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Abstract

While the literature has explored the relationship between FDI and productivity, a consensus has yet to be reached regarding FDI's impacts on the productivity of local companies in developing host countries. Motivated by various results in the literature, this paper tries to specify the conditions under which industries enjoy horizontal, backward, or forward technology spillovers. Previous works have begun to consider the possibility that technology spillovers may vary depending on foreign affiliate characteristics. Our analysis extends this research and sheds light on the necessity of distinguishing local establishment characteristics when discussing potential benefits from FDI. The results show that horizontal and backward spillovers can occur simultaneously when hosting FDI. However, in order to enjoy forward spillovers, the host government needs to attract FDI in industries different from the industries that enjoy horizontal and backward spillovers.

JEL classification: F2; O1; O3

Keywords: Foreign Direct Investment (FDI); Productivity; Technology Spillovers; Vertical Linkages

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1. Introduction

Does Foreign Direct Investment (FDI) really assist host countries in the economic development process? International organizations advocate access to the global economy via foreign direct investment, specifically for developing countries. Anti-globalization movements do not necessarily agree that foreign direct investment positively influences host countries. Self-interested, multinational companies may exploit a host country's resources, impairing subsequent development. For the purposes of long-run economic growth, it may be better to protect domestic infant industries rather than rely on foreign capital. Industrial policy regarding FDI is one of the major policy debates faced by the World Bank and IMF today.

This paper studies conditions under which FDI benefits local establishments in host countries via increased productivity. The literature has explored the impacts of FDI on local companies' productivity (see Görg and Strobl (2001) for a survey). Caves (1974) on Australia, Globerman (1979) on Canada, and Blomström and Persson (1983) on Mexico are seminal empirical studies. More recent works include Kokko (1994) on Mexico and Blomström and Sjöholm (1999) on Indonesia; both use cross-sectional analysis. Haddad and Harrison (1993) on Morocco and Aitken and Harrison (1999) on Venezuela employ firm-level panel data analysis. In spite of the multitude of studies conducted, the literature has yet to reach a consensus regarding the impacts of FDI on domestic companies' productivity.

We expand upon the findings of previous works by incorporating endogenous input decision-making, establishment heterogeneity, and vertical linkages across industries. The regressions in the aforementioned literature treat inputs as exogenous variables. However, input levels do vary with firm-specific characteristics. For example, firms with positive productivity shocks may use more inputs. The literature studies the potential correlation between input levels and firm-specific productivity shocks in estimating production functions (e.g., Griliches and Mairesse, 1998). Ignoring the possibility that input choice may be endogenous could bias coefficient estimates. Problems might arise when analyzing FDI's productivity spillover on local companies. Our analysis incorporates input endogeneity by using estimation methods proposed by Levinsohn and Petrin (2003).[1] Additionally, previous works such as Aitken and Harrison (1999) and Javorcik (2004) show that the analysis with firm fixed-effects would yield different interpretation of FDI effects. Omitted firm heterogeneity such as management quality and financial conditions may affect productivity. Our analysis controls for unobserved establishment characteristics. Furthermore, the aforementioned literature has studied only horizontal spillovers (or intra-industry spillovers). Previous empirical studies examine whether the presence of multinational companies affects the productivity of local companies operating in the same sector. Theoretical works discuss FDI's spillover effects via vertical linkages (Rodorigues-Clare, 1996; Markusen and Venables, 1999; Lin and Saggi, 2007). Thus, we empirically test whether FDI affects the productivity of local suppliers that sell intermediate goods to the industrial sector. The final component of our analysis looks at the productivity of local establishments that purchase intermediate goods from the industrial sector.

The importance of these factors has been acknowledged in the recent literature on technology spillovers (Javorcik, 2004; Kugler 2006; Lileeva, 2007; Blalock and Gertler, 2007). Among them, the Javorcik (2004) study has been particularly influential. Using firm-level panel data from Lithuania, Javorcik demonstrates that FDI has positive spillover effects on the productivity of intermediate goods suppliers. Using Javorcik as a benchmark, we examine whether the results hold when the analysis is applied to a country with different characteristics, Thailand. Thailand has experienced success under a policy of FDI-led growth, making the country relevant for analyzing the FDI's impacts on productivity spillovers.

The analysis uses establishment-level panel data from an industrial survey from 1999 to 2003. The survey was conducted by the National Statistical Office (NSO) of Thailand. Our analysis focuses on the time period after the East Asian Crisis of 1997, when Thailand experienced a large increase in FDI inflows.

Our exposition is distinct from previous works. We specify the conditions under which industries enjoy horizontal, backward, or forward technology spillovers based on establishment

[1] The literature often uses the Olley and Pakes (1996) estimation procedure to address the simultaneity problem (or endogenous input decision-making). Keller and Yeaple (2003) and Javorcik (2004) use the Olley and Pakes' method in their analysis on FDI's productivity spillovers. Olley and Pakes' method is applicable to establishments with non-zero-investment. In order to use the Olley and Pakes' method establishments without investment need to be eliminated from the sample. Levinsohn and Petrin propose an alternative method that is applicable to the situation in developing countries where many establishments report no investment.

characteristics. The results show that, on average, FDI improved local establishments' productivity in the same sector, but did not affect the productivity of local establishments in the upstream and downstream sectors. At first glance, the results differ from those of Javorcik (2004). However, further investigation shows that our results are consistent with the Lithuania case presented in Javorcik. We explore FDI's impacts by classifying establishments into sub-samples based on several characteristics such as export orientation, material import, operation years, and size. By examining the nature of industries, which are estimated to have the same coefficient sign on technology spillover terms, we identify the following trends. Both horizontal and backward spillovers operated in small foreign share industries. Industries enjoying horizontal spillovers are similar to industries enjoying backward spillovers. Local establishments in small foreign share industries (where multinational companies are not dominant) may learn from multinational companies. The analysis does not observe horizontal and backward technology spillovers in industries where multinationals dominate. Additionally, industries enjoying horizontal and backward spillovers are completely different from industries enjoying forward spillovers. Our analysis using sub-samples shows that a co-existence between horizontal and backward spillovers but not with forward spillovers. This is consistent with the results of Javorcik. Country-wide technology spillovers are averaged effects across industries. Our analysis highlights the need to distinguish local establishment characteristics when discussing benefits from FDI. Spillover effects vary depending on not only foreign establishment characteristics but also local establishment characteristics.

The paper proceeds as follows. In Section 2, we summarize the data used for the analysis. Section 3 describes the empirical model used for studying productivity spillovers. Results of the analysis are presented in Section 4. Section 5 concludes the paper and suggests future lines of research.

2. Data

We use an establishment-level panel dataset from an industrial survey conducted by the National Statistical Office (NSO) of Thailand between 1999 and 2003 (and an industrial census in 1997). The NSO staff interviewed the owners of the manufacturing establishments with 10 persons or more which were selected using a combination of stratified sampling and systematic sampling. The NSO stratified establishments in each province according to industry codes and the number of workers. Then samples were selected from each province-industry-worker stratum using systematic sampling. The samples cover nearly half of the establishments with 10 persons or more operating in Thailand and are thus representative of Thai companies from various industries and sizes. The survey provides information on ownership (whether an establishment has foreign capital), sales, outputs, labor (the number of employees), capital (book value of fixed assets), material and electricity costs, an export-output ratio, an imported material ratio, location (province), and industrial classification. The survey provides information on the prior years date (e.g., the 2001 survey provides 2000 data).[2]

The analysis examines manufacturing in Thailand from 1998-2002. FDI inflows increased rapidly during the period, making this specific time period particularly relevant for analyzing technology spillovers. Thailand experienced a large increase in FDI inflows after 1997 (see Figure 1). Thailand's success under FDI-led growth policy makes the country choice relevant for the analysis. Thailand has served as a host country to FDI, since the 1960s. FDI inflows into Thailand began to increase dramatically in 1988. Average net FDI inflows were 6.6 billion Baht (US$ 276 million) per year during 1980-87, but increased to 47.5 billion Baht (US$ 1.9 billion) during 1988-95. It was during this time that the government shifted its trade policy from one of import substitution, as was typical in the 1960s and 1970s, to one of export promotion, which prevailed throughout the 1980s. Correspondingly, the economic growth rate increased from 5.9 percent (the average rate between 1980 and 1987) to 9.1 percent (the average rate between 1988 and 1995). More recently, Thailand experienced another large increase in FDI after the Asian Financial Crisis. Average net FDI inflows were 166.4 billion Baht (US$ 4.0 billion) per year during 1998-2002 (the Bank of Thailand; http://www.bot.or.th/ bothomepage/databank/EconData/EconFinance/index03e.htm). Our analysis focuses on the more recent FDI intensive time period following the East Asian Crisis of 1997.

Other data sources include the Bank of Thailand which provides various price indices

[2] The establishment-level panel dataset we use spanning 1998 through 2002 does not include 2001 establishment-level panel dataset. 2001 establishment-level panel dataset is not available.

(http://www.bot.or.th/bothomepage/databank/EconData/EconData_e.htm). We deflate outputs using a producer price index (PPI) by product group, capital stock by a PPI of capital equipments at the stage of processing, intermediate inputs by a PPI of intermediate materials by product group, and electricity expenditures by a consumer price index. All variables are measured in 2000 Thai Baht. Depreciation rates of capital are obtained from the Office of the National Economic and Social Development Board, Office of the Prime Minister (NESDB), Capital Stock of Thailand, 2004 (http://www.nesdb.go.th/econSocial/macro/macro_eng.php). The analysis uses input-output tables in order to relate industries in upstream and downstream sectors. We obtain 1998 and 2000 input-output tables and relevant information from the NESDB. The original input-output (I-O) tables have 180 industry sectors. Among the 180 sectors, 90 sectors are manufacturing related. We classified the 90 manufacturing sectors into 22 sectors based on ISIC 2-digit codes (ISIC 15-36). We drop sector 37 (recycling) from the analyses since there is no recycling sector in I-O tables. Then, the analysis calculates backward and forward spillover measures by using 1998 I-O data for the compilation of 1998 and 1999 datasets, and 2000 I-O data for 2000 and 2002 dataset.

Table 1 presents the sample's summary statistics. We have 24,248 observations (about 6,000 plants in each year) after eliminating outliers and establishments with missing variables. The sample includes 22 industries at the 2-digit ISIC level. Comparing our sample to Javorcik (2004) highlights where we expect to find different outcomes. The presence of foreign affiliates within the same industry is more common in Thailand. The mean horizontal value (we will define the value later) is 0.48 in Thailand, while the mean horizontal value is 0.19 in Lithuania. Foreign affiliates in Thailand purchased slightly more of their intermediate goods from upstream industries as compared to foreign affiliates in Lithuania. Similarly, the ratio of foreign affiliates that sold their goods to downstream industries is slightly greater in Thailand than in Lithuania. The mean backward and forward values are 0.08 and 0.11 respectively in Thailand. In Lithuania, the mean backward value is 0.05 and the mean forward value is 0.07.

Other differences include trends of FDI by sector. In Lithuania, the food and textile sectors attract a large share FDI, while the majority of FDI flows into the computing and electronic machinery and radio and television sectors in Thailand. The origin of FDI is another interesting aspect worthy of note. Table 1 shows national origin of FDI. Japanese multinational companies are dominant in Thailand. Taiwan is the second major FDI source, but the number of establishments with Taiwanese FDI is less than half of those with Japanese FDI. FDI tends to come from countries with geographic proximity to the host country. U.S. FDI's share is considerably smaller than Japan or Taiwan's. 30 percent of establishments have Japanese FDI while only 4.8 percent have U.S. FDI. Additionally, 28 percent of establishments import materials and 23 percent of establishments export goods abroad. Local establishments are less likely to export and import than foreign establishments. The employment size of local establishments is smaller than the one of foreign establishments. The following empirical analysis proves useful in examining whether these differences affect FDI's impacts on productivity spillovers.

3. Model

We use the following model to examine the impacts of FDI on local establishments' productivity:

$$\begin{aligned}\ln Y_{ijrt} &= \beta_0 + \beta_1 \ln K_{ijrt} + \beta_2 \ln L_{ijrt} + \beta_3 \ln M_{ijrt} + \beta_4 \ln F_{ijrt} + \beta_5 Foreign_{ijrt} + \beta_6 Horizontal_{jt} \\ &+ \beta_7 Backward_{jt} + \beta_8 Forward_{jt} + HHI_{jt} + \alpha_t + \alpha_r + \alpha_j + \alpha_i + \varepsilon_{ijrt}\end{aligned} \quad (1)$$

Output, Y_{ijrt}, is the real output of establishment i in industry sector j in region r at time t. The output is calculated by deducting from sales changes in inventories of finished goods and taxes. The first of the four input variables is capital, K_{ijrt}, is measured as the value of fixed assets at the beginning of the year. The second input, labor, L_{ijrt}, is the number of workers. Materials, M_{ijrt}, is the value of material inputs. Finally, F_{ijrt}, is establishment i's electricity expenses. $Foreign_{ijrt}$ is an indicator variable for foreign capital, taking a value of 1 if establishment i contains foreign equity and 0 otherwise.[3]

[3] While our data allow us to use an establishment level index, other works use a sector level index (Aitken and Harrison, 1999). The sector level index is calculated as a weighted foreign equity share averaged over all plants in the sector. The fraction used to create the weight is the number of employees in a plant divided by the total number

The term, *Foreign*, controls for the fact that foreign establishments are usually more productive. While it would be more appropriate to use the share of foreign investors among establishment i's total equity, the survey does not provide this information. This is the original classification used by the Thailand industry survey. "FDI is the acquisition of shares by a firm in a foreign-based enterprise that exceeds a threshold of *10 percent*, implying managerial participation in the foreign enterprise" (Goldin and Reinert, 2006, p.80). In order to check the relevance of the term "FDI" we refer to the 1996 census. The 1996 census shows that the share held by foreigners is at least 50 percent among 36 percent of establishments with foreign shares. The rest (64 percent) are classified as establishments where less than 50 percent of shares are held by foreigners. While even the 1996 census does not provide further information, use of the term FDI seems appropriate.

We examine horizontal and vertical linkages between local establishments' productivity and FDI by using the following time-variant, sector specific variables. $Horizontal_{jt}$ measures intra-industry spillovers. We calculate an average foreign presence in sector j at time t by using the weight of establishment i's output to total output in the sector to which establishment i belongs. The weight captures the magnitude of establishment i's effects on other establishments in the same sector:

$$Horizontal_{jt} = \left(\sum_i Foreign_{it} * Y_{it} \right) \Big/ \sum_{i \in j} Y_{it} \text{ .}$$

$Backward_{jt}$ measures spillover effects on local establishments that supply intermediate goods to the same industry sector j:

$$Backward_{jt} = \sum_k \alpha_{jk} Horizontal_{kt} \text{ ,}$$

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of employees in all plants in the industry: $\sum_{i=1}^{m} \mu_{ijt} emp_{ijt} \Big/ \sum_{i=1}^{m} emp_{ijt}$, where μ_{ijt} is foreign equity share, emp is the number of employees, and m is the total number of plants in industry j.

where α_{jk} is the share of sector j's output supplied to sector k.[4] This measure excludes goods supplied for final consumption, imports of intermediate goods, and inputs supplied within the sector. $Forward_{jt}$ measures spillover effects on local establishments that purchase intermediate goods from the same industry sector j:

$$Forward_{jt} = \sum_{m} \sigma_{jm} Horizontal_{mt} .$$

In the equation above, σ_{jm} is the share of inputs that industry j bought from industry m among sector j's total input purchases.[5] Inputs purchased within the sector are not included.

FDI affects local establishments' productivity through two different channels. The first is knowledge spillovers. Domestic companies learn how to employ superior technologies already used by foreign establishments. The second is an efficiency improvement via structural changes in the market. The entry of multinational companies will cause more competition in the host country, which may induce local establishments to operate more efficiently. The literature shows that market competition is positively correlated with productivity (Nickell, 1996). Following Javorcik (2004), we include the Herfindahl index, HHI_{jt}, which measures industry concentration in order to separate the effects of changes in the market structure from knowledge spillovers. The index is calculated as the sum of squared market shares of the four largest producers in a given sector.

Other terms incorporate unobservable factors that may influence output levels. Year fixed-effects, α_t, are time varying elements that affect all regions and industries in a given year.

[4] Javorcik (2004) justifies including imported materials in calculating α_{jk}, since she does not have input-output (IO) tables to distinguish imported materials in Lithuania. Her input-output tables are the so-called competitive import tables. Our analysis excludes imported materials. We have the so-called noncompetitive import IO tables. Noncompetitive import IO tables include the information on the consumption structure of imported materials, while competitive import IO tables do not. The use of noncompetitive import IO tables is preferable for the analysis of economic structure. One needs to assume that the consumption structure of imported materials is the same across all industries when the analysis uses competitive import IO tables. However, use of noncompetitive import IO tables is not as restrictive.

[5] Firms can export their goods. Intermediate goods sold to the foreign market may not cause spillover effects on domestic companies. It may be desirable to exclude these goods in calculating the value of forward spillovers. Unfortunately, our data do not contain enough information to allow for this distinction.

Regional fixed-effects, α_r, are time and sector invariant elements that differ across regions. For example, higher quality infrastructure in a particular region would be controlled for with a regional fixed effect. Industry fixed-effects, α_j, capture time and region invariant elements that differ across industries.

We compare results obtained without using establishment fixed-effects to with those with establishment fixed-effects. Omitted establishment heterogeneity such as management quality and financial conditions may affect productivity, while the *Foreign* term may proxy for part of the heterogeneity. Aitken and Harrison (1999) and Javorcik (2004) show that the analysis with plant fixed-effects yields a different interpretation of FDI effects. Our analysis controls for time invariant unobserved characteristics, α_i, using fixed-effects at the establishment level. We estimate equation (1) by taking the first differences of the data to control for the heterogeneity.

The analysis with establishment fixed-effects requires matching data in different years for the same establishments. Due to privacy considerations, the original survey does not provide an identifier for each establishment in different years. Additionally, the data is unbalanced panel meaning that establishments surveyed in one year are not necessarily surveyed the following year. We try to match different establishment data across years by using ISIC codes, resident regions, year of establishment, the existence of foreign equity, and the level of capital at the end of one year and the level of capital at the beginning of next year. We conjecture that those who are matched using these criteria are the same establishments in the following analysis. In other words, our matching system enables us to overcome the data limitations and identify which establishments remain in the data from year to year.

We further extend our analysis by distinguishing several establishment characteristics. The analysis examines whether there are any different vertical linkage effects depending on export orientation, imported materials, age, and size. For example, export oriented establishments may be required to satisfy higher quality standard than domestic market oriented establishments. This will put competitive pressure on inputs supplying sectors and may affect backward technology spillovers. We stratify the sample into two sub-samples: export oriented establishments and non-export oriented establishments. We classify establishments as being export oriented if an establishment exports at least 70 percent of its products. Otherwise, the establishment is classified as being non-export oriented. The threshold of 70 percent is chosen for the following two reasons. First, after experimenting with several threshold levels, we observe different spillover trends between two sub-samples with the threshold. Second, initially we conjecture that establishments separated by the threshold based on another project (Tomohara and Yokota, 2007). When we study whether FDI caused wage inequality between skilled and unskilled labor in Thailand, we observe that establishments separated by the threshold are different in nature. Similarly, we stratify the sample into two sub-samples: establishments with a high imported materials ratio and establishments with a low imported materials ratio. We classify establishments as being establishments with a high imported materials ratio if an establishment imports at least 70 percent of its intermediate materials and otherwise classified as being establishments with a low imported materials ratio. Additionally, we stratify the sample into two sub-samples: old establishments (operative years are at least 10 years) and young establishment (otherwise); large size establishments (more than 27 employees) and small size establishments (otherwise). The threshold levels are the median values of establishment years and employment size.

Spillover effects may vary depending on not only local establishment characteristics but also foreign establishment characteristics. Our analysis examines whether export oriented foreign establishments have different spillover effects than the foreign establishments of local market orientation using the following backward measure:

$$BackwardEX_{jt} = \sum_{k,k\neq j}\alpha_{jk}\left(\sum_{i,i\in k} Export_{it} * Foreign_{it} * Y_{it} \Big/ \sum_{i,i\in k} Y_{it}\right),$$

where *Export* takes a value of 1 if foreign establishment *i* exports at least 70 percent of its products and 0 otherwise. Similarly, we use the following forward measure to examine whether foreign establishments with a high import material ratio affect the productivity of local establishments differently from foreign establishments without a high import material ratio:

$$ForwardIM_{jt} = \sum_{m,m\neq j}\sigma_{jm}\left(\sum_{i,i\in m} \mathrm{Im}\,port_{it} * Foreign_{it} * Y_{it} \Big/ \sum_{i,i\in m} Y_{it}\right),$$

where *Import* takes a value of 1 if foreign establishment *i* imports at least 70 percent of its intermediate materials and otherwise 0.

The Simultaneity Problem

Estimating equation (1) using least squares assumes that production inputs are exogenous. However, decisions regarding input usage are endogenous if the levels of inputs used vary with establishment-specific characteristics. Establishments may use more inputs if establishments experience positive productivity shocks. The literature has studied the potential correlation between input levels and firm-specific productivity shocks in estimating production functions [see the seminal work by Marshack and Andrews (1944) and recent work by Griliches and Mairesse (1998)]. This simultaneity problem violates the conditions under which ordinary least square methods will obtain unbiased and consistent estimators. The problem may be more severe for inputs that adjust quickly (Marshack and Andrews, 1944).

Previous works often use the semiparametric estimation procedure proposed by Olley and Pakes (1996) in order to handle the simultaneity problem. Olley and Pakes (1996) use investment to control for correlation between input levels and unobserved firm-specific productivity shocks in estimating the parameters of the production functions. Olley and Pakes' method is only applicable to establishments reporting non-zero-investment. Unfortunately, many establishments in developing countries do not report positive levels of investment. In our sample, nearly two-thirds of the establishments report zero investment. In order to use Olley and Pakes' method we would need to truncate the sample. Truncating these establishments changes the nature of the sample, which can be avoided in this case.

Levinsohn and Petrin (2003) propose an alternative method, using an intermediate input such as electricity to address the simultaneity problem.[6] The method allows the analysis to proceed without reducing the sample size. Another benefit to Levinsohn and Petrin's method is it's applicability to non-convex adjustment cost cases. Non-convexity occurs when adjustment

[6] Another method is Blundell and Bond's (2000) GMM estimator. However, their method uses lagged inputs and is not appropriate given our short time-series sample.

costs cause kinked points in the investment demand functions. Establishments may not respond to productivity shocks (Levinsohn and Petrin, 2003, p.318).

Our analysis uses a semiparametric estimation by referring to Levinsohn and Petrin (2003). A step-by-step exposition of the estimation procedure follows. Consider the following production function:

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \beta_f f_{it} + \omega_{it} + \eta_{it}, \tag{2}$$

where y_{it} is output, l_{it} is labor, k_{it} is capital, m_{it} is material input, and f_{it} is electricity expenses of establishment i at time t. All terms are measured in logarithm units. We assume that labor, materials, and electricity expenses are variable inputs that can adjust instantly. Capital is assumed to be a fixed input that requires time to adjust. The establishment selects variable inputs and a level of investment, i_{it}, at the beginning of every period. Capital accumulates according to $k_{it+1} = (1-\delta)k_{it} + i_{it}$, where δ is the rate of depreciation. Thus, capital is a state variable that the establishment controls. The error term is additively separable, composed of an index of the establishment's efficiency (or productivity), ω_{it}, and a measurement error, η_{it}. The establishment chooses input levels based on productivity and, thus, ω_{it} is a state variable. The index, ω_{it}, is observed by the establishment, but it cannot be observed by econometricians. Since input levels are correlated with productivity, ordinary least square methods yield biased coefficient estimates. The error, η_{it}, is not forecastable when the choice of inputs is made and, thus, does not affect the establishment's input decisions.

We use electricity expenses to control for correlation between input levels and unobserved establishment-specific productivity shocks in estimating the production function's parameters. In the model, electricity expenses are a function of the two state variables, $f_{it} = f_{it}(\omega_{it}, k_{it})$. This function is assumed to be strictly increasing in ω_{it} for any k_{it}. This implies that a positive productivity shock leads to more input usage. This monotonicity assumption allows us to express unobserved productivity, ω_{it}, using observable electricity expenses, f_{it}, and capital, k_{it}, as $\omega_{it} = \omega_{it}(f_{it}, k_{it})$. Using this, we rewrite (2) as

$$y_{it} = \beta_l l_{it} + \beta_m m_{it} + \varphi_{it} + \eta_{it}, \text{ where } \varphi_{it} = \beta_0 + \beta_k k_{it} + \beta_f f_{it} + \omega_{it}(f_{it}, k_{it}). \quad (3)$$

We follow three steps to estimate the production function. First, estimating equation (3) provides consistent estimates of the coefficients on labor and materials. The estimation procedure requires specifying the unknown functional form of φ. We approximate the function of φ using a third-order polynomial expansion in electricity expenses and capital. Next, we consider the following expectation to identify the coefficients on capital and electricity expenses:

$$E[y_{it+1} - \beta_l l_{it+1} - \beta_m m_{it+1} \mid k_{it+1}] = \beta_0 + \beta_k k_{it+1} + \beta_f f_{it+1} + E[\omega_{it+1} \mid \omega_{it}]. \quad (4)$$

We assume that ω_{it} follows a first-order Markov process. Let innovation in productivity over last period's expectation be $\xi_{it+1} = \omega_{it+1} - E[\omega_{it+1} \mid \omega_{it}]$. Denote $g(\omega_{it}) = \beta_0 + E[\omega_{it+1} \mid \omega_{it}]$. The production function can be rewritten as

$$y_{it+1} - \beta_l l_{it+1} - \beta_m m_{it+1} = \beta_k k_{it+1} + \beta_f f_{it+1} + g(\varphi_{it} - \beta_k k_{it} - \beta_f f_{it}) + \xi_{it+1} + \eta_{it+1}. \quad (5)$$

Estimating (5) provides consistent estimates of the coefficients on capital and electricity expenses. In the procedure, we substitute the estimates of β_l, β_m and φ into (5) and approximate the unknown functional form of g using a third-order polynomial expansion of $\varphi - \beta_k k - \beta_f f$.

Finally, the production function is estimated. From the production function, we calculate a measure of total factor productivity as the difference between the actual output and predicted output:

$$TFP_{it} = y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_k k_{it} - \hat{\beta}_m m_{it} - \hat{\beta}_f f_{it} . \quad (6)$$

We conduct the final analysis by regressing the TFP measure on the variables in equation (1).

4. Results of the Analysis

The results of the analysis are summarized in Table 3-7 and 9. Table 3 shows the results by using all establishments. Table 4 presents the results using only local establishments. Tables 5 and 6 are the results using all establishments and local establishments for each but both control for establishment heterogeneity. Table 7 abstracts the estimates of spillover effects from Tables 5 and 6. Table 9 shows the results after adjusting for establishment heterogeneity and endogenous input decision-making. While Tables 3 (or 5) and 4 (or 6) use different samples, both tables analyze the effects of FDI on local establishments. Foreign establishments are more productive in general. The analysis using all establishments controls for the fact by including the *Foreign* term. Thus, as is shown below, we obtain the same results regarding FDI's productivity spillovers in both the all establishment and local establishment case. For each table, columns (1)-(2) are the results of estimating equation (1) using the whole sample. Columns (3)-(10) present the results using sub-samples, where we stratify the sample based on local establishment characteristics. Column (11) contains the results from *BackwardEX* and *ForwardIM* distinguishing foreign establishment characteristics.

The analysis corrects standard errors for clustering within industry-year cells. We study the effects of aggregate variables (the time-variant, sector specific horizontal and vertical variables) on micro units (the real output of the individual establishment). Previous works show that analysis without correcting for correlation among observations within the same group understates standard errors of coefficient estimates and, thus, leads to overestimated t-statistics (e.g., Moulton, 1990).[7]

The analysis indicates that local establishments could benefit from FDI depending local establishment characteristics. Let us explain our results of spillover effects individually.

Tables 3 and 4 show no horizontal spillovers regardless of establishment characteristics. Additionally, the analysis estimates backward spillovers to be negative and forward spillovers to be positive. While the latter estimate is not at statistically significant at conventional levels, the results are suggestive of possible forward spillovers (the p-values are between 10-13 percent). Table 5 in Javorcik (2004) estimates backward spillovers to be positive and no forward spillovers (the analysis without controlling for firm heterogeneity and endogenous input decision-making). We obtain different results from those in the literature regarding spillover effects. Since it is not obvious where the difference comes from, we decompose our analysis to further explore local establishment characteristics. The analysis shows that, for example, the estimates of backward spillovers are positive for export oriented establishments but negative for non-export oriented establishments. Since the number of non export oriented establishments dominates our sample, on average, the analysis shows negative backward spillovers.

Some of the results in Tables 3 and 4 do not lend themselves to clear interpretation. We obtain more intuitive results after controlling for establishment characteristics (Tables 5 and 6). Some results change completely once we control for establishment fixed-effects, a finding consistent with other works. This does not necessarily mean that the analysis in Tables 3 and 4 is useless. In fact, the analysis provides clues regarding how to examine spillovers by distinguishing local establishment characteristics.

Table 7 summarizes the results of spillovers from Tables 5 and 6, together with p-values. The analysis in Tables 3 and 4 shows that non-export oriented establishments have the same estimated coefficient signs as found for establishments with a low import material ratio, old establishments, and small size establishments. The analysis in Tables 5 and 6 shows that non-export oriented establishments have the same estimated coefficient signs as establishments with a

[7] The literature, such as Kloek (1981), Greenwald (1983), and Moulton (1986), shows that "the magnitude of the downward bias for the standard errors increases with the average group size, the intraclass correlation of the disturbances, and the intraclass correlations of the regressors" (Moulton, 1990, p. 335).

low import material ratio. Old establishments have the same estimated coefficient signs as small size establishments. Additionally, export oriented establishments have the same estimated coefficient signs as young establishments. While these estimates are not statistically significant at conventional levels, the results seem to show some patterns regarding spillovers.

We examine the relationships among establishments by characteristics in Table 8. Among non-export oriented establishments in Thailand 18,381 of 19,713 have a low import material ratio. Further, 10,233 of 19,713 are old establishments and 12,158 of 19,713 are small size establishments. While these establishments share many observations, the primary overlap occurs between non-export oriented establishments and those with a low import material ratio. Old establishments do not correspond to small size establishments. Among old establishments, 5,818 of 12,321 are small size establishments. Young establishments are not necessarily indicative of a high import martial ratio. Among establishments with a high import material ratio, 720 of 1,600 are young establishments.

The analysis shows that there are three groups where each group has the same signs on the estimated coefficients regarding horizontal and vertical spillovers. Observations within each group do not necessarily overlap. Establishment characteristics turn out to be related to the industry category. Using Table 2, we match each establishment characteristic to corresponding industry sectors. Industries such as food products and beverages, tobacco products, and publishing, printing and reproduction of recorded media include relatively old and small size establishments. Let us denote these as “Industry H” group. Industry H plus industries such as paper and paper products, and other non-metallic mineral products include relatively non-export oriented establishments and establishments with a low import material ratio. Denote these as “Industry B” group. Industry H and Industry B groups are composed of similar industry sectors. Industries such as wearing apparel, tanning and dressing of leather, luggage handbags, saddlery, harness and footwear, office, accounting and computing machinery, radio, television and communication equipment and apparatuses, and furniture include establishments that tend to be export oriented and relatively young. Denote these as “Industry F” group.

The analysis shows that Industry H group enjoyed positive horizontal spillovers, Industry B group enjoyed backward spillovers, and Industry F group enjoyed forward spillovers. We obtain results consistent with those in Javorcik (2004). She estimates positive horizontal and backward spillovers but no forward spillovers in Lithuania, where the food, textile, and other non-metallic mineral product sectors attract a large share of FDI. In Thailand, both Industry H and Industry B groups were composed of similar industries. The results indicate these industries have the potential to enjoy horizontal and backward spillovers. These results are not sensitive to the inclusion of the Herfindahl index.[8]

The results imply that technology spillovers operate both horizontally and backwardly in the industries where foreign establishments are not dominant. What is common in Industries H and B is small "Share" (the number of foreign establishments divided by the total number of establishments within industry) (see Table 2). It is possible that local establishments in these industries have greater potential for learning from FDI. The analysis presented here does provide support for the following insight: FDI's impact on local establishments' productivity varies with the stages of industrial development. FDI benefits local establishments in the initial stage, where foreign establishments are not dominant. Local establishments may learn from foreign establishments' advanced technology. At the second stage, when foreign establishments come to dominate, local establishments do not enjoy a productivity increase via the same channel. Another plausible interpretation is that technology spillovers occur when technology gaps are small between foreign and local establishments. Technology gaps are smaller in industries such as food products and beverages, and tobacco products than in industries such as electrical machinery, medical instruments, and motor vehicles.

Concerning forward spillovers, no common characteristics are observed in the sectors which make up Industry F group. However, sectors in the Industry F group do not overlap with sectors in either the Industry H or the Industry B groups. Industries which enjoyed forward spillovers may be fundamentally different from industries which enjoyed horizontal and backward spillovers. The implications are consistent with the findings in Javorcik (2004) which shows the coexistence of horizontal and backward spillovers but no forward spillovers. Our

[8] The coefficient of the Herfindahl index is estimated to be negative. The result agrees with the findings in the literature (e.g., Nickell, 1996). Productivity is negatively correlated with a less competitive market. While we obtain the predicted sign, the coefficient is not estimated to be statistically significant.

results show that industries which did not attract much FDI in Lithuania enjoyed positive forward spillovers in Thailand.

Table 9 shows the results adjusting for both establishment heterogeneity and endogenous input decision-making. The results are similar to those of Tables 5 and 6, but the results in Table 9 are statistically significant at conventional levels. Obtaining intuitive results in Table 9 indicates the importance of controlling for establishment fixed-effects as well as endogenous input decision-making.

When all establishments in Thailand are evaluated together there appear to be positive horizontal spillovers but no backward or forward spillovers. Positive horizontal spillovers are consistent with Javorcik (2004). The higher the within industry foreign presence, the higher is the productivity of local establishments. But our results are different from hers regarding backward spillovers. The possibility that FDI's impacts on local establishments' productivity varies at different stages of industrial development may explain the difference between Javorcik (2004) and the results presented here. The two studies examine different stages of FDI inflows. Javorcik (2004) examines FDI inflows in the initial stage: "Lithuania had been virtually closed to foreign investment until 1990" (p.609). Her panel data covers the period 1996-2000 when Lithuania began to experience non-negligible amounts of net FDI inflows (Figure 1, p.609). Thailand has a long history of FDI. Our study examines the period when Thailand experienced a second surge of net FDI inflows.

Our analysis is distinctive in distinguishing which industries could benefit from FDI. From the above discussion, we know there are three groups similar in nature. Again, in Table 9 old establishments are estimated to have the same coefficient signs as small size establishments. Non-export oriented establishments are estimated to have the same coefficient signs as establishments of a low import materials ratio. Similarly, export oriented establishments have estimated coefficient signs similar to those of young establishments. Industry H (small and old establishments) enjoyed positive horizontal spillovers at statistically significant levels. Industry B (non-export oriented establishments and the establishments of a low import materials ratio) enjoyed positive horizontal and backward spillovers at statistically significant levels. Industry B had only backward spillovers in Tables 5 and 6. The current results are more reasonable since

Industries H and B share some sectors. Backward spillovers were derived from sectors in Industry B but not Industry H such as paper products, other non-metallic mineral, and possibly motor vehicles and other transport equipment. Industry F (young, export oriented establishments) enjoyed forward spillovers at statistically significant levels. Furthermore, export oriented establishments did not enjoy horizontal nor backward spillovers. The lack of backward spillovers is intuitive considering that export oriented establishments overlap with establishments with a high import materials ratio. Establishments with a high import materials ratio were also estimated to have negative backward spillovers. Concerning negative horizontal effects, the situation requires that local export oriented establishments compete with foreign export oriented affiliates. Such competition with foreign establishments may have detrimental effects on local establishments.

FDI's spillover effects have been characterized using local establishment characteristics. The analysis extends to FDI's spillover effects from foreign establishment characteristics. Column (11) in Tables 3-6 contains results using *BackwardEX* and *ForwardIM*. While the sign of the estimates remains the same, the magnitudes become larger for both terms than the initial *Backward* and *Forward*. While the impacts are not statistically significant, the coefficients suggest that export oriented foreign establishments face higher product standard in the foreign markets than in the Thailand market. Local establishments need to improve upon existing production technologies in order to provide higher quality intermediate goods to downstream sectors, where foreign establishments have high standards for their inputs. Similarly, a higher import materials ratio is often used as a proxy for advanced technology.[9] Foreign establishments with a high import material ratio produce sophisticated goods. FDI enables to supply such goods as intermediates to local establishments. FDI has positive externalities on downstream local establishments.

[9] Imported materials as a share of total plant materials purchased is commonly used as a measure of technology in the literature on skill upgrading (Harrison and Hanson, 1999; Pavcnik, 2003). Feenstra and Hanson (1996) use a similar term, the imported intermediate inputs by domestic companies, to examine the effect of outsourcing on an increased relative demand for skilled labor in the U.S.

5. Concluding Remarks

This paper studies the impacts of FDI on local establishments' productivity. Although numerous studies have examined technology spillovers, the issue of the impacts of FDI on local establishments' productivity remains unresolved. The present analysis introduces vertical linkages and controls for establishment heterogeneity as well as endogenous input decision-making. The importance of these factors has been acknowledged in the recent literature on technology spillovers. Among them, Javorcik (2004) has emerged as a seminal study. We examine whether her results hold in other countries with different characteristics, using a different estimation method. Our method is more appropriate for analysis of developing countries.

Our exposition is distinct, since we distinguish which industries enjoy horizontal, backward and/or forward technology spillovers based on various establishment characteristics. The results show that, on average, FDI improves local establishments' productivity in the same sector, but does not affect the productivity of local establishments in the upstream and downstream sectors. We further investigate FDI's impacts by comparing the results from two sub-samples based on several local establishment characteristics. The analysis classifies the results based on the establishment characteristics and examines the nature of industries, which are estimated to have the same coefficient sign on spillover effects. Both horizontal and backward spillovers operated only in small foreign share industries. Industries enjoying horizontal spillovers overlap with industries enjoying backward spillovers. However, industries enjoying horizontal and backward spillovers are completely different from industries enjoying forward spillovers. Our analysis using sub-samples shows a co-existence between horizontal and backward spillovers but not with forward spillovers. Country-wide technology spillovers, or averaged effects across industries, do not provide policymakers with particularly useful information. Identifying local establishment characteristics conducive to successful FDI should prove to be more useful to potential host country governments.

Our analysis is applicable to a variety of situations. One possible extension could be to examine how the magnitudes of technology spillovers vary depending on either full or partial foreign ownership. Similarly, it is of interest to distinguish FDI's impacts on Greenfield investments from M&A. Unfortunately, the current data sets do not provide enough information to allow for such analysis. Another extension could be to incorporate how the entry/exit of establishments affects FDI's technology spillovers. For example, the exit of poorly-performing establishments increases productivity. Olley and Pakes (1996) propose an estimation method to resolve this issue. Again, the current dataset does not allow us to explore the question. The National Statistical Office of Thailand does not collect data on the same establishments year after year, and, thus, does not track the exit (and entry) of establishments. The availability of rich data sets will improve the accuracy of the analysis. All of these topics represent potential future lines of research.

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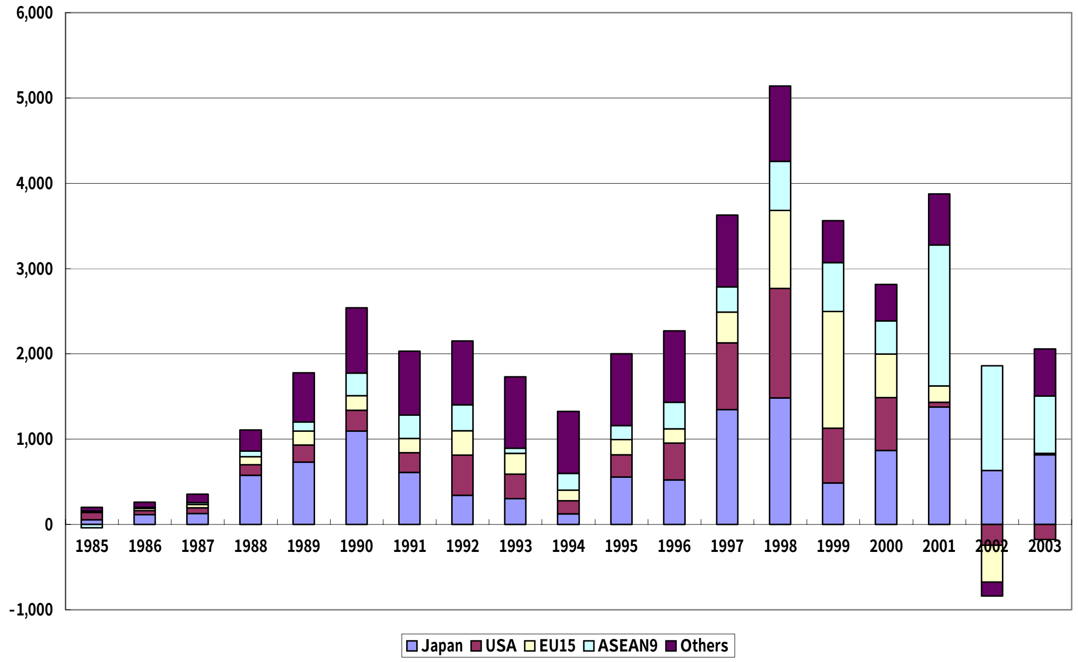
Figure 1: Net Foreign Direct Investment by Country in Thailand

(US$ million)



Source: The Bank of Thailand, the Balance of Payment Data

(http://www.bot.or.th/bothomepage/databank/EconData/EconFinance/index03e.htm)

Table 1 Summary Statistics

		All Establishments			Local Establishments		
Variables	Units	Observation	Mean	Std. Dev.	Observation	Mean	Std. Dev.
ln(Output)	Baht	24248	15.81	3.31	21135	15.37	3.19
ln(Capital)	Baht	24248	15.60	2.76	21135	15.24	2.62
ln(Labor)	Person	24248	3.48	1.49	21135	3.25	1.36
ln(Material)	Baht	24248	14.84	3.53	21135	14.37	3.41
ln(Electricity)	Baht	24248	12.16	2.73	21135	11.78	2.61
Horizontal	Share	24248	0.48	0.23	21135	0.47	0.22
Backward	Share	24248	0.08	0.09	21135	0.08	0.09
Forward	Share	24248	0.11	0.08	21135	0.11	0.08
Herfindahl	Share	24248	0.06	0.10	21135	0.06	0.10
Employment	Person	24248	128.15	418.10	21135	84.84	252.20

Foreign			Frequency	Percent	Cum. Percent			
	No FDI	(=Local)	21,135	87.16	87.16			
	FDI	(=Foreign)	3,113	12.84	100			
	FDI Origin	Japan	918	3.79	90.95			
		Taiwan	420	1.73	92.68			
		USA	151	0.62	93.3			
		Others	725	2.99	96.29			
		Unclassified	899	3.71	100			
Export			Frequency	Percent	Cum. Percent	Frequency	Percent	Cum. Percent
	(0-1 dummy)	No export	18,614	76.77	76.77	17,869	84.55	84.55
		Export	5,634	23.23	100	3,266	15.45	100
	(Share; percent)	70=<Export	2,714	11.19		1,422	6.73	
Import			Frequency	Percent	Cum. Percent	Frequency	Percent	Cum. Percent
	(0-1 dummy)	No import	17,450	71.96	71.96	16,676	78.9	78.9
		Import	6,798	28.04	100	4,459	21.1	100
	(Share; percent)	70=<Import	2,469	10.18		1,600	7.57	

Note: FDI origin: Unclassified means establishments with foreign investments from plural host countries.

Table 2 Industrial Characteristics

	Division of Industry	Foreign	Local	Share	Hor	Back	For	H4	Export	Import	Young	Large Size
15	Manufacture of food products and beverages	414	5699	6.8	35.6	0.4	4.4	1.1	8.7	5.8	39.7	41.6
16	Manufacture of tobacco products	9	245	3.5	26.9	0.0	2.5	60.5	2.4	0.0	15.0	28.0
17	Manufacture of textiles	191	1349	12.4	30.6	19.0	10.8	3.0	11.6	9.4	48.1	55.2
18	Manufacture of wearing apparel; dressing and dyeing of fur	80	714	10.1	46.5	0.7	17.1	6.2	22.9	8.9	64.2	50.1
19	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	89	615	12.6	27.4	0.5	12.5	2.9	23.2	15.5	58.1	61.1
20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	47	1022	4.4	12.2	19.6	6.6	1.4	12.2	10.8	51.0	47.6
21	Manufacture of paper and paper products	74	393	15.8	30.8	12.3	3.7	8.9	7.5	9.4	57.6	63.0
22	Publishing, printing and reproduction of recorded media	30	647	4.4	15.4	1.8	23.1	10.0	0.6	8.1	32.3	28.8
23	Manufacture of coke, refined petroleum products and nuclear fuel	24	55	30.4	57.2	5.8	0.4	32.7	2.5	16.5	44.3	60.8
24	Manufacture of chemicals and chemical products	280	730	27.7	60.0	18.2	5.7	6.3	7.8	19.1	42.5	62.2
25	Manufacture of rubber and plastic products	269	1177	18.6	48.7	17.8	16.8	1.3	17.1	11.5	51.7	61.4
26	Manufacture of other non-metallic mineral products	143	2456	5.5	58.3	8.3	9.7	3.6	4.5	5.6	52.3	36.6
27	Manufacture of basic metals	93	452	17.1	52.7	38.2	3.5	12.9	4.4	14.1	45.7	54.5
28	Manufacture of fabricated metal products, except machinery and equipment	227	1878	10.8	54.2	17.8	26.9	3.1	5.6	10.4	51.1	40.0
29	Manufacture of machinery and equipment n.e.c. (not elsewhere classified)	206	748	21.6	82.5	14.3	15.3	9.7	9.4	18.2	45.1	54.6
30	Manufacture of office, accounting and computing machinery	45	15	75.0	97.2	0.5	11.8	26.5	56.7	36.7	65.0	90.0
31	Manufacture of electrical machinery and apparatus n.e.c.	167	261	39.0	89.8	5.9	18.3	8.2	21.5	23.6	48.1	72.7
32	Manufacture of radio, television and communication eqquipment and apparatus	190	146	56.5	95.6	6.0	7.4	15.5	43.8	29.8	59.5	82.1
33	Manufacture of medical, precision and optical instruments, watches and clocks	68	129	34.5	86.7	0.6	11.5	17.9	34.0	25.4	41.1	61.9
34	Manufacture of motor vehicles, trailers and semi-trailers	155	713	17.9	91.4	1.5	22.2	28.2	2.8	10.9	53.7	41.5
35	Manufacture of other transport equipment	50	273	15.5	83.3	0.0	14.7	23.2	3.7	11.1	45.5	52.3
36	Manufacture of furniture; manufacturing n.e.c.	262	1418	15.6	57.4	0.4	10.3	4.4	25.8	11.2	52.1	52.2
	Total	3113	21135	20.7	56.4	8.6	11.6	13.1	14.9	14.2	48.3	54.5

Note: Foreign: the number of establishments with foreign capital. Local: the number of establishments without foreign capital. Share: the number of foreign establishments divided by the total number of establishments (expressed in percentage). Export: the ratio of export-oriented establishments. Import: the ratio of establishments with a high import material ratio. Young: establishments with less than 10 operation years. Large size: the ratio of establishments with more than 27 employees. All these four columns are expressed in percentage. H4: Herfindahl index. 'Hor', 'Back', 'For', and 'H4' are multiplied by 100.

Table 3 Results: All Establishments (without controlling for establishment heterogeneity and endogenous input decision-making)

	All		Export		Import		Operation years		Size		All
			Export-oriented	Non-export-oriented	High material import	Low material import	Old	Young	Large	Small	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
ln(Capital)	0.037	0.037	0.014	0.037	0.009	0.038	0.043	0.034	0.032	0.038	0.037
	(0.010)***	(0.010)***	(0.013)	(0.011)***	(0.024)	(0.010)***	(0.000)***	(0.024)**	(0.007)***	(0.008)***	(0.010)*
ln(Labor)	0.184	0.184	0.129	0.187	0.215	0.181	0.268	0.129	0.186	0.142	0.184
	(0.032)***	(0.032)***	(0.036)***	(0.035)***	(0.068)***	(0.032)***	(0.000)***	(0.001)***	(0.000)***	(0.010)**	(0.032)***
ln(Materials)	0.674	0.674	0.830	0.664	0.741	0.670	0.583	0.737	0.672	0.674	0.674
	(0.040)***	(0.040)***	(0.049)***	(0.041)***	(0.060)***	(0.041)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.040)***
ln(Electricity)	0.117	0.117	0.034	0.122	0.077	0.121	0.131	0.100	0.117	0.119	0.117
	(0.034)***	(0.034)***	(0.029)	(0.035)***	(0.035)**	(0.035)***	(0.000)***	(0.004)***	(0.000)***	(0.007)***	(0.034)***
Foreign	0.194	0.194	0.080	0.211	0.134	0.196	0.243	0.153	0.175	0.279	0.195
	(0.033)***	(0.033)***	(0.040)**	(0.044)***	(0.065)**	(0.041)***	(0.000)***	(0.002)***	(0.000)***	(0.000)***	(0.033)***
Horizontal	0.049	0.048	-0.038	0.046	0.055	0.033	0.032	0.031	0.104	0.003	0.053
	(0.093)	(0.092)	(0.145)	(0.103)	(0.174)	(0.104)	(0.747)	(0.818)	(0.301)	(0.982)	(0.103)
Backward	-1.731	-1.674	2.420	-2.157	1.176	-1.932	-2.612	-1.112	-0.051	-3.509	
	(0.638)***	(0.623)***	(0.674)***	(0.670)***	(1.930)	(0.644)***	(0.000)***	(0.150)	(0.930)	(0.001)***	
Forward	1.089	1.051	0.267	1.236	1.614	0.937	1.150	1.109	0.279	1.778	
	(0.673)	(0.665)	(0.938)	(0.743)*	(0.539)***	(0.758)	(0.115)	(0.087)*	(0.532)	(0.061)*	
Backward (Export-oriented)											-0.797
											(0.437)*
Forward (Import-oriented)											0.132
											(0.499)
Herfindahl		-0.204	0.152	-0.202	-0.210	-0.179	-0.251	-0.201	-0.082	-0.238	-0.274
		(0.212)	(0.620)	(0.225)	(0.443)	(0.226)	(0.223)	(0.563)	(0.827)	(0.391)	(0.228)
Constant	3.193	3.190	2.203	3.262	2.949	3.211	4.026	2.700	3.290	3.271	3.213
	(0.264)***	(0.264)***	(0.398)***	(0.271)***	(0.505)***	(0.267)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.264)***
Observations	24248	24248	2714	21534	2469	21779	12755	11493	11639	12609	24248
Adjusted R-squared	0.750	0.750	0.850	0.720	0.770	0.740	0.737	0.757	0.712	0.617	0.751

*** statistically significant at the 1% level; ** at the 5% level; * at the 10% level. Standard errors in parentheses are corrected for clustering industry-year cells.

Note: The dependent variable is the log of output. All models include year, region, and industry dummies. Export-oriented: establishments whose export-output ratio is at least 70%; Non-export-oriented: establishments whose export-output ratio is a less than 70%. High material import: establishments whose imported material ratio is at least 70%. Low material import: establishments whose imported material ratio is less than 70%. Old: establishments whose operation years are at least 10 years; Young: establishments whose operation years are less than 10 years. Large size: establishments with more than 27 employees; Small size: establishments with less than or equal to 27 employees.

Table 4 Results: Local Establishments (without controlling for establishment heterogeneity and endogenous input decision-making)

	All		Export		Import		Operation years		Size		All
			Export-oriented	Non-export-oriented	High material import	Low material import	Old	Young	Large	Small	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
ln(Capital)	0.035	0.035	0.009	0.036	-0.002	0.037	0.037	0.036	0.028	0.036	0.035
	(0.011)***	(0.011)***	(0.014)	(0.011)***	(0.027)	(0.011)***	(0.002)***	(0.027)**	(0.042)**	(0.012)**	(0.011)***
ln(Labor)	0.182	0.182	0.079	0.185	0.225	0.179	0.264	0.130	0.176	0.144	0.182
	(0.035)***	(0.035)***	(0.046)*	(0.037)***	(0.090)**	(0.036)***	(0.000)***	(0.002)***	(0.000)***	(0.010)**	(0.035)***
ln(Materials)	0.674	0.674	0.900	0.664	0.719	0.671	0.585	0.735	0.673	0.672	0.674
	(0.043)***	(0.043)***	(0.052)***	(0.043)***	(0.074)***	(0.043)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.043)***
ln(Electricity)	0.124	0.124	0.014	0.127	0.104	0.125	0.139	0.103	0.132	0.120	0.124
	(0.036)***	(0.036)***	(0.033)	(0.036)***	(0.045)**	(0.037)***	(0.000)***	(0.005)***	(0.000)***	(0.007)***	(0.036)***
Horizontal	0.098	0.096	0.006	0.097	0.102	0.089	0.089	0.066	0.223	0.011	0.099
	(0.107)	(0.106)	(0.251)	(0.116)	(0.391)	(0.120)	(0.430)	(0.667)	(0.047)**	(0.942)	(0.121)
Backward	-1.885	-1.835	3.244	-2.222	2.579	-2.084	-2.937	-1.131	-0.133	-3.430	
	(0.700)***	(0.689)***	(0.974)***	(0.736)***	(2.680)	(0.718)***	(0.000)***	(0.192)	(0.836)	(0.001)***	
Forward	1.045	1.014	0.871	1.210	1.657	0.887	1.195	1.029	0.022	1.776	
	(0.745)	(0.737)	(1.369)	(0.791)	(0.882)*	(0.824)	(0.175)	(0.115)	(0.965)	(0.068)*	
Backward (Export-oriented)											-0.910
											(0.486)*
Forward (Import-oriented)											-0.016
											(0.544)
Herfindahl		-0.164	1.137	-0.147	-1.200	-0.113	-0.185	-0.264	0.112	-0.251	-0.238
		(0.209)	(1.309)	(0.213)	(1.120)	(0.210)	(0.333)	(0.511)	(0.708)	(0.371)	(0.229)
Constant	3.149	3.148	1.458	3.225	3.097	3.147	3.977	2.664	3.172	3.299	3.171
	(0.288)***	(0.289)***	(0.525)***	(0.288)***	(0.646)***	(0.290)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.288)***
Observations	21135	21135	1422	19713	1600	19535	11106	10029	8814	12321	21135
Adjusted R-squared	0.720	0.720	0.840	0.700	0.700	0.710	0.699	0.722	0.684	0.609	0.716

*** statistically significant at the 1% level; ** at the 5% level; * at the 10% level. Standard errors in parentheses are corrected for clustering industry-year cells.

Note: The dependent variable is the log of output. All models include year, region, and industry dummies. Export-oriented: establishments whose export-output ratio is at least 70%; Non-export-oriented: establishments whose export-output ratio is a less than 70%. High material import: establishments whose imported material ratio is at least 70%. Low material import: establishments whose imported material ratio is less than 70%. Old: establishments whose operation years are at least 10 years; Young: establishments whose operation years are less than 10 years. Large size: establishments with more than 27 employees; Small size: establishments with less than or equal to 27 employees.

Table 5 Results: All Establishments (with controlling for establishment heterogeneity but not endogenous input decision-making)

	All		Export		Import		Operation years		Size		All
			Export-oriented	Non-export-oriented	High material import	Low material import	Old	Young	Large	Small	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
ln(Capital)	0.090	0.090	0.128	0.083	-0.001	0.094	0.081	0.094	0.152	0.053	0.091
	(0.020)***	(0.020)***	(0.072)*	(0.023)***	(0.067)	(0.022)***	(0.027)***	(0.030)***	(0.032)***	(0.029)*	(0.020)***
ln(Labor)	0.447	0.445	0.494	0.421	0.450	0.423	0.400	0.450	0.414	0.437	0.445
	(0.045)***	(0.046)***	(0.123)***	(0.040)***	(0.125)***	(0.033)***	(0.048)***	(0.065)***	(0.050)***	(0.068)***	(0.046)***
ln(Materials)	0.214	0.214	0.104	0.235	0.045	0.241	0.275	0.181	0.177	0.249	0.214
	(0.042)***	(0.042)***	(0.109)	(0.038)***	(0.084)	(0.036)***	(0.055)***	(0.053)***	(0.059)***	(0.047)***	(0.043)***
ln(Electricity)	0.090	0.090	0.219	0.084	0.167	0.084	0.097	0.086	0.130	0.073	0.090
	(0.024)***	(0.024)***	(0.092)**	(0.024)***	(0.080)**	(0.024)***	(0.028)***	(0.027)***	(0.033)***	(0.021)***	(0.024)***
Foreign	0.041	0.041	0.101	-0.011	0.101	0.033	0.006	0.076	0.052	0.062	0.043
	(0.044)	(0.044)	(0.075)	(0.045)	(0.132)	(0.035)	(0.049)	(0.079)	(0.050)	(0.156)	(0.044)
Horizontal	0.036	0.042	-0.443	0.047	-0.024	0.048	0.140	-0.069	-0.118	0.207	0.056
	(0.094)	(0.096)	(0.275)	(0.095)	(0.259)	(0.096)	(0.101)	(0.136)	(0.112)	(0.130)	(0.092)
Backward	0.208	0.193	-0.124	0.258	0.121	0.261	0.261	0.040	0.149	0.212	
	(0.190)	(0.190)	(0.432)	(0.171)	(0.628)	(0.168)	(0.211)	(0.272)	(0.223)	(0.233)	
Forward	0.400	0.389	0.685	0.217	1.663	0.141	0.025	0.756	0.240	0.361	
	(0.418)	(0.427)	(0.529)	(0.335)	(1.135)	(0.359)	(0.467)	(0.472)	(0.522)	(0.427)	
Backward											0.243
(Export-oriented)											(0.270)
Forward											0.699
(Import-oriented)											(0.724)
Herfindahl		-0.062	2.134	-0.097	-0.322	-0.089	-0.077	-0.195	0.183	-0.109	-0.063
		(0.080)	(1.108)*	(0.073)	(1.053)	(0.075)	(0.066)	(0.232)	(0.212)	(0.109)	(0.078)
Constant	-0.036	-0.031	0.055	-0.028	0.077	-0.027	-0.053	0.011	0.066	-0.133	-0.020
	(0.046)	(0.044)	(0.106)	(0.044)	(0.220)	(0.042)	(0.055)	(0.056)	(0.068)	(0.055)**	(0.040)
Observations	1539	1539	167	1372	107	1432	792	747	738	801	1539
Adjusted R-squared	0.440	0.440	0.413	0.454	0.330	0.465	0.538	0.366	0.467	0.422	0.440

*** statistically significant at the 1% level; ** at the 5% level; * at the 10% level. Standard errors in parentheses are corrected for clustering industry-year cells.

Table 6 Results: Local Establishments (with controlling for establishment heterogeneity but not endogenous input decision-making)

	All		Export		Import		Operation years		Size		All
			Export-oriented	Non-export-oriented	High material import	Low material import	Old	Young	Large	Small	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
ln(Capital)	0.090	0.090	0.154	0.084	0.076	0.090	0.086	0.088	0.175	0.051	0.091
	(0.024)***	(0.024)***	(0.116)	(0.025)***	(0.105)	(0.025)***	(0.031)***	(0.032)***	(0.038)***	(0.029)*	(0.024)***
ln(Labor)	0.469	0.467	0.704	0.428	0.829	0.432	0.426	0.465	0.443	0.446	0.467
	(0.052)***	(0.053)***	(0.130)***	(0.043)***	(0.217)***	(0.041)***	(0.053)***	(0.068)***	(0.063)***	(0.068)***	(0.052)***
ln(Materials)	0.198	0.198	0.051	0.225	-0.027	0.231	0.260	0.166	0.142	0.249	0.198
	(0.041)***	(0.041)***	(0.075)	(0.037)***	(0.046)	(0.035)***	(0.054)***	(0.051)***	(0.054)**	(0.047)***	(0.041)***
ln(Electricity)	0.087	0.087	0.232	0.083	0.171	0.082	0.093	0.085	0.121	0.073	0.087
	(0.023)***	(0.024)***	(0.116)*	(0.024)***	(0.059)***	(0.024)***	(0.028)***	(0.027)***	(0.033)***	(0.022)***	(0.024)***
Horizontal	0.044	0.048	-0.936	0.074	-0.419	0.068	0.153	-0.083	-0.191	0.229	0.062
	(0.101)	(0.103)	(0.282)***	(0.104)	(0.299)	(0.105)	(0.113)	(0.146)	(0.114)	(0.133)*	(0.100)
Backward	0.182	0.169	-0.593	0.246	0.548	0.235	0.218	0.069	0.189	0.171	
	(0.217)	(0.216)	(0.538)	(0.184)	(0.634)	(0.190)	(0.245)	(0.328)	(0.261)	(0.240)	
Forward	0.391	0.379	0.618	0.167	0.999	0.148	-0.118	0.876	0.089	0.380	
	(0.452)	(0.462)	(0.502)	(0.358)	(1.291)	(0.390)	(0.520)	(0.478)*	(0.579)	(0.427)	
Backward											0.215
(Export-oriented)											(0.295)
Forward											0.68
(Import-oriented)											(0.780)
Herfindahl		-0.050	3.221	-0.091	-1.178	-0.080	-0.077	-0.158	0.269	-0.108	-0.053
		(0.086)	(1.015)***	(0.077)	(1.183)	(0.078)	(0.073)	(0.293)	(0.250)	(0.105)	(0.083)
Constant	-0.039	-0.034	0.127	-0.038	0.183	-0.036	-0.046	-0.003	0.097	-0.142	-0.025
	(0.045)	(0.044)	(0.115)	(0.044)	(0.233)	(0.043)	(0.064)	(0.056)	(0.072)	(0.056)**	(0.041)
Observations	1345	1345	92	1253	54	1291	688	657	557	788	1345
Adjusted R-squared	0.425	0.425	0.478	0.442	0.544	0.450	0.526	0.348	0.449	0.424	0.42

*** statistically significant at the 1% level; ** at the 5% level; * at the 10% level. Standard errors in parentheses are corrected for clustering industry-year cells.

Table 7 Technology spillovers after adjusting establishment heterogeneity

	All		Export		Import		Operation years		Size	
			Export-oriented	Non-export-oriented	High material import	Low material import	Old	Young	Large	Small
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
					All Establishments					
Horizontal			-				+			+
			(0.117)				(0.174)			(0.118)
Backward				+		+				
				(0.138)		(0.129)				
Forward			+		+			+		
			(0.204)		(0.152)			(0.117)		
					Local Establishments					
Horizontal			-		-		+		-	+
			(0.003)		(0.174)		(0.182)		(0.102)	(0.095)
Backward				+		+				
				(0.189)		(0.224)				
Forward			+					+		
			(0.231)					(0.075)		

Note: *p*-values are in parentheses.

Table 8 Establishment Characteristics

		Frequency					Percentage		
		Low material import					Low material import		
		0	1	Total			0	1	Total
Non-export-oriented	0	268	1,154	1,422	Non-export-oriented	0	18.8	81.2	100
	1	1,332	18,381	19,713		1	6.8	93.2	100
	Total	1,600	19,535	21,135		Total	7.6	92.4	100
		Old					Old		
		0	1	Total			0	1	Total
Non-export-oriented	0	549	873	1,422	Non-export-oriented	0	38.6	61.4	100
	1	9,480	10,233	19,713		1	48.1	51.9	100
	Total	10,029	11,106	21,135		Total	47.5	52.5	100
		Small					Small		
		0	1	Total			0	1	Total
Non-export-oriented	0	1,259	163	1,422	Non-export-oriented	0	88.5	11.5	100
	1	7,555	12,158	19,713		1	38.3	61.7	100
	Total	8,814	12,321	21,135		Total	41.7	58.3	100
		Young					Young		
		0	1	Total			0	1	Total
High material import	0	10,226	9,309	19,535	High material import	0	52.3	47.7	100
	1	880	720	1,600		1	55.0	45.0	100
	Total	11,106	10,029	21,135		Total	52.5	47.5	100
		Old					Old		
		0	1	Total			0	1	Total
Small	0	3,526	5,288	8,814	Small	0	40.0	60.0	100
	1	6,503	5,818	12,321		1	52.8	47.2	100
	Total	10,029	11,106	21,135		Total	47.5	52.5	100

Table 9 Results: (with controlling for establishment heterogeneity and endogenous input decision-making)

	All		Export		Import		Operation years		Size	
	All	Local	Export-oriented	Non-export-oriented	High material import	Low material import	Old	Young	Large	Small
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Foreign	-0.029									
	(0.027)									
Horizontal	0.119	0.118	-1.459	0.158	0.264	0.124	0.274	-0.010	-0.176	0.361
	(0.064)*	(0.065)*	(0.136)***	(0.064)**	(0.537)	(0.066)*	(0.135)*	(0.056)	(0.142)	(0.117)***
Backward	0.128	0.076	-1.847	0.275	-2.578	0.292	0.073	0.108	0.079	0.098
	(0.167)	(0.182)	(0.432)***	(0.133)*	(1.340)*	(0.122)**	(0.275)	(0.215)	(0.361)	(0.195)
Forward	0.398	0.407	3.649	-0.134	5.223	-0.131	-0.387	1.441	0.879	-0.065
	(0.274)	(0.288)	(1.072)***	(0.375)	(1.682)***	(0.340)	(0.444)	(0.234)***	(0.520)*	(0.322)
Herfindahl	-0.161	-0.164	5.159	-0.205	1.883	-0.212	-0.162	-0.493	0.060	-0.183
	(0.156)	(0.161)	(0.943)***	(0.146)	(0.482)***	(0.149)	(0.211)	(0.102)***	(0.180)	(0.233)
Constant	-0.010	-0.005	0.306	-0.011	-0.031	0.001	-0.022	-0.012	0.207	-0.174
	(0.032)	(0.032)	(0.0921)***	(0.035)	(0.204)	(0.030)	(0.059)	(0.036)	(0.088)**	(0.079)**
Observations	1539	1345	92	1253	54	1291	688	657	557	788
Adjusted R-squared	0.004	0.003	0.099	0.004	0.131	0.004	0.009	0.007	0.006	0.011

*** statistically significant at the 1% level; ** at the 5% level; * at the 10% level. Standard errors in parentheses are corrected for clustering industry-year cells.

The dependent variable is the difference in the log of TFP.