. The Arellano–Bond GMM estimates on spillover present similar conclusions as those of Table 8. By adding a lagged dependent variable and once-lagged variables as instruments, the results show a positive and significant affect of spillover on productivity growth and technological progress. However, the level of significance of the coefficient on technological progress in this model is lower than those shown in Table 8, which may be due to the lack of good instruments.

7. CONCLUSION AND POLICY IMPLICATIONS

This study examines the productivity spillovers from FDI in the Indonesian chemical and pharmaceutical sectors by using a unique and extensive firm-level panel data covering the period 1988–2000. Unlike most of the previous studies on FDI productivity spillovers, this paper uses the stochastic frontier production function following Battese and Coelli (1995) and a generalized *Malmquist* output-oriented index to decompose productivity growth. The intra-industry productivity spillovers are examined through the spillover variable, and the roles of competition and R&D in extending spillovers from FDI are evaluated to test a channel of productivity spillovers.

The empirical results show that intra-industry productivity spillovers are present in the Indonesian chemical and pharmaceutical sectors. It also shows that competition facilitates spillovers from a foreign presence in the industry. Firms with R&D expenditure receive more productivity spillovers than those without R&D expenditure. Furthermore, technological progress is the major driver of productivity growth in the Indonesian chemical and pharmaceutical firms. FDI spillovers have been found to be positive and significant for technological progress; however, positive but not significant for technical and scale efficiency change.

Despite the presence of positive spillovers from FDI, the policy implications of these findings are not straightforward. These results may support the continuing fiscal and investment incentives provided by the Indonesian government for FDI. However, with many countries competing for FDI, particularly in the presence of an asymmetric competition among countries, there are undesirable welfare effects for a developing country, such as Indonesia (Bjorvata & Eckel, 2006). This suggests policies for strengthening the absorptive capacity of domestic firms through investing in knowledge and human capital formation may be superior to policies that provide concessions for FDI. There is also a need for further institutional reforms including political system, economic management and government administration, and trade policies in order to develop a more competitive environment in the manufacturing sector. More general policies should be pursued, which not only attract FDI but also benefit domestic firms, for example, build modern infrastructure, increasing and strengthening the institutions for accelerating and sustaining economic growth.

NOTES

1. Following Smeets (2008), knowledge is defined broadly as managerial know-how, superior technology, and the ability to exploit scale efficiency.

2. UNCTAD (2003) reported that of the 1,641 national regulatory changes to FDI from 1991 to 2001, 94% provide more favorable incentives for FDI.

3. The figure is calculated from the Annual Survey of Large and Medium Manufacturing Industry conducted by Indonesian Central Bureau of Statistics (Badan Pusat Statistik, BPS) for the period 1975–2000. During this period, chemical and pharmaceutical sectors are the second most productive sector in manufacturing industry (among nine sectors) in terms of value added per labor, just slightly below metal products (which is around 1.58 times of the manufacturing average). Please see Appendix A for the explanation about the Annual Survey.

4. The figure is calculated from the Annual Survey of Large and Medium Manufacturing Industry.

5. One recent study decomposes productivity spillover of FDI (Girma & Gorg, 2007), but it only decomposes productivity growth into two components (TP and SE) by using a deterministic approach called Divisia index, which has some severe limitations. For example, no allowance is made for measurement error and other statistical noise, so that the resulting productivity measures from this index are likely to be contaminated.

6. For example, the effective rate of protection (ERP) was reduced from 133% in 1984 to 19% in 1987 (Fane & Philips, 1991; Sjoholm, 1999a).

7. Since the liberalization in 1988, the government had provided a range of incentives for FDI through a set of consecutive reforms (which were undertaken in 1992, October 1993, and June 1994). The incentives included permission for foreign ownership up to 100% in priority sectors and targeted areas, a reduction in capital requirement from US$ 1 million to US$ 250,000, an open-up for export-oriented FDI, an automatic renew of foreign license for next 30 years, and a relaxation of domestic-material requirement (Pangestu, 1996). During the crisis and after, the provided incentives have been more extensive. The government simplified the administration procedure and granted income tax facilities. The enactment of the Law no. 25/2007 and the Government Regulation no. 1/2007 on investment provide non-discriminatory treatment for both foreign and domestic investors and income-tax dispensation to 15 sectors, including chemicals (Adiningsih, Lestari, Rahutami, & Wijaya, 2009).

8. The figures are obtained from Indonesian Economic and Financial Statistics (Statistik Ekonomi dan Keuangan Indonesia or SEKI) published by Central Bank of Indonesia, various years.

9. Figures are calculated from the Annual Survey of Large and Medium Manufacturing Industries.

10. For a comprehensive survey, please see Cuyveys, Soeng, Plasmans, and Van den Bulcke (2008).

11. As is widely known, the conventional approach of the production function assumes that all firms are fully efficient, which is unlikely to happen in reality. This means a productivity improvement is exclusively related to a shift of a production frontier. Hence, the productivity advantage from FDI under this conventional approach is determined solely by technological progress.

12. In the literature of stochastic frontiers, a simultaneous estimation of a production function and an efficiency function is known as a one-stage estimation procedure. This procedure is preferable since a two-stage estimation procedure is inconsistent in its assumption regarding the independently and identically distributed technical inefficiency effects (Kumbhakar, Ghosh, & McGuckin, 1991). Moreover, the two-stage estimation procedure is unlikely to provide estimates that are as efficient as those obtained using the single-stage estimation procedure. For more details, see Kumbhakar and Lovell (2000).

13. Battese and Coelli (1995) model is commonly classified as an extension of random-effect model in the panel data stochastic frontier analysis. An excellent discussion on the classification of panel-data stochastic frontier models into fixed-effect and random-effect is provided in chapter 4 of Kuenzle (2005).

14. The mathematical derivation of the maximum likelihood function and its related variance parameters are discussed in Battese and Coelli (1993).

15. The data are available in an electronic format (*d*-base file) and obtained under a license.

16. This study uses a balanced panel data for the purpose of decomposing total factor productivity growth into its components (efficiency change, technological change, and scale efficiency change), which are then used as dependent variables for the analysis of FDI spillovers on sources of productivity growth. In the original data, some firms appeared only in certain years and some others even appeared only in one year, which made calculations of the growth variables for these firms impossible. Therefore, this study excludes these firms from the final dataset since they might not provide a consistent growth data for the observed years. The authors are aware of the possibility of neglecting the relatively new foreign and

domestic firms which might be on the frontier. However, since the objective is also to decompose total factor productivity (TFP) growth, this study proceeds by using the balanced data.

17. For explanation regarding a mixed chi-squared and a test for no inefficiency effect, see Battese and Coelli (1988).

18. A simpler picture emerges in Model 2, where neutrality of technical change is imposed. Here the coefficient of time is positive and statistically significant, suggesting technological progress. However, the coefficient of time squared is negative and statistically significant, suggesting technological progress is falling over the sample period.

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APPENDIX A

A.1. *Sources of data and construction of dataset*

The annual surveys of medium and large manufacturing establishments (*Survey Tahunan Statistik Industri* or SI hereafter) cover 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 labor 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 number of establishments surveyed varies depending on 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 have been conducted since 1975, and the most recent available data are for the year 2005. However, this study uses only the period of data from 1988 to 2000. The year 1988 is chosen as a starting year because the data on the replacement value of capital is not available before 1988. The 2002–05 period is excluded because the BPS does not present the specific identification code (SID from hereafter) in the years 2002–04 and the inclusion of 2001 data reduces the number of establishments by almost 50% of the total sample when a balanced panel is constructed.

In order to construct a unique balanced panel data covering the selected period and only for chemical and pharmaceutical firms, this study follows several steps:

Step 1: Adjustment for industrial code:

The BPS reclassifies the industrial code twice (in 1990 and 1998) to accommodate the growing number of manufacturing establishments as well as the revisions to International Standard Industrial Classification (ISIC). Fortunately, the BPS provides concordance tables for these reclassifications. The concordance tables and the SID are used to obtain a consistent industrial code for the selected period.

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 authors went through the survey questionnaires to obtain consistent variable 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 and/or labor are removed.

b. If a firm reported a missing value for a particular variable in a given time but reported 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% of the total observations.

c. Typographical errors (or key-punch error) in the raw data are adjusted for consistency. For example, if in the raw data, foreign share of a firm for the whole of the selected period is typed as a 100%, except for a certain year being typed as 0%, then the 0% share is adjusted to 100%.

d. Observations that are considered as outliers are removed from dataset by sorting the data based on output and removing 1.5% of the lowest values and 1.5% of the highest values, as suggested by Takii (2005).

Step 4: Back casting the missing values of capital.

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

Step 5: Choosing only chemical and pharmaceutical firms (ISIC 351 and 352).

Based on the industrial code, chemical and pharmaceutical firms are chosen. In this study, the chemical and pharmaceutical sectors are defined as ISIC 351 (industrial chemicals) and ISIC 352 (pharmaceuticals and other chemicals).

Step 6: Balanced panel dataset is constructed for the selected period by matching firms based on the specific identification code (SID).

Step 7: All monetary variables (output and material) are deflated using a wholesale price index provided by the BPS at a constant price of 1993.

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