FDI Spillovers in Indonesia's Chemical Industry: A Stochastic Production Frontier Analysis

Ahmad Helmy Fuady

Abstract

There has been increasing role of Foreign Direct Investment (FDI) in developing countries since the 1980s. Interestingly, FDI is not only expected to bring direct effects, but also indirect effects or "spillovers" to a hosti economy. This paper aims to investigate FDI spillovers in the Indonesia's chemical industry, whether domestic firms benefit or not from foreign invesment. A stochastic production frontier approach is adopted to a firm level panel data for the periode of 1998-2000. There are three important findings. First, there is a clear hierarchy of technical efficiency of chemical firms based on their ownership status. Foreign owned firms have the highest level of technical efficiency, followed by joint ventures and domestic firms. Second, even though this paper confirms positive spillovers in the industry, the magnitude is relatively small. It shows that the Indonesian chemical industry has not yet been able to take full advantage of foreign presence. Third, a wider technology gap between domestic and foreign firms results in a higher spillovers. Findings of this paper imply that more FDI inflow into the Indonesia's chemical industry may benefit the industry. However, understanding the process of how the foreign presence affects domestic firms is important to take full advantage of the foreign presence.

Key words: FDI, spillovers, chemical industry, Indonesia, stochastic production frontier.

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I. INTRODUCTION

Since the 1980s, there has been a surge in foreign direct investment (FDI) into developing countries. In 2004, FDI inflows to developing countries shared 36 percent of world FDI inflows (UNCTAD 2005). Moreover, Aitken and Harrison (1999; 605) note that FDI has become the largest source of developing countries' external financing in the 1990s; FDI accounted for about 50 percent of private capital flows to developing countries in 1997. Interestingly, FDI is not only expected to bring direct effects, such as lower prices for consumers, higher quality products, higher tax revenue for government and higher employment, but also indirect effect or "spillovers" to a host economy (Blomstrom 1989: 35-6). Moreover, spillovers as indirect effect of FDI are claimed as the most significant contribution of foreign investment (Blomstrom 1989: 36). The spillovers could influence the industrial structure of a host economy and domestic firms' performance (Blomstrom 1989: 36 and Imbriani and Reganati 1999:9).

Spillovers can occur at least through three channels: competition, technology diffusion, and demonstration effect (Blomstrom 1989: 36-9; lyer, et al. 2004: 9; Karpaty and Lundberg 2004:3). First, foreign investment can enhance competition, which could then drive inefficient firms out of business, increase domestic firms' efficiency and increase allocative efficiency in the host country industrial structure (Karpaty and Lundberg 2004:3; lyer, et al. 2004: 9). Second, technology diffusion occurs, for example, through licensing or trained labor who move from foreign firms to domestic firms. Foreign affiliates can accelerate technology diffusion in a host country, for example, through licensing. Trained labor and management by foreign firms, who later can move to domestic firms, can improve the host country's human capital. Finally, demonstration effect occurs in domestic firms through observing foreign practices.

In line with the increasing FDI flows to developing countries, recently there has been wide interest in FDI spillovers. There are a number of studies examining spillovers from FDI, such as Blomstrom (1989), Haskel, et al. (2002), Thong and Hu (2003), Karpaty and Lundberg (2004), Sena (2004), Haddad and Harrison (1993), Djankov and Hoekman (2000), Kathuria (2000) and Peter, et al. (2004). However, these studies do not end in a single conclusion on the evidence of FDI spillovers (Dhanani and Hasnain 2002).

Many empirical studies confirm a positive relationship between FDI and productivity. Using value added per employee in domestically owned firms as a measure of technical efficiency, Blomstrom (1989)

shows that foreign investment had a positive effect on the firms' efficiency in Mexico. Similarly, Haskel, *et al.* (2002) shows a significant positive correlation between domestic plant's total factor productivity (TFP) and the foreign-affiliate share of activity using plant-level panel in the United Kingdom manufacturing from 1973-1992. Thong and Hu
(2003) show that the employment shares of foreign affiliates are associated with higher domestic productivity. Karpaty and Lundberg
(2004) find that the presence of foreign ownership in the same industry and region seems to improve total factor productivity of domestic firms in Swedish manufacturing. While, Sena (2004) shows that, in the Italian chemical sector, the technical change registered by high-tech firms significantly affects productivity growth of non-high-tech firms.

On the other hand, other empirical studies show that FDI has a negative spillovers effect on the host country. Haddad and Harrison (1993) find evidence of negative spillovers for Morocco. Djankov and Hoekman (2000) report that negative spillovers occurred for Czech enterprises without foreign affiliation. Kathuria (2000) confirms the negative spillovers for Indian manufacturing firms. Similarly, Peter *et al.* (2004) find that, in Russia and the Czech Republic, the distance to the frontier for domestic firms in industries with greater share of foreign firms is larger than domestic firms in industries that have a smaller foreign presence.

There have been also several studies on spillovers in Indonesian industries, for instance, by Sjoholm (1997), Blalock and Gertler (2004), Thee (2005), Jacob and Meister (2005), and Takii (2005). Sjoholm (1997) and Takii (2005) confirm the positive spillovers that benefited domestic firms, but the effect differs across industries. Moreover, Sjoholm (1997) finds that the spillovers occurred in sectors with a high degree of competition, and that the larger technology gap between domestic and foreign firms resulted in larger spillovers. Blalock and Gertler (2004) also confirm that firms that have a narrow technology gap benefit less from foreign presence. Jacob and Meister (2005) find a significant positive spillover in Indonesian manufacturing, particularly in post-liberalization period (1988-1996). In contrast, Thee (2005), notes that Indonesia has not yet been able to take full advantage of technology transfer from FDI. These studies, however, indicate that the spillovers are influenced by sectoral characteristics and industrial market structure.

Taken together, the literature suggests that spillovers require a certain level of technology, human capital, and a sound business environment for transfer of technology. FDI does not automatically bring substantial spillovers and linkage effects, nor does it necessarily lead to technological upgrading, and complementary efforts are necessary to maximize the technological benefits of FDI (Sjoholm 1997: 3; Okamoto and Sjoholm 2001: 28). A minimum threshold stock of human capital sufficient to absorb advanced technology from FDI in order to contribute to growth, for example, is needed (Borensztein, *et al.* 1998). The least developed countries might not learn much from foreign presence possibly because they lack the absorptive capacity (Blomstrom *et al.* 1994). The characteristics of the host country's industry and policy environment are also important determinants of the net benefits of FDI (Blomstrom and Kokko 1997).

Even though a considerable amount of research has been done on the existence of spillovers, so far, there has been no study that gives particular attention to spillovers in the Indonesian chemical industry. This present study attempts to fill this gap, by investigating the spillover effect of FDI in Indonesia's chemical industry. A question remains whether foreign presence brings spillovers in the Indonesian chemical industry and benefits domestic firms. Moreover, in providing new evidence in this area, this paper also adopts a stochastic production frontier analysis, which has not been used previously to examine FDI spillovers in Indonesia. Thus, unlike previous studies, such as by Sjoholm (1997), Blalock and Gertler (2004) and Jacob and Meister (2005), this paper examines not only the spillovers, but also whether the foreign presence enables domestic firms to catch up with the best performing firms.

The spillovers of FDI are measured by their respective contribution towards increasing technical efficiency. First, this paper estimates the effect of the foreign presence in the overall industry. Second, it estimates the spillover effects on domestic firms; whether domestic firms benefited or not from foreign presence and what factors could influence the spillovers.

A stochastic production frontier approach is adopted to a firm level panel data for 1998-2000 period. This approach is employed since it can capture the technical efficiency effect of a firm in comparison with the best practice production frontier. Moreover, the approach also corrects the problem of a productivity measurement, where TFP is assumed as synonymous with technical change, which usually appears in standard assessment (lyer, *et al.* 2003: 4). The stochastic production frontier allows for decomposing a growth rate of TFP into the technical efficiency change and the technological progress components (lyer, *et al.* 2003: 4). In addition, only few studies have applied a stochastic production frontier in analyzing the effect of foreign presence on a host country. Among this exception are Kathuria (2000) for India and lyer, *et al.* (2003) that measure spillovers from alternative forms of foreign investment.

This paper consists of six sections. Section 2 provides a brief description of Indonesia's chemical industry. Section 3 presents the methodological framework. Section 4 describes the data and variables to be used. Section 5 provides the estimation, findings and discussion, which lead to the conclusion in the final section.

II. INDONESIA'S CHEMICAL INDUSTRY

Before going further, it is important to note that Indonesia's chemical industry becomes the particular interest of this paper since the chemical industry is an important part of the manufacturing sector in Indonesia. In 1994 and 1995, for example, the share of this sector in total medium and large scale industry was 11 percent of employment, 15 percent of output value and 13 percent of value added (EPS 1994 and BPS1995).

In terms of exports, the chemical also made a significant contribution to the Indonesian economy. Prior to the crisis, the share of the chemical industry's exports to total exports was approaching 9 percent. It then was relatively stable at 8 percent until 2001, and since then, it continuously increased to more than 10 percent in 2004 as Figure A.I shows (Appendix A). Moreover, based on Asian Development Bank (ADB) key indicators, the exports value of the chemical slightly increased from end of 1980s to 2004. If in 1987 the chemical exports were US$ 1,245 million, it has reached US$ 3,839 million in 1997 and US$ 7,544 million in 2004.

Moreover, the chemical industry is a favorite sector that attracts large amounts of FDI into this industry. Even though it experienced a fluctuation, from 1994 to 2004, on average, around 30 percent of total FDI are approved to involve in the chemical and pharmaceutical sector as shown in Figure A.2 (Appendix A). As a percentage of total implemented FDI, the chemical also shows its significance. Before experiencing a decreasing trend after the Asian crisis, the contribution of the chemical's industry reached more than 45 percent of total implemented foreign investment in Indonesia in 1997 as Figure A.3 shows (Appendix A). In addition, even though experiencing a decreasing trend after the Asian crisis, based on this paper's calculation, on average the foreign share of total Indonesia's chemical output is still more than 13 percent annually during the 1998-2000 period.

III. METHODOLOGICAL FRAMEWORK

A stochastic production frontier is able to capture the inefficiency effect, which is ignored in neoclassical production theory (Kong *el al.* 1999: 268-9). As introduced by Aigner, *et al.* (1977) and Meeusen and van den Broeck (1977), the stochastic production frontier can capture the inefficiency effect through its non-negative component in the error term (Kompas 2002:14). In panel data with firm *i* = 1, 2,..., n, and time *t* = *1*,*2*, ..., T, following Battese and Coelli (1995), the model can be expressed as:

$$Y_{it} = f(X_{it}, p, t)$$

(3.1)

Where Y,> indicates output, *Xu* is a vector of inputs, *ft* denotes a vector of parameters to be estimated. The systematic component *(vn)* includes random deviation caused by variables outside the control of firms, and it is distributed as N (0, o_v^2). While, the error term *Un* > 0 captures production technical efficiency.

Following Kong *et al.* (1999:270), taking the derivative of logarithm of equation (3.1) with respect to time *t*, it defines:

$$X \qquad (3.2)$$

Dotted variables denote time derivatives, e^and e//, indicate the output elasticities of / (X,>, */3, t)* with respect to $X_{,(}$ and *t*, respectively. Equation (3.2) shows that output changes consist of three parts (Kong *et* «/.1999:269). First, it corresponds to the input changes, weighted by output elasticities. The effect of random error v_u can be ignored since it is equal to zero because *v* is distributed as N (0, a_v^2). The rate of total factor productivity change is determined by *e* <•/, and U_H , which denotes the rate of technological change and technical efficiency change respectively.

Since stochastic frontier analysis imposes a common production technology across firms, it is vulnerable to an error in model specification. This paper uses a panel data model with a translog specification of the production function. As noted by lyer *et al.* (2004: 8), this translog specification is a flexible functional form that can minimize the error in a model specification. This paper also adopts a log likelihood ratio to test the model against other functional forms, such as Cobb-

Douglas or translog with neutral technology change. The translog model adopted in this paper is expressed as:

In* „ \n$_{Xjl/}$ In*„,

where Xs denote inputs;; and *k* index inputs (/,..., fc=l,...,4) represents capital, raw material, fuel, and labor, respectively; *t* indicates time trend; *VH* denotes random deviation in output caused by variables outside the control of firms, and it is distributed to be identically and independently as N(0, CTv^2). Technical efficiency error, *UH* is assumed to be distributed as a non-negative half-normal with N (0, $<r_u^2$). However, the assumption of un to be *iid* N(0, a_u^2) is no longer relevant if technical efficiency is affected by some factors, and truncated into N(ui_t, $o\,^2$) (Battese and Coelli 1995). As suggested by Battese and Coelli (1995) and Kong *et al*. (1999), the inefficiency distribution parameter, UH depends on some factors of *Z*,

//it = <5b + E *SZ.it* (3.4)

where *Sis* parameter to be estimated and *Zu* denotes variables associated with technical inefficiency of production.

For the estimation, consider $<r_u^2$ as variances of the one-sided parameters (u), ov^2 as variances of the systematic (v), $a^2=av^2+o\i^2$ and $y=cru^2/(c7v^2+o\text{-}u^2)$ (Coelli 1996). If the y parameter is significant, the stochastic frontier production function is needed. However, if the y parameter is equal to zero (y=0), then ordinary least square (OLS) is enough because it shows that a_u^2 is also equal to zero and therefore the MU could be removed (Coelli 1996). A set of log-likelihood tests can be used to determine the existing stochastic frontier, its functional form of production function and type of technical change.

Following Kong *et* «/.(1999), Equation (3.3) allows for non-neutral technical change, with the rate of technological change, $e_{f\,j\,t}$, as:

$e_{f\,l\,l}$ = (3.5)

The technical change will absent if /?r = *PTT* = *PTI* = 0, while ySr; = 0 result in neutral technical change. Moreover, when /?rr = /?r; = *fy* - *ftjk* = 0, Equation

(3.3) will result in a Cobb-Douglas production frontier, which is a specia case of the translog frontier.

Furthermore, as suggested by Battese and Coelli (1988) and Coelli *e al.* 1998, the estimation of technical efficiency of firms *i* in period *t* usinj the expectation of conditional random variable EU can be expressed as:

$$TE_{it} = \frac{E(Yit \mid Uit, XiQ}{E(Yst|uit = 0,Xit} \bullet = \exp(-Uit) \quad (3.6)$$

Total factor productivity growth can be estimated as the summatior of the rate of technical efficiency change and the rate of technologica change. Since the rate of technical efficiency change is defined from twc consecutive years, $TEC = \frac{TE_{a}}{,,-u} = TE^{\wedge}$ a matching rate of technologica

change *($TP_{lt-(l}$)* is needed. Kong *et al.* (1999) solve this problem bj simply averaging the rates of technological change of the consecutive years, $TP_{U-\backslash}, = \quad + \quad$. Therefore, as suggested by Kong *et al* (1999), the rate of total factor productivity is estimated as:

$$TFP_{ll.l} = (e_{f/l-l} + e_{f/l})/2 \quad \frac{TE_U}{i} \quad (3.7)$$

IV. DATA, MODEL AND VARIABLES

4.1 Data

Data is drawn from the annual survey for industrial firms, conducted and compiled by the Indonesian Statistics Agency *(Badan Pusat Statistik,* EPS). The raw database includes output (total value of all processed goods in thousand of rupiah), capital (total value in thousand rupiah, including land, machinery, car and building), number of production and non production labour, total paid labour (average number of workers), fuel (total value of solar, premium, oil, coke and gas, in thousand ol rupiah), material input (total value in thousand of rupiah), ownership share of foreign, private domestic, and state (central and local), and the year when firms started to operate commercially. Since the data are ir current value, an adjustment is made using a GDP deflator of the manufacturing sector obtained from *Statistik Ekonomi dan Keuangan*

Indonesia, Bank Indonesia, with 1993 as the base year. **Table 4.1** provides a description and summary statistics of the variables.

Table 4.1 ***Variables description and summary statistics***

Variables	Description	Mean	Std. Dev.	Min	Max
V	Output (000 Rp)	9,440,897.00	40,000,000.00	6,337.42	979,000,000.00
K	Physical capital (000 Rp)	6,889,741.00	71,900,000.00	88.31	2,540,000,000.00
M	Material inputs (000 Rp)	5,503,140.00	21,200,000.00	17.23	535,000,000.00
f	Fuel value (000 Rp)	223,550.10	4,132,271.00	0.33	188,000,000.00
L	Workers (person)	180.58	370.01	16.00	5,466.00
P	Foreign Presence (%)	13.15	6.35	4.40	18.88
TG	Technology Gap	1.03	3.33	0.00	62.29
LP	Labor Quality	0.78	0.18	0.04	1.00
AGE	Firms Age (year)	16.60	14.01	1.00	101.00

Firms existed in the chemical industry in 1998 are chosen as the basis of the dataset. After removing some missing firms and variables over the period 1998 to 2000, only 1,188 firms remain for estimation purposes. The first estimation uses unbalanced panel data set, that consists of 1,188 firms over the period 1998-2000, or 3,202 observations with 362 observations not in the panel. In this first dataset, firms were estimated regardless of their ownership status; foreign owned firms, joint ventures, and domestic firms. In 1998, there were 1,046 firms, consisting of 18 foreign firms, 86 joint ventures, and 942 domestic firms.[1] In 1999, there are 1,070 firms, consisting of 29 foreign firms, 83 joint ventures, and 958 domestic firms. In 2000, there were 1086 firms, consisting of 31 foreign firms, 92 joint ventures, and 963 domestic firms.

4.2 The Model

Two estimations are conducted in this paper. First, this paper estimates the effect of foreign presence on Indonesia's chemical industry as a

Unlike the standard classification, in this dataset a firm is classified as foreign firm if it fully owned by foreign shareholder, classified as joint venture if its ownership is held by domestic and foreign shareholders, regardless of their share of ownership, and classified as domestic if fully owned by domestic shareholders that could be central government, local government and or private domestic.

whole. Besides that, this first estimation is also needed to see the difference of technical efficiency between firms that have a foreign affiliation and firms without foreign affiliation. The translog model adopted for this first estimation is specified as:

$InYi, = po + PilnKi, + p_2lnMit + p_3lnFi, + pJnLi, + p_5T + pJnKi, lnK_{it} +$
$p_7lnMi;lnMu + p_8lnFitlnF_{it} + pglnLitlnLu + pioTT + Pn lnKi_tlnM_{it} + Pn$
$pulnKi,T + p_{]5} lnM_{it}lnFi, + Pi_6 lnM_{it} lnL_{it} + p$
$lnF_{it}T + p2olnL_{it}T + (v_{it} - u_{it})$........................
(4.1)

$_{Uit} = 3_0 + 5jP_{it} + 8_2TG_{it} + 5_3LP_{it} + 6_4DF_{it} + 5_5DJ_{it} + 8_6AGEi, + co_{it}$ (4.2)

where, Yu denotes production value, *KH* denotes physical capital (land, machinery, car and building), LJ, denotes total paid labor, MU denotes material input, FI, denotes fuel (solar, premium, oil, coke and gas), T indexes time trend, P_t denotes the share of foreign output in the industry, TCit denotes technological gap, *LPn* denotes the ratio of production labor to total paid labor, *DFn* and D/i, are dummy variables for foreign ownership (if fully foreign owned firm DFu = 1, if joint venture D/u = 1, if domestic firm $DFi_{(}=D/i_t=0$), and *AGEn* denotes age of firms.

The second estimation is conducted to estimate the effect of the foreign presence on domestic firms' technical efficiency. This second estimation is of particular interest to this paper to measure the spillovers in the Indonesia's chemical industry; whether foreign presence promotes an increase domestic firms' technical efficiency or not. Moreover, this second estimation is also designed to see some factors that may contribute to the spillovers. Technology gap and labor quality are two variables that are tested to measure the absorptive capacity of domestic firms. The translog model for this second estimation is specified as:

$= Po + P \quad p_2lnM_{it} + p_3lnF_{it} + p_4lnL_{it} lnF_{lt} + \quad lnK_{it}$
$p_7lnMitlnMi, + \quad frlnUlnLi, + PioTT + + pislnKulnLi,$
$+ pulnKuT + + pi_8lnFi_tlnLu + p_w$
$lnF_{it}T + ...$ (4.3) $\quad (v_{it} -$
$u_{i(}) .$

$5_5P*LP_{it} + 5_6AGE_{it} + co_{it}$

uit = 60 + Si (4.4) $8_2TG_{it} + 8_3LPit$

where $P*TGi_t$ denotes the interaction variable between the foreign presence and the technology gap, and *P*LPn* denotes the interaction variable between the foreign presence and labor quality. These two variables are needed to estimate the absorptive capacity of domestic firms.

It should be noted that for the second estimation, only domestic firms are included in the dataset. The unbalanced panel data, used in the second estimation, consists of 938 domestic firms over the 1998-2000 period, or 2,634 observations with 180 observations not in the panel.

4.3 Inefficiency Variables

This section discusses the explanatory variables included in the inefficiency models.

(1) Foreign Presence

Foreign presence (P) may be measured either through the foreign share of total production or total inputs, such as employment or capital stock. Many studies, such as Blomstrom (1989) and Aitken and Harrison (1999), use foreign share of total employment to measure the foreign presence. However, following Sjoholm (1997), this paper uses the first measure, based on production. This measure is chosen because it is not only able to capture foreign participation in the industry, but it also can indicate competition pressure from foreign firms. Technically it is calculated as:

(4.5)

where FS_{it} denotes share of foreign ownership in firm *i* at time *t*, and Y_u denotes output. A significant negative correlation is expected between foreign presence and technical inefficiency if the foreign presence increases the technical efficiency of firms in the industry.

(2) **Technology Gap**

Technology gap (TG) is measured by comparing labor productivity of firm *i* at time *t* (/„) to average labor productivity of foreign firms at time

'(£)•

TG_a = ^- .... (4.6)

';

The higher value of TG, the lower the gap between firm's technology to the average foreign firm's technology. Thus, TG may indicate the level of technology of a firm. Therefore, a negative correlation between TG and technical efficiency is expected.

TG is also a common indicator for absorptive capacity for spillovers. Thus, interaction variable between TG and foreign presence is used to measure the effect of TG on spillovers. However, as noted by Karpaty and Lundberg (2004: 7), there is disagreement on the effect of TG to spillovers. On the one hand, to absorb the spillovers, a certain level of technological capacity is required. In other words, a higher level of technology will result in a higher spillovers absorptive capacity (Karpaty and Lundberg 2004: 7). However, there is also an argument that spillovers absorptive capacity should be greater the larger the technology gap (Sjoholm 1997, Karpaty and Lundberg 2004: 7). Therefore, a positive or negative correlation between the interaction variable and technical inefficiency can be expected.

(3) **Labor Quality**

Labor quality (LP) is usually measured by labor education or the ratio between white and blue collar labor. However, there are not enough data available for those indicators to be used. Therefore, in this paper, labor quality (LP) is measured as the percentage of production labor to total labor. The higher LP means the lower labor quality. Thus, a positive correlation between LP and technical inefficiency, or that a higher labor quality will result in higher technical efficiency, is expected.

Like technology gap, labor quality also determines the absorptive capacity for spillovers. The interaction variable between LP and the foreign presence can be used to measure the effect of labor quality on spillovers. However, unlike the technology gap, labor quality seems to have only positive effect on spillovers. A higher labor quality will result in a higher spillovers absorptive capacity. Therefore, a positive correlation between the interaction variable and technical inefficiency is expected.

(4) Ownership Dummies

Two dummy variables (DF and *DJ)* are used to differentiate firms based on their ownership status; whether they are foreign owned firms, joint venture, or domestic firms (DFu = 1 if fully foreign owned firm, D/u = 1 if joint venture, and DFi_t=D/ii=0 if domestic firm). As suggested by Djankov and Hoekman (2000), it is expected that fully-owned foreign firms produce most efficiently, followed by joint ventures and domestic firms. Therefore, a negative correlation between those dummies and technical inefficiency is expected.

(5) Age

The age of firms is an important determinant of the firms' productivity. It does not only measure how long the firms have been in the industry, but it also indicates firms' experience with competition and learning opportunity. The learning curve effect suggests that a firm will produce more efficiently as it gets more experience. Therefore, a negative correlation between age and technical inefficiency is expected.

The summary of expected effects of the inefficiency explanatory variables is provided in **Table 4.2.**

Table 4.2 ***Inefficiency Variables and Expected Effects***

Inefficiency Variables	Notation	Expected Effect
Foreign Presence	*P*	Negative
Technology Gap	*TG*	Negative
Labor Quality	*IP*	Positive
Foreign Presence x Technology Gap	P*TG	Negative/Positive
Foreign Presence x Labor Quality	*P*LP*	Positive
Dummy Foreign	*DF*	Negative
Dummy Joint venture	*DJ*	Negative
AGE	*AGE*	Negative

V. FINDINGS AND DISCUSSION

The estimation of the models uses the FRONTIER 4.1 program, by Coelli (1996). It is a handy program that can provide maximum likelihood estimates of the parameters of a number of stochastic production and cost functions, so it can estimates the inefficiency models in one steps process. Basically, the program follows a three-steps procedure in estimating the maximum likelihood estimates of the parameters of a stochastic frontier production function, i.e, ordinary least-squares estimates, grid search and the final maximum likelihood estimates (Coelli 1996).

The estimation begins with a model selection to choose an appropriate production and technical inefficiency function. The following are the estimation stages and empirical results.

5.1 Model Selection

Prior to estimating the models (Model 4.1 and 4.3), a model selection is conducted to choose the appropriate production function. In selecting the production function specification, a likelihood ratio test is adopted for both translog production functions against three alternative models, (1) translog with neutral technical change (*ftu* = *PU* = *Pw* = *fao* = 0), (2) translog with no technological change (/fe = *Pw* = *PU* = *Pi?* = *Pw* = *fho* = 0), and (3) Cobb-Douglas production function (/?$_w$ = *Pn* = *flu* = *PK* = *flu* = *Pis* = /?i6 = *fin* = *PIS*=*Pi9* = /?2o = 0).

The likelihood ratio test compares the null hypothesis (L(Ho)) and the alternative hypothesis (L(Hi)) as follows:

LR= -2|ln[L(Ho)]-ln[L(Hi)]} .... (5.1)

Table 5.1 *Model Selection for First Estimation*

Production Functions	Test statistic x^2	Critical value a = 0.01	Decision
Full Translog (Model 4.1)			
Translog neutral technical change (HO:PH=P17=P19=P20=0)	26.01	12.48	Rejected
Translog no technical change (HO:p5=PlO=Pl4=Pl7=Pl9=P20=0)	57.34	16.07	Rejected
Cobb-Douglas (H0:p6=p7=...=p2o=0)	748.37	29.93	Rejected
T=50=81=62= ... =86=0	309.42	19.38	Rejected
81=82=83=... =86=0	313.23	16.07	Rejected
80=81=82=83= .. .=86=0	313.23	17.76	Rejected
r=o	61.54	5.41	Rejected

Note: the critical values for mixed x^2 are based on Kodde and Palm (1986)

Table 5.2 *Model*
Selection for Second Estimation

Production Functions	Test statistic X^2	Critical value a = 0.01	Decision
Full Translog (Model 4.3)			
Translog neutral technical change (HO:p,4=pi7=pi9=Pa>=0)	225.14	12.48	Rejected
Translog no technical change (HO:p.s=PlO=Pl4=pl7=Pl9=P20=0)	264.89	16.07	Rejected
Cobb-Douglas (H0:p6=p7=...=p2i>=0)	554.77	29.93	Rejected
y=SO=51=82= ...=86=0	303.84	19.38	Rejected
51=82=63=... =56=0	307.07	16.07	Rejected
80=51=82=53=. ..=*86=0*	307.07	17.76	Rejected
y=0	90.49	5.41	Rejected

Note: the critical values for mixed x^2 are based on Kodde and Palm (1986)

The critical values for mixed x^2 are taken from Kodde and Palm (1986) for the 1 percent level of significance. The result of the test is provided in Table 5.1 and Table 5.2. As can be seen, the null hypothesis for the translog with neutral technical change, the translog with no technical change and the Cobb-Douglas functional forms are rejected for both the first and the second estimations. Thus, the full translog production function is the most appropriate model for both estimations on the industry as a whole and on the domestic firms only.

Second, following Kompas and Che (2005), this paper also adopts a test on the parameters of the stochastic production frontier and technical efficiency. As can be seen from Tables 5.1 and 5.2, the null hypothesis that inefficiency effects are not stochastic (y=0) is rejected. The null hypothesis that there is no technical efficiency effects (y=SO=Sl=82= ... =87=0), and that the chosen inefficiency variables do not influence technical efficiency (51=52=53=...=57=0 and 50=51=52=53=...=57=0) are also rejected. Even though the coefficient parameter y is relatively low (see Table B.I and Table B.2), all statistical results indicate that the stochastic and inefficiency effects are significant. In other words, the traditional production function, with no technical inefficiency, is not the best representation of the datasets. Therefore ordinary least square (OLS) estimates will not be appropriate for this paper.

5.2 **Technical Efficiency and Technological Changes**

Technical efficiency levels are calculated from its distance to the production frontier, which are defined by the best performing firms (Kong *et al.* 1999:276). The average efficiency level will be relatively high if the performance of the firms in the industry are convergent, and will be relatively low if the performances of firms in the industry are going diverge. Table *5.3* presents average technical efficiency of all firms in the •hemical industry. As can be seen, foreign firms have the highest average technical efficiency, followed by the joint venture and domestic firms. Compared to total firms in the industry, foreign firms and joint ventures have higher average technical efficiency, while domestic firms have lower average technical efficiency compared to total firms in the industry.

Table 5.3 Average Technical Efficiency

Year	Foreign Firms	Joint Venture	Domestic	Total
1998	0.7601	0.7203	0.4748	0.4999
1999	0.5794	0.5451	0.4045	0.4201
2000	0.3843	0.3581	0.2718	0.2823
Average	0.5746	0.5412	0.3837	0.4008

The rate of technological progress in the industry seems to explain the apparent average technical efficiency in the industry. As noted by Kong *et al.* (1999: 276-7), besides competition, technological progress enables firms to catch up with the best performing firms. Table 5.4 shows that foreign and joint venture firms experience relatively rapid technological change compared to total firms in the industry. Therefore, the gap between those firms and the best performing firms in the industry is lower, leading to high technical efficiency. In contrast, the domestic firms, which have lower technological progress compared to that of total firms in the industry, cannot catch up with the average technological progress, which then leads to low technical efficiency.

Table 5.4 *Rate of Technological Change*

Year	Foreign Firms		Joint Ventures		Domestic		Total Industry	
	em	TPit-i,i	*em*	TPiM.,	*em*	TPiH.,	*em*	TPu-M
1998	0.1114		0.1127		0.0454		0.0898	
1999	0.3500	0.2307	0.3662	0.2394	0.2995	0.1725	0.3386	0.2142
2000	0.6226	0.4863	0.6150	0.4906	0.5545	0.4270	0.5974	0.4680

5.3 **Total Factor Productivity Growth**

Table 5.5 presents the calculated growth rates of total factor productivity (TFP). It shows that overall, the chemical industry experienced negative TFP growth. Differentiating firms based on their ownership also show a similar result. On average, the TFP of the industry grew by minus 0.13. A significant reduction in average technical efficiency and low technological progress may have caused the results. Interestingly, there is a different growth rate of firms' TFP, based on their ownership. This is in line with Djankov and Hoekman's (2000) finding that firms with foreign affiliation tend to have higher TFP compared to pure domestic firms. Moreover, as suggested by Borensztein *et al.* (1998: 133), since domestic firms have better access to domestic markets, a foreign firm to enter the domestic market should have lower cost and higher efficiency to compete with its domestic competitors.

Table 5.5 *Growth Rate of Total Factor Productivity*

Year	Foreign Finns	Joint Venture	Domestic	Total Industry
1998/1999	-0.0071	-0.0038	0.0243	0.0546
1999/2000	0.1495	0.1476	0.0990	0.1400
Average	0.0712	0.0719	0.0617	0.0973

5.4 **Inefficiency Variable Estimation**

Table 5.6 provides the estimation of technical inefficiency variables. The foreign presence (P) has a negative and significant coefficient for both **Model** 4.2 and **Model 4.4.** This means that a higher foreign presence in the industry resulted in a higher technical efficiency for firms in the industry. Moreover, given particular attention to domestic firms, estimation result of **Model 4.4** confirms the positive spillovers in the industry; higher foreign presence in the industry resulted higher efficiency for domestic irms. The coefficient of foreign presence, however, is relatively small, and therefore suggests weak evidence of its effect on the chemical industry.

Table 5.6 ***Parameter Estimates of the Inefficiency Functions***

	Coefficients	Standard Error
Inefficiency Variables (Model 4.2)		
Constant	1.207*"	0.322
P	-0.033*	0.018
TG	-0.050***	0.003
LP	0.374***	0.042
DA	-0.278***	0.047
D1	-0.173***	0.031
AGE	-0.001***	0.000
Inefficiency Variables (Model 4.4)		
Constant	1.327***	0.143
P	-0.015*	0.011
TG	-1.021***	0.055
LP	0.298**	0.100
P*TG	0.049***	0.003
P*LP	0.002	0.007
AGE	-0.002***	0.001

Note: ***, ** and * denote statistical significance at the 0.01, 0.05 and 0.10 levels, respectively.

In addition, there is different magnitude of the effect of foreign presence on the total chemical industry (-0.033), without distinguishing firms' ownership, and on domestic firms only (-0.015). The difference shows that an increase in foreign presence will increase technical efficiency of foreign affiliated firms more than its effect in increasing technical efficiency of domestic firms. This is not surprising since joint ventures and foreign firms have better access to technology transfer from their overseas principals. In addition, calculation on technological progress (Table 5.4) shows that the rate of technological change for foreign owned firms and joint ventures are higher than that of domestic firms. Moreover, as noted by Djankov and Hoekman (2000:20), usually joint ventures invest more in technology capacity which enables them to absorb and benefit from know-how diffusion.

Moreover, when estimating the spillovers effect on domestic firms, it excludes foreign owned and joint venture firms from the dataset. Thus, the best performing frontier for the estimation comes from domestic firms that have lower productivity compared to joint venture and foreign owned firms. Therefore, the spillovers estimation for domestic firms to benefit from foreign presence may be over-estimated. Thus, concerning a relatively low coefficient of the foreign presence in Model 4.4 (-0.015) and the possibility of over-estimation, this suggests that domestic firms, like the overall Indonesia's chemical industry, have not yet been able to take full advantage from the foreign presence in the industry.

The inability to take full benefit of foreign presence is in line with Thee's (2005) conclusion. Thee (2005: 233) notes that the inability is due to the fact that Indonesia's policymakers did not have a clear idea of what is expected from FDI and lacked the understanding of how the process of technology transfer was. This is reflected in frequent changes in policies toward FDI, which are not conducive to technology transfer. Moreover, a shortage of trained and skilled domestic labor in Indonesia's industry inhibits the technology transfer because it limits the absorptive capacity of the firm (Thee 2005:233).

In particular for **Model** 4.2, dummy variables for foreign ownership (DF and DJ) are negative and significant. This means that fully foreign owned firms have higher technical efficiency compared to joint venture firms and domestic firms, and that the joint ventures have higher technical efficiency compared to domestic firms. This result supports Djankov and Hoekman's (2000) finding that foreign affiliated firms tend to have higher TFP compared to pure domestic firms. There is a clear hierarchy of technical efficiency of chemical firms based on their ownership status. This is not surprising since foreign affiliated firms need to have better technology to compete with domestic establishments. Otherwise, foreign affiliated firms will not enter the domestic market (Borensztein *et al.* 1998:133).

The age variable (AGE) has a negative and significant coefficient. This indicates that firms' efficiency increases over time. This may be because firms with longer experiences in the market have opportunity to learn, and therefore could have better technology. Thus, this also confirms the learning curve effect that stems from dynamic scale economies. Another possible rationale comes from competition argument. As suggested by Kong *et al.* (1999: 277), the level of competition in an industry has a strong effect on the average technical efficiency. Competition will drive inefficient firms out of the industry, and only efficient firms remain. Firms which could stay longer in the industry are most likely those that could produce efficiently.

For both **Models 4.2** and 4.4, the result for the technology gap (TG) coefficient is unsurprisingly negative. This means that less technology gap or better technology results in higher firms' technical efficiency in the industry. The coefficients of labor quality (LP) for both models are also as expected. The positive and significant LP coefficient means that an increase in labor quality leads to a higher level of firms' efficiency. In other words, a higher ratio of production labor to total labor results in a lower firms' technical efficiency. This is not surprising because the chemical industry typically uses capital intensive technology, which does not require a relatively large number of labors. Therefore a higher labor employment is likely to result in a lower return, and decreases firms' technical efficiency.

In Model 4.4, the interaction variable between technology gap (TG) and the foreign presence has a significant positive effect on technical inefficiency. This means that a higher technology gap will result in a higher spillover effects for domestic firms in the industry. This supports Sjoholm (1997) and Blalock and Gertler (2004) findings that Indonesian firms which have narrow technology gap benefit less from foreign presence. As noted by Blalock and Gertler (2004), 'the marginal return to new knowledge is greater for firms that have more room to "catch up" than it is for already competitive firms.' It may imply that it is more benefit to invite FDI in a sector which has poor technology development to accelerate its technological progress, than to invite FDI in a sector that has a well developed technology. The issue, here, is not to suppress domestic technological progress to gain FDI spillovers benefit, but to accelerate domestic technological progress through foreign involvement.

The interaction variable between labor quality (LP) and foreign presence has a positive effect on technical inefficiency as expected. However, since the coefficient is not significant, it cannot lead to a conclusion that labor quality positively determines the spillovers effect for domestic firms. The choice of the labor quality parameter is possibly the rationale of such result. The education level of workers is possibly more sensitive to determine spillovers absorptive capacity rather than the ratio of production labor to total labor.

VI. CONCLUSION

There is an increasing role of FDI in developing countries. FDI can play an important role in the industrial and technological upgrading of a country. Interestingly, FDI is not only expected to bring direct effects, but also indirect effect or spillovers to a host economy (Blomstrom 1989: 35). Moreover, spillovers as an indirect effect of FDI are arguably the most significant contribution of foreign investment (Blomstrom 1989: 36). A number of studies have examined FDI spillovers, particularly whether it benefits domestic firms or not. These studies, however, result in a mixed conclusion on the evidence of spillovers. This paper has examined FDI spillovers in the Indonesia's chemical industry, whether it could increase technical efficiency of domestic firms or not, and what factors determine the spillovers.

Using a stochastic production frontier analysis, this paper found a clear hierarchy of technical efficiency of the chemical firms based on their ownership status. Foreign owned firms have the highest level of technical efficiency, followed by joint ventures and domestic firms. It also confirms a learning curve effect for firms in the industry.

In examining the positive spillover hypothesis, this paper found that a higher foreign presence increases technical efficiency of firms in the industry, but the magnitude is very small. Even though this paper supports the argument for positive spillovers in Indonesia's chemical industry, it found that domestic firms have not yet been able to take full advantage of foreign investment.

Regarding factors that determine the spillovers, this paper found that the absorptive capacity of domestic firms determines the spillovers gain. This paper also supports the argument that a wider technological gap between domestic firms and foreign firms resulted in higher spillovers effects. In addition, even though it has a positive effect, labor quality does not significantly affect the spillovers.

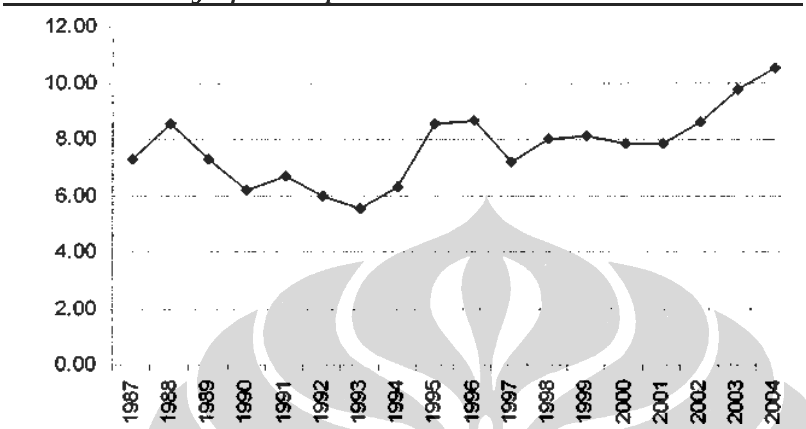
The implications of these findings are that increasing foreign presence through attracting more FDI into the Indonesia's chemical industry may benefit the industry. Moreover, since the spillovers for firms with a wider technology gap is stronger than for those with narrow one, the foreign presence will accelerate technological progress in the industry. However, understanding the process of how the foreign presence affects domestic firms is important in order to take full advantage of the foreign presence.

Limitations of this paper are mainly due to the shortage of data, particularly for variables that may determine spillovers absorptive capacity. A shortage of data on the level of education of firms' workers, for example, narrows the choice of indicator for labor quality.

For future research, extending this research through adding some variables that possibly determine spillovers, such as level of competition, level of research and development (R&D) and policy environment, will give a better understanding on FDI spillovers. This, of course, needs data availability, and therefore improving the database of Indonesian industry is another task.

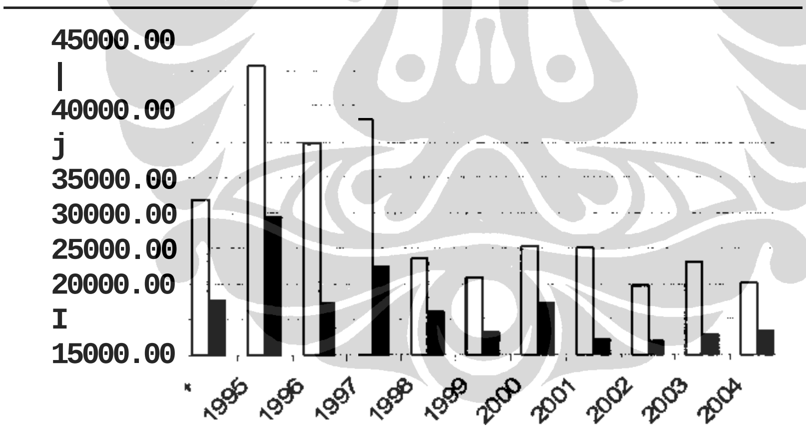
Appendix A
Figures on the Indonesia's Chemical Industry

Figure A.I ***Exports of Chemical as Percentage of Total Exports 1987-2004***



Note: here, chemical industry consists of chemical product, plastics and rubber.
Source: calculated from ADB Key Indicator.

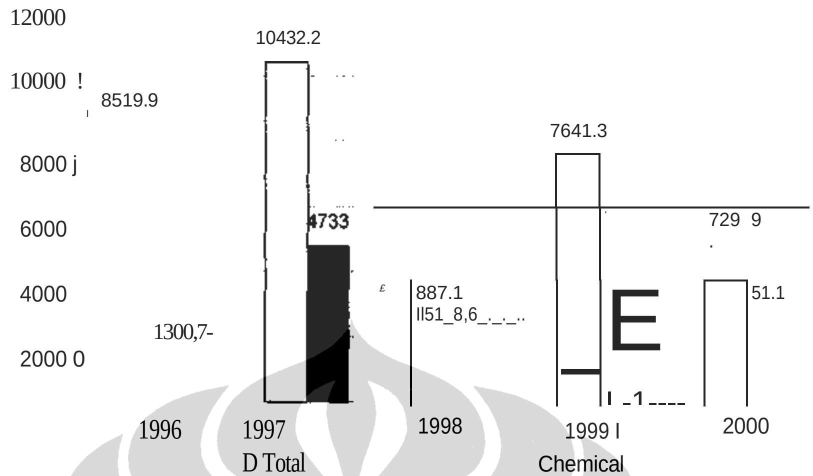
Figure A.2 *Approved Foreign Investment 1994-2004 (US$ million)*



I n Total • Chemical and Pharmaceutical

Source: Central Bank of Indonesia (Bank Indonesia).

Figure A.3 ***Implemented Foreign Investment 1996-2000** (US$ **million)***



Note: For 2000, data up to July.
Source: calculated from CEIC Asia Database.

Appendix B
The Stochastic Production Frontier and Technical Inefficiency Estimation Results

Table B.I *Parameter Estimates for Model 4.1*

	Coefficients	Standard Error
Production Function		
Constant	4.577***	0.339
K	0.146***	0.039
M	0.224***	0.039
F	0.225***	0.037
L	0.565***	0.078
T	-0.538***	0.227
K2	0.004***	0.001
M2	0.050***	0.002
F2	0.015***	0.002
L2	-0.001	0.009
T2	0.127*	0.089
KM	-0.025***	0.003
KF	0.009***	0.004
KL	0.014**	0.007
KT	_ 0.013**	0.006
MF	-0.047***	0.004
ML	-0.041***	0.007
MT	0.018***	0.007
FL	0.014**	0.007
FT	0.010*	0.007
LT	-0.037***	0.012
Inefficiency Function		
constant	1.207***	0.322
P	-0.033*	0.018
TG	-0.050***	0.003
LP	0.374***	0.042
DA	-0.278***	0.047
DJ	-0.173***	0.031
AGE	-0.001***	0.000
sigma-squared	0.149***	0.004
gamma	0.221***	0.024
log likelihood function = -1486.19		
LR test of the one-sided error = 309.42		

Note: ***, ** and * denote statistical significance at the 0.01, 0.05 and 0.10 levels, respectively.

Table B.2 ***Parameter Estimates for Model 4.3***

	Coefficients	Standard Error
Production Function		
Constant	3.139***	0.387
K	0.240***	0.048
M	0.440***	0.050
F	0.297***	0.042
L	0.174*	0.099
T	0.190*	0.136
K2	0.000	0.002
M2	0.042***	0.002
F2	0.018***	0.003
12	-0.030**	0.010
T2	-0.017	0.053
KM	-0.027***	0.004
KF	0.007*	0.004
KL	0.025***	0.007
KT	0.002	0.007
MF	-0.058***	0.004
ML	-0.013*	0.008
MT	-0.011*	0.007
FL	0.024***	0.007
FT	0.006***	0.007
IT	0.013	0.015
Inefficiency Function		
Constant	1.327***	0.143
P	-0.015*	0.011
TG	-1.021***	0.055
LP	0.298**	0.100
P*TG	0.049***	0.003
P*LP	0.002	0.007
AGE	-0.002***	0.001
sigma-squared	0.139***	0.004
gamma	0.457***	0.038
log likelihood function = -1099.01		
LR test of the one-sided error = 0.303.84		

Note: ***, ** and * denote statistical significance at the 0.01, 0.05 and 0.10 levels, respectively.

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