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Do vertical spillovers differ by investors' productivity? Theory and evidence from Vietnam*

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Abstract

Developing countries are eager to host foreign direct investment to receive positive technology spillovers to their local firms. However, what types of foreign firms are desirable for the host country to achieve spillovers best? We address this question using firm-level panel data from Vietnam to investigate whether foreign Asian investors in downstream sectors with different productivity affect the productivity of local Vietnamese firms in upstream sectors differently. Using endogenous structural breaks, we divide Asian investors into low-, middle-, and high-productivity groups. The results suggest that the presence of the middle group has the strongest positive spillover effect. The differential spillover effects can be explained by a simple model with vertical linkages and productivity-enhancing investment by local suppliers. The theoretical mechanism is also empirically confirmed.

KEYWORDS

endogenous structural break, FDI spillovers, firm-level data, heterogeneous productivity, vertical Cournot model

JEL CLASSIFICATION

D22; D24; F21; F23

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1 | INTRODUCTION

Hosting foreign direct investment (FDI) is essential for enhancing economic growth in developing countries. In addition to positive impacts on local economies such as expansion in local sales and employment, one of the greatest benefits foreign multinationals could bring is technology spillovers to local firms. Through transactions and interactions with multinationals, local firms learn multinationals' sophisticated technology and improve their productivity. One notable example is a US sewing-machine company, Singer, which started its operations in Taiwan in 1964, where there were small sewing-machine manufacturers with poor technology (Lall, 1996). To meet the local-content requirement mandated by the government, the company sent several technical and management staff to Taiwan to train local suppliers. The forced local-content policy results in a significant technology transfer, helping local suppliers become major exporters. Policymakers in developing countries expect FDI to bring such positive spillovers and act as a catalyst for industrial development (Markusen & Venables, 1999).

Previous studies on FDI spillovers have shown evidence of positive spillovers from backward industrial linkages (Blalock & Gertler, 2008; Javorcik, 2004; Liu, 2008; Wooster & Diebel, 2010 for meta-analysis).[1] In particular, an increase in FDI in downstream industries improves the productivity of local firms in upstream industries. Using firm-level data in Lithuania, Javorcik (2004) measured the presence of downstream FDI from the input–output table and examined how it affects the productivity of local firms. She found that a 1 standard deviation increase in the foreign presence is associated with a 15% increase in the output of each local firm in supplying industries. Following Javorcik (2004), Blalock and Gertler (2008) and Liu (2008) also found positive vertical spillovers in Indonesia and China, respectively.

Recent studies have shown that the degree of vertical spillovers depends on the characteristics of both local firms and foreign investors (Blalock & Gertler, 2009; Javorcik & Spatareanu, 2008, 2011; Ni, Spatareanu, Manole, Otsuki, & Yamada, 2017). For local firms to benefit better from vertical spillovers, their capabilities measured by research and development (R&D) activities and the share of educated workers are important (Blalock & Gertler, 2009 for Indonesia). Turning to foreign investors' aspects, the ownership structure in FDI projects (100% foreign ownership vs. joint domestic and foreign ownership) does matter (Javorcik & Spatareanu, 2008 for Romania). Another important feature of foreign investors is their origin; those from particular source countries bring more positive vertical spillovers (Javorcik & Spatareanu, 2011 for Romania; Ni et al., 2017 for Vietnam).

We take one step forward from these studies by highlighting the role of foreign investors' productivity. In particular, we decompose downstream foreign investors into subgroups depending on their total factor productivity (TFP). We mainly focus on Asian investors for two facts: (1) Asian investors have a larger presence in Vietnam than others (Figure 1) and (2) they tend to have a more significant effect.[2] The grouping is not arbitrary but is based on a statistical method using endogenous structural breaks (Lai, Wang, & Zhu, 2009). We use the thresholds to divide Asian investors into three groups: those with high/intermediate/low levels of TFP. We find that foreign productivity has an inverted U-shaped effect on the degree of vertical spillovers, that is, the most significant positive spillovers coming from the intermediate group.

The inverted U-shaped spillover effect can be explained by a simple Cournot oligopoly model with downstream foreign firms and a local upstream firm (see also Appendix B for an extended model for horizontal spillovers). Before producing an intermediate good, the local supplier invests in reducing his or her marginal cost (i.e., doing R&D) while considering the input demand by foreign customers. The local supplier's productivity defined by the inverse of his or her marginal cost thus changes in response to changes in the number of foreign firms through his or her investment, which we consider

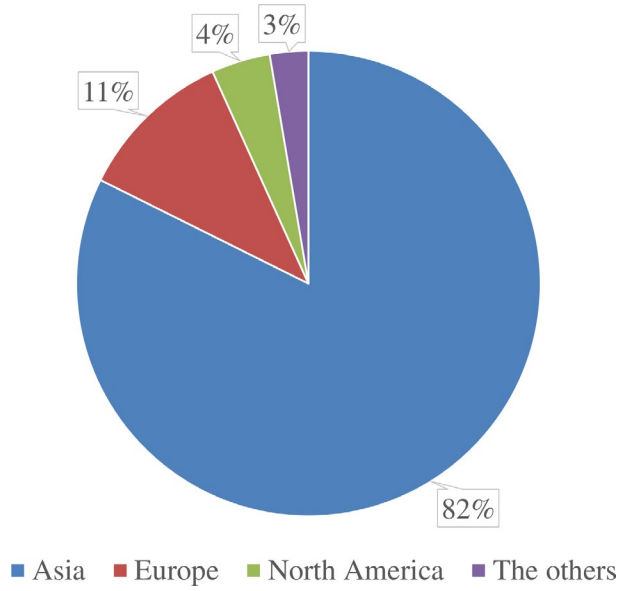

FIGURE 1 Share of foreign direct investment firms by country of origin (years 2002–2011) [Colour figure can be viewed at wileyonlinelibrary.com]

as vertical spillovers. It turns out that foreign firms with intermediate productivity demand more inputs than those with high/low productivity, inducing the local supplier to invest and thus increasing his or her productivity most effectively. We further empirically test the mechanism and confirm it.

We believe that our focus on the different productivity levels of foreign investors is a novel contribution to the literature on vertical spillovers. There have been some attempts to investigate the role of the productivity gap between local firms and foreign investors (Blalock & Gertler, 2009 for Indonesia; Kokko, 1994 for Mexico; Zhang, Li, Li, & Zhou, 2010 for China).[3] These studies, however, define the gap as a distance between the productivity of each local firm and that of the *representative* foreign investor (typically, the highest or the mean/median productivity). Foreign investors with different productivity levels are treated as one group, and thus their potential heterogeneous spillover effects are ignored.

Another contribution is our simple theory that explains the inverted U-shaped effect. A similar theoretical result can be found in Rodriguez-Clare (1996): hosting downstream FDI would increase the productivity of local suppliers if the number of locally produced input variety is close to that produced in the origin country. His emphasis is on the foreign investors' input substitution between local and imported inputs, which is different from ours on their productivity-enhancing investment.[4] Our theory is more suitable for further empirical checks because firm-level data on R&D or related activities can be obtained more easily than those on input sourcing patterns.

Finally, our methodological contribution to identifying spillover effects is worth noting. Inspired by the identification strategy of Lu, Tao, and Zhu (2017) in the context of China, we use the relaxation in FDI regulations upon Vietnam's World Trade Organization (WTO) accession as a quasi-natural experiment to conduct a difference-in-difference (DID) estimation. To be specific, we compare firm performance in the treatment group (defined as the encouraged industries) with that in the control group (i.e., the no-change industries) before and after Vietnam's WTO accession. We do this to reduce the influence of self-selected FDI inflow into particular industries and pin down the pure effect of foreign presence on local suppliers. The method, to our knowledge, is the pioneer of its kind.

1.1 | Related studies in the context of Vietnam

Among other countries, Vietnam provides us with an ideal setting to investigate the relationship between FDI and technology spillover for two reasons. First, Vietnam experienced remarkable economic growth due to the adoption of a major economic reform called Doi Moi in 1986 and the accession to the WTO in 2006.[5] It is becoming one of the most successful countries in the region to attract FDI across the world. The secrets lie in its labor abundance, low wage rate, and the successful liberalization of the investment environment.[6] Second, the average productivity level of most Vietnamese local firms is lower than that of foreign investors entering Vietnam (Ni et al., 2017), which gives Vietnamese firms more potential to catch up. How such a technology gap can be filled is one of the challenges that developing countries face.

There are important contributions on the spillover effect of FDI on Vietnamese firms, such as Nguyen (2008), Anwar and Nguyen (2014), Le and Pomfret (2011), and Newman, Rand, Talbot, and Tarp (2015).[7] Nguyen (2008) and Anwar and Nguyen (2014) highlight the location of local firms and report a positive effect of downstream FDI on local firms' TFP only in some regions. Le and Pomfret (2011) found mixed effects of the labor-productivity gap between foreign and local firms on the degree of vertical spillovers. Using the survey data of over 4,000 Vietnamese manufacturers, Newman et al. (2015) observed whether a local firm has foreign firms as customers. Such a direct linkage, however, is found to have no significant effect on the local firm's TFP.

We attempt to advance these studies in two ways.[8] First, more careful attention is paid to TFP measures and the identification of spillover effects. Nguyen (2008) and Anwar and Nguyen (2014) computed the local firms' TFP from the Solow residuals of the Cobb–Douglas production function. Such a TFP measure is subject to an endogeneity bias in the sense that factor inputs are correlated with the error term (TFP measure) when applying simple ordinary least squares (OLS) to estimate the Cobb–Douglas production function.[9] We apply the stochastic frontier method to estimate TFP, which overcomes this drawback by separating technical efficiency from the statistical noise. The TFP measure is then regressed on the foreign presence to see spillover effects. Our identification strategy using Vietnam's WTO accession as a quasi-natural experiment is most likely to sort out the self-selection bias of FDI entry.

Second, as emphasized before, we consider potential heterogeneity in spillover effects from Asian investors. While aforementioned studies highlight the characteristics of local firms such as their location (Anwar & Nguyen, 2014; Nguyen, 2008), they look at neither the role of origin countries nor that of heterogeneous productivity among foreign investors. By contrast, we focus on these aspects and find an inverted U-shaped relationship between the TFP of downstream Asian investors and that of local suppliers. We further propose a plausible theoretical mechanism for the findings and empirically confirm it. Our results would give more precise policy implications on which types of foreign firms bring the largest spillovers.

The rest of the paper is organized as follows. Section 2 describes the data and estimation strategy. Section 3 presents the results and examines the robustness. Section 4 develops a simple model to explain the empirical results. The theoretical mechanism is further empirically checked. Section 5 concludes the paper.

2 | DATA AND ESTIMATION STRATEGY

2.1 | Data

This paper applies a firm-level panel data set constructed from the Vietnam Enterprise Survey, collected annually by the General Statistics Office (GSO) of Vietnam for all industrial sectors as of

March 1 of each year. The general objectives of this survey are (1) to collect the business information needed to compile national accounts, (2) to gather up-to-date information on business registrations, and (3) to develop a statistical database of enterprises. The majority of the firms in the data set can be found in the list of Vietnam Standard Industrial Classification (VSIC) codes, including all 22 manufacturing sectors out of 42 in total.[10]

Profiles of firms concerning ownership, labor, capital stock, turnover, assets, total wage, material inputs, and information on FDI are provided. In our estimation model, we measure capital and labor by fixed assets and total labor at the end of the year. Output and capital are deflated using annual gross domestic product (GDP).[11]

This panel data set covers 10 years, from 2002 to 2011, whereas the census is conducted for firms with more than 10 employees (over 20 employees in 2010 and 2011). The GSO surveyed all multinational enterprises, which are defined as firms that have foreign capital.[12] An advantage of this data set is that for foreign-owned firms, the GSO also reports the country of origin of the largest shareholders of the targeting firm. In practice, we only count the foreign ownership with the largest share because more than 96% of the firms have only a single shareholder. For example, if Japan's share of investment is the largest, we consider the targeting firm to be a Japanese-invested firm. Each firm is given a unique "enterprise code," which is used together with the province code to identify firms and construct the panel data set (unbalanced).

To achieve more accurate estimation results, following Javorcik and Spatareanu (2011), we eliminate the missing observations and outliers by deleting samples in the top and bottom 1 percentile of all firm-specific output and input variables (in the means of annual growth). The top and bottom 1% of output/capital and output/labor are also excluded. This gives us 1,780,508 observations in total, but the observations for each variable can vary substantially due to data availability. See Appendix Table A1 for the statistical summary.

2.2 | Estimating firm productivity

TFP is the most commonly used measure of the effect of FDI spillover on a firm's performance in the literature (e.g., Javorcik, 2004). Although there are many ways to estimate TFP, we choose the stochastic frontier method, which can isolate statistical noise from genuine productivity.[13]

Let us begin by using the traditional econometric approach to estimate TFP to illustrate the advantages of our approaches. The Cobb–Douglas production function is written as

$$\ln Y_{it} = \alpha_0 + \alpha_k \ln K_{it} + \alpha_l \ln L_{it} + \varepsilon_{it}, \tag{1}$$

where Y_{it} stands for firm i's net revenue in year t. K and L represent capital and labor, respectively, ε_{it} is the unobserved error term. Once this model is estimated using OLS, TFP is calculated by normalizing the exponential transformation of the residual. The well-known drawback of this approach is its inability to isolate the genuine productivity from the statistical noise.

The stochastic frontier analysis overcomes this drawback by including two error components representing both (the inverse) the technical efficiency and statistical noise. According to Kumbhakar and Lovell (2003), the model is specified as

$$\ln Y_{it} = \alpha_0 + \sum_n \alpha_n \ln x_{ni} + v_i + u_i, \tag{2}$$

where x_{ni} is a vector of inputs. v_i is the noise component, and u_i is the nonnegative technical inefficiency component. Here, the technical efficiency derived by inverting the technical inefficiency estimate is the measure of TFP. Half-normal, exponential, and Gamma distributions are often assumed on u_i to ensure the nonnegativity of productivity estimates, whereas a full normal distribution is assumed on v_i as is common for random noise. The conditions for the error components for the half-normal model are (1) $v_i \sim \text{i.i.d.}N\left(0,\sigma_v^2\right)$, (2) $u_i \sim \text{i.i.d.}N^+\left(0,\sigma_v^2\right)$, and (3) v_i and u_i are distributed independently of each other and of the regressors.

This model is estimated using maximum likelihood estimation. Once estimates of u_i are obtained from the residual of the model, the technical efficiency of the firm can be obtained by

$$TE_i = \exp\left(-\hat{u}_i\right), \tag{3}$$

where $\hat{u}_i$ is $E(u_i|\varepsilon_i)$.[14] Alternative distributional assumptions on u_i can be accommodated simply by replacing (2).

2.3 | Estimating the spillover effect

Now, we proceed to the methodology to estimate the effect of FDI on the estimated TFP. A standard reduced form is used where a firm's TFP is regressed on measures of the FDI spillover and other covariates, as in Javorcik and Spatareanu (2011). The FDI spillover variables are built based on the influence of FDI within the same industry and downstream industries, namely, horizontal spillover and vertical spillover, respectively. We focus on Asian investors' impact for the reasons aforementioned while controlling for investors from other major areas. The baseline estimation specification is as follows:

$$\ln \text{TFP}_{ijt} = \text{Horizontal\_Origin}_{jt-1} + \beta \text{Vertical\_Origin}_{jt-1} + \text{Herfindal}_{jt-1} + \alpha_i + \eta_t + u_{ijt}, \tag{4}$$

where the coefficients of explanatory variables except for Vertical_Asia are omitted for brevity. In Equation 4, the dependent variable In TFP_{ijt} is the logarithm of TFP of a local firm i in sector j, at time t. All spillover variables are lagged by one period to take into account the possible delay for the spillover to take effect. Following the formula developed by Javorcik and Spatareanu (2011), we define $\text{Horizontal\_Origin}_{jt}$ as the share of sector j's output produced by foreign firms in year t, differentiated by their origin. Because we focus on foreign investors from Asia, Europe, and North America, Horizontal_Origin will be a vector including Horizontal_Asia, Horizontal_Europe, and Horizontal_North America. To explore the horizontal spillover impact by all the foreign firms, Horizontal_Origin will be replaced by Horizontal_total.

In the meantime, $\text{Vertical\_Origin}_{jt}$ measures the foreign presence in downstream industries. Following the literature, vertical spillovers in this study refer only to backward spillovers to upstream suppliers. In addition, we include the Herfindahl index of industry concentration in the regression. Time dummies are included to control for a time-specific shock. Firm fixed effects α_i are included to control for firms' heterogeneity.

The variable $\text{Vertical\_Origin}_{jt}$ is defined as

$$\text{Vertical\_Origin}_{jt} = \sum_{k \neq j} \gamma_{jkt} \text{Horizontal\_Origin}_{kt}. \tag{5}$$

Here γ_{jkt} is the coefficient representing the proportion of sector j's output used by sector k in year t.[15] All the coefficients are taken from the Vietnamese Input–Output Table (IO Table) 2007. Because the enterprise survey follows the VSIC code industry classification, we should match the industries in our data set with those used in the IO Table (see Ni et al. 2017 for a detailed matching procedure). We end up with 42 two-digit industries, which are listed in Appendix Table A2. Furthermore, the VSIC code system changed from VSIC code 1993 to VSIC code 2007 in the year 2007, and therefore, the industry codes before 2007 are converted in accordance with VSIC code 2007 by using a 1993–2007 concordance table.[16]

$\text{Vertical\_Origin}_{jt}$, our key variable of interest, captures the potential interaction between foreign firms in j and local suppliers in k. In accordance with the construction of horizontal spillovers, we include Vertical_Asia, Vertical_Europe, and Vertical_North America as well. In the previous study, Ni et al. (2017) found different backward vertical spillovers induced by investors from various regions. Even among Asian investors, the vertical spillover is heterogeneous. We then use the same data set to calculate the mean TFP of the firms from different regions and summarize the relationship between the mean TFP and the significance of vertical spillover. As shown in the upper panel of Table 1, among all firms, Asian ones are the most likely to induce vertical spillover to local suppliers. This motivates us to focus on Asian investors and further explore whether technology difference *within* Asian investors affects the magnitude of spillover. We first divide Asian investors into subgroups based on different TFP thresholds and then construct new vertical spillover variables using these subgroups of samples. The revised specification is written as

$$\begin{aligned}\ln \text{TFP}_{ijt} = {} & \text{Horizontal\_total}_{jt-1} + \sum_{\varphi=\varphi_0}^{P} \beta^{\varphi} \text{Vertical\_Asia}_{jt-1}^{\varphi} + \text{Vertical\_Europe}_{jt-1} \\ & + \text{Vertical\_North America}_{jt-1} + \text{Herfindal}_{jt-1} + \alpha_i + \eta_t + u_{ijt},\end{aligned} \tag{6}$$

where the coefficients of explanatory variables except for Vertical_Asia are omitted for brevity; φ indicates a specific TFP threshold; and P stands for the total number of TFP thresholds we use. In Section 2.4, we elaborate on the procedure of how to determine φ and P.

TABLE 1 TFP level and significance of vertical spillover by country origin

Region	Mean_TFP	Vertical_Spillover
Vietnam	0.576	-
Europe	0.622	×
North America	0.608	×
other Asia	0.594	○
ASEAN	0.637	×
Japan and Korea	0.592	×
other Asia	0.586	○

Abbreviation: TFP, total factor productivity.

Source: Ni et al. (2017).

2.4 | Dividing the Asian investors into subgroups

When it comes to the grouping of the Asian investors, we need to find the TFP threshold, φ, below or above which the subgroups of investors tend to have a structurally different spillover impact on domestic firms located in the upstream industry. For example, after we have decided on a single threshold φ_0, we divide Asian investors into two subgroups: the first group of firms whose TFP is above φ_0 and the second group of firms whose TFP is below φ_0.[17] Guided by the previous studies that found heterogeneous spillover effects from foreign investors with different characteristics, we would expect the first group to induce different spillover from the second group. Such an argument can be extended to multiple thresholds case, in which more than one structural transition should be observed.

The next question is: how can we determine the number of thresholds or P as noted previously? Rather than choosing the thresholds arbitrarily, we adopt a modified stepwise Chow test and conduct statistical verification that can help us capture the "structural changes" (Lai et al., 2009). We first assume the following baseline estimation model:

$$\ln \mathrm{TFP}_{ijt} = \delta_0 + \delta_1 \mathrm{Vertical\_Asia}_{jt-1} + u_{ijt}. \tag{7}$$

We want to verify that apart from the total vertical spillover induced by Asian investors, will it cause substantial variation to the estimation system if we include an additional vertical spillover variable using the subgroup of Asian investors? In the next step, we construct an augmented model:

$$\ln \mathrm{TFP}_{ijt} = \delta_0 + \delta_1 \mathrm{Vertical\_Asia}_{jt-1} + \delta^{\varphi} \mathrm{Vertical\_Asia}^{\varphi}_{jt-1} + u_{ijt}. \tag{8}$$

$\mathrm{Vertical\_Asia}^{\varphi}$ captures the additional impact from the subgroup of Asian investors, whereas φ is the threshold based on which we divide the samples. To locate the spike better even during trivial transitions, we sort all Asian firms according to their TFP level. After doing this, (1) we use the lowest 5% of the samples to calculate $\mathrm{Vertical\_Asia}^{\varphi_{5\%}}$; (2) we estimate Equations 7 and 8, retrieve the sum of squared residuals from each result to test the null hypothesis $H_0{:}\delta^{\varphi} = 0$; and (3) during the process, we calculate the F-statistics as follows:

$$F = \frac{\mathrm{SSR}_1 - \mathrm{SSR}_2}{\mathrm{SSR}_1} \frac{N-k}{q}. \tag{9}$$

q is the number of restrictions, k is the number of parameters, and SSR_1 comes from Equation 8. The larger the F-statistics are, the less likely that $\delta^{\varphi} = 0$.

We then repeat processes (1)–(3), except that we replace $\mathrm{Vertical\_Asia}^{\varphi_{5\%}}$ with $\mathrm{Vertical\_Asia}^{\varphi_{10\%}}$, that is, using the lowest 10% of the samples to calculate the additional term. The rest will be the same as the previous one. We continue this practice using the lowest 15%, 20%, and so forth, until 100%. Finally, we plot the F-statistics extracted each time against the percentage level of the TFP. The results are shown in Figure 2.

As we can see, at the 80% threshold there is a huge spike, which indicates that the inclusion of $\mathrm{Vertical\_Asia}^{\varphi_{80\%}}$ brings about the most structural variation compared with the original specification (see Equation 7). Thus, we first use 80% TFP cutoff as our main criterion and divide Asian investors into those whose TFP is above the lowest 80% of the total distribution and those below the lowest 80%.

Besides, at the 35% threshold, another spike is observed, but the magnitude is not as larger as that at the 80% threshold. This guides us to use the 35% cutoff further to divide the "<80%" group of Asian

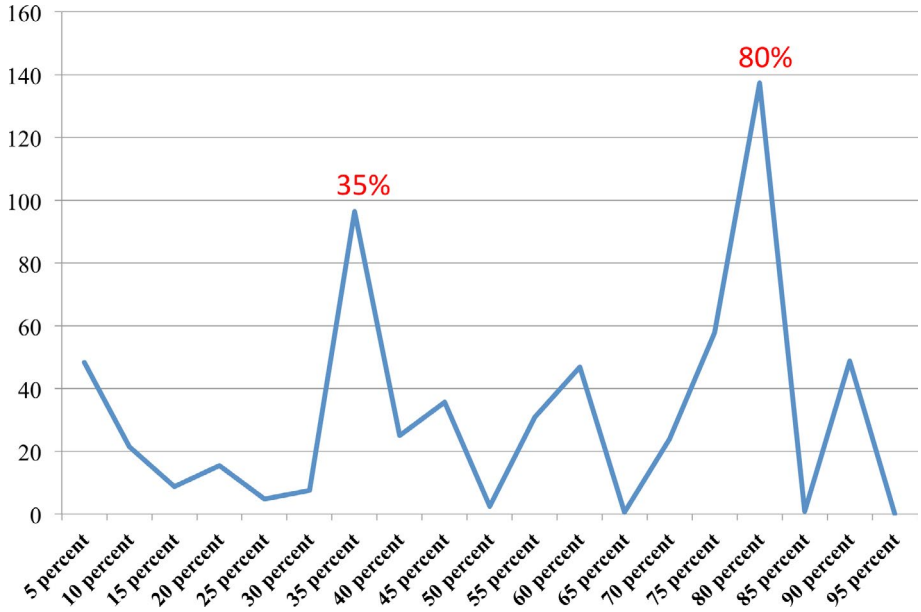

FIGURE 2 *F*-statistics by total factor productivity level (the lowest % of all Asian samples) [Colour figure can be viewed at wileyonlinelibrary.com]

investors into "<35%" and "35%<80%" subgroups. We will show the results for both practices in Section 3.

3 | ESTIMATION RESULTS

3.1 | Results using the 80% TFP cutoff

Table 2 shows the baseline estimation results using Equation 6. Columns (1) and (2) present the results excluding industry control variables, whereas columns (3) and (4) report results with industry controls. We find negative signs for Horizontal_Group throughout the models, indicating the presence of a strong replacement effect by investors in the same industry. As for the variable of interest—Vertical_Asia—only the variable constructed using the sample of Asian investors whose TFP level is "<80%" shows consistent and significant results. In addition, the coefficient is larger than that of the spillover index induced by the ">80%" group. This reveals that Asian investors endowed with a relatively lower TFP level have the most spillover effect on their upstream Vietnamese suppliers.

3.2 | Results using both the 35% and 80% TFP cutoffs

When we decompose the "<80%" group by adding the 35% TFP cutoff, the result is even more explicit. As Table 3 shows, among the low-, middle-, and high-TFP Asian investors, only those within the middle-TFP range (35%–80%) induce the most positive and significant vertical spillover in all specifications. Meanwhile, Asian investors within the low-TFP range (<35%) have a negative impact on Vietnamese suppliers' TFP. This is because Asian investors with the most similar technology to that of local firms are likely to purchase the same parts that local firms will also use. Under certain

TABLE 2 Baseline grouping (80% TFP cutoffs)

	(1)	(2)	(3)	(4)
	Stochastic frontier			
Dependent Variable	**LnTFP**	**LnTFP**	**LnTFP**	**LnTFP**
Horizontal_total (lag 1)	−0.0285***		−0.0109	
	(0.0103)		(0.00923)	
Vertical_Asia (lag 1) (<80%)	0.0409***	0.0387***	0.0445***	0.0449***
	(0.0136)	(0.0136)	(0.0124)	(0.0129)
Vertical_Asia (lag 1) (>80%)	−0.00330	−0.000231	−0.00861	−0.00805
	(0.00760)	(0.00780)	(0.00885)	(0.00917)
Vertical_Europe (lag 1)	0.220**	0.239**	0.257***	0.263***
	(0.0998)	(0.0989)	(0.0942)	(0.0953)
Vertical_NorthAme (lag 1)	−1.686**	−1.840***	−1.576***	−1.630***
	(0.668)	(0.684)	(0.487)	(0.506)
Herfindal Index	−0.0309	−0.0650**	−0.0231	−0.0215
	(0.0357)	(0.0280)	(0.0288)	(0.0290)
Observations	1,230,433	1,228,710	1,229,073	1,228,688
R-squared	0.046	0.046	0.053	0.053
Horizontal_origin_control	No	Yes	No	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Industry control	No	No	Yes	Yes

Note: Robust standard errors in parentheses, clustered at industry level. Horizontal_origin includes Horizontal_EU, Horizontal_NorthAme, Horizontal_Asia (<80%), and Horizontal_Asia (>80%). Industry control includes the number of foreign firms in an industry (in log form) and industry-level capital ratio of state-owned firms.

Abbreviation: FE, fixed effects; TFP, total factor productivity.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

circumstances, it is difficult for the spillover to occur, and on the contrary, these Asian investors will pose as a "threat" to their local suppliers and thus suppress their TFP growth.

3.3 | Endogeneity

3.3.1 | Identification strategy

A crucial assumption for obtaining an unbiased estimate as in Equation 6 is that the regressor of interest, namely, the vertical spillover variable, is uncorrelated with the error term. However, this assumption can likely be violated in our setting. For example, foreign downstream firms with higher productivity are more likely to enter industries/places with high-productive domestic suppliers. This leads to a positive correlation between foreign presence and productivity of domestic firms resulting simply from the location decision by foreign investors rather than the positive spillover effects of their investment. In such a case, failure to control foreign investors' self-selection into particular local industries would lead to a biased (upward) estimation of foreign investors' positive

TABLE 3 Baseline grouping (35% and 80% TFP cutoffs)

	(1)	(2)	(3)	(4)
	Stochastic frontier			
Dependent Variable	**LnTFP**	**LnTFP**	**LnTFP**	**LnTFP**
Horizontal_total (lag 1)	−0.0283***		−0.0111	
	(0.0101)		(0.00913)	
Vertical_Asia (lag 1) (<35%)	−0.0340	−0.143	−0.0560	−0.0955
	(0.251)	(0.250)	(0.200)	(0.196)
Vertical_Asia (lag 1) (35%~80%)	0.0511***	0.0530***	0.0545***	0.0567***
	(0.0173)	(0.0181)	(0.0161)	(0.0168)
Vertical_Asia (lag 1) (>80%)	−0.00420	−0.000999	−0.00946	−0.00878
	(0.00775)	(0.00794)	(0.00903)	(0.00934)
Vertical_Europe (lag 1)	0.213**	0.237**	0.254***	0.261***
	(0.0993)	(0.0981)	(0.0951)	(0.0955)
Vertical_NorthAme (lag 1)	−1.644**	−1.822***	−1.521***	−1.585***
	(0.660)	(0.677)	(0.479)	(0.499)
Herfindal Index	−0.0323	−0.0660**	−0.0244	−0.0249
	(0.0358)	(0.0284)	(0.0287)	(0.0289)
Observations	1,230,433	1,228,710	1,229,073	1,228,688
R-squared	0.046	0.046	0.053	0.053
Horizontal_origin_control	No	Yes	No	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Industry control	No	No	Yes	Yes

Note: Standard errors in parentheses, clustered at industry level. Horizontal_origin includes Horizontal_EU, Horizontal_NorthAme, Horizontal_Asia (<35%), Horizontal_Asia (35%–80%), and Horizontal_Asia (>80%); industry control includes the number of foreign firms in an industry (in log form) and industry-level capital ratio of state-owned firms.

Abbreviation: FE, fixed effects; TFP, total factor productivity.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

effect on domestic firms' TFP. We can consider similar scenarios for investors with low and middle productivity.

To deal with the identification problem, we follow Lu et al. (2017) and use the relaxation in FDI regulations upon Vietnam's WTO accession to conduct a DID estimation. The "Foreign Investment Law" in Vietnam was issued first in December 1987 to create more favorable conditions for foreign investors and underwent two major amendments in 2000 and 2005. Although Vietnam has been officially encouraging foreign investment as part of its development strategy since the Doi Moi economic reform, it was not until the Investment Law of 2005 that Vietnam provided a more detailed and legal framework for foreign investment. The law distinguishes four types of sectors: (1) prohibited sectors, (2) encouraged sectors, (3) conditional sectors applicable to both foreign and domestic investors, and (4) conditional sectors applicable only to foreign investors (UNCTAD, 2008). The list of encouraged industries, for example, includes high-technology, agriculture, labor-intensive industries (employing 5,000 or more employees), and infrastructure development. Foreign investors in the encouraged sectors are considered to have better access to Vietnam's

domestic market and engage more with the local firms compared with investors in other categories.

On January 11, 2007, Vietnam became the 150th member of the WTO. Upon its WTO accession, Vietnam committed to gradually open more sectors.[18] The relaxation of the FDI regulations can be considered an exogenous economic shock, which gives us the setting in which to conduct DID.[19] The treatment group includes the sectors that experienced the change in FDI regulations after 2006, that is, the prohibited and conditional sectors mentioned earlier, whereas the control group contains the sectors that were already encouraged before Vietnam's entry into the WTO. We then apply firm-level data covering 2002–2011 to compare the spillover effect between the treatment group and the control group, before and after Vietnam's entry into the WTO.

3.3.2 | Estimation specification

We adopt an augmented version of Equation 6:

$$\begin{aligned}\ln \mathrm{TFP}_{ijt} = {} & \mathrm{Treatment}_j \times \mathrm{Post06}_t + \mathrm{Horizontal\_total}_{jt-1} + \mathrm{Vertical\_Origin}_{jt-1} \\ & + \mathrm{Herfindal}_{jt-1} + \alpha_i + \eta_t + u_{ijt},\end{aligned} \tag{10}$$

where the coefficients of explanatory variables are omitted for brevity. Our main interest lies in the coefficient of the interaction term in Equation 10. $\mathrm{Treatment}_j$ indicates whether industry j belongs to the treatment group, as defined earlier. $\mathrm{Post06}_t$ is a dummy variable indicating the post-WTO period, that is, $\mathrm{Post06}_t = 1$ if $t > 2006$ and 0 if $t \leq 2006$. While controlling for the other trends that might affect domestic firms' TFP, it is assumed that the Asian firms located in FDI-prohibited industries will induce a larger spillover effect after Vietnam's entry into the WTO. Because of the relaxation of the regulations, there will be more interaction between Asian investors and local suppliers, which is why we are expecting a positive sign for the interaction term.

Another point worth mentioning is that because we create vertical spillover variables using different subgroups of Asian investors, the interaction term $\mathrm{Treatment}_j \times \mathrm{Post06}_t$ might overestimate the impact induced by Asian investors with middle-range TFP. Thus, it is necessary to control for the level of interaction between a specific subgroup of Asian investors and their local suppliers. Antras (2003) argued that the costs of physical capital are easier to share than those of labor inputs and that headquarters provides affiliates with machinery and equipment or assists their suppliers in the acquisition of capital equipment. It is reasonable to assume that capital-intensive firms will have a higher propensity to interact actively with local suppliers. Previous studies use the scale of industry-specific capital intensities to measure sourcing intensity (e.g., Kohler & Smolka, 2015).

To follow this practice, we first calculate the average capital–labor ratio using the samples of Asian investors whose TFP levels are between 35% and 80% of the total distribution, in each industry. Then, we interact this ratio with $\mathrm{Treatment}_j \times \mathrm{Post06}_t$ and use it as a robustness for our DID verification.[20]

3.3.3 | Estimation results

As shown in Table 4, the Horizontal_total is always negative, which is consistent with the previous findings that foreign investors have an even more substantial replacement impact on domestic firms in the same industry after Vietnam's entry into the WTO. In the case of vertical spillovers, when we

TABLE 4 Results using the DID method (80% TFP cutoff)

	(1)	(2)	(3)	(4)
	Stochastic frontier			
Dependent Variable	**LnTFP**	**LnTFP**	**LnTFP**	**LnTFP**
Horizontal_total (lag 1)	−0.0288**	−0.0117	−0.0296**	−0.0132
	(0.0118)	(0.0112)	(0.0119)	(0.0107)
Vertical_Asia (lag 1) (<80%)	0.0395*	0.0431***		
	(0.0208)	(0.0141)		
Vertical_Asia (lag 1) (>80%)	−0.00701	−0.0118	−0.00933	−0.0141
	(0.00789)	(0.0102)	(0.00744)	(0.0104)
Vertical_Europe (lag 1)	0.219	0.256**	0.323**	0.369***
	(0.137)	(0.124)	(0.149)	(0.130)
Vertical_NorthAme (lag 1)	−1.734**	−1.617***	−1.507**	−1.367***
	(0.807)	(0.543)	(0.710)	(0.493)
Treatment ×Post06	0.00503**	0.00465*	0.00578**	0.00551**
	(0.00198)	(0.00250)	(0.00222)	(0.00272)
Herfindal Index	−0.0247	0.0164	−0.0254	0.0150
	(0.0280)	(0.0526)	(0.0275)	(0.0528)
Observations	1,230,432	1,229,072	1,230,432	1,229,072
R-squared	0.046	0.053	0.045	0.052
Time Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Industry control	No	Yes	No	Yes

Note: Robust standard errors in parentheses, clustered at industry level. Industry control includes the number of foreign firms in an industry (in log form) and industry-level capital ratio of state-owned firms.

Abbreviations: DID, difference-in-difference; FE, fixed effects; TFP, total factor productivity.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

divide Asian firms into low- and high-TFP groups, our regressor of interest, $\text{Treatment}_j \times \text{Post06}_t$, is positive and significant in all specifications. These results show that domestic suppliers in industries with FDI inflows encouraged after the WTO accession experienced an increase in their productivity levels compared with those in industries without much change in FDI regulations. This confirms our previous finding that the vertical spillovers are mainly due to the low-TFP group of Asian firms located in downstream industries.

In addition, when we further divide the samples by 35% and 80% thresholds, a similar trend as in the previous cases is seen (Table 5). Horizontal_total still has negative signs, as expected. On the contrary, regardless of whether we include $\text{Vertical\_Asia}\,(35\%-80\%)$, the variable of interest, $\text{Treatment}_j \times \text{Post06}_t$, is positive and significant in all specifications. Table 4 shows that among the low-TFP group of investors, Asian firms in the middle-TFP range (35%–80%) induce the most significant vertical spillover to the local suppliers. Thus, by applying the supplementary robustness checks using DID, we are reassured of the significant productivity-promoting influence of Asian investors whose TFP level is within the middle range of the total distribution.

TABLE 5 Results using the DID method (35% and 80% TFP cutoffs)

	(1)	(2)	(3)	(4)
	Stochastic frontier			
Dependent Variable	**LnTFP**	**LnTFP**	**LnTFP**	**LnTFP**
Horizontal_total (lag 1)	−0.0288**	−0.0119	−0.0304**	−0.0140
	(0.0117)	(0.0109)	(0.0123)	(0.0109)
Vertical_Asia (lag 1) (<35%)	−0.0185	−0.0399	0.220	0.217
	(0.192)	(0.161)	(0.226)	(0.157)
Vertical_Asia (lag 1) (35%~80%)	0.0490*	0.0523***		
	(0.0254)	(0.0192)		
Vertical_Asia (lag 1) (>80%)	−0.00775	−0.0125	−0.00881	−0.0136
	(0.00795)	(0.0103)	(0.00757)	(0.0106)
Vertical_Europe (lag 1)	0.211	0.253*	0.297*	0.343**
	(0.140)	(0.127)	(0.149)	(0.133)
Vertical_NorthAme (lag 1)	−1.692**	−1.562***	−1.535**	−1.395***
	(0.794)	(0.541)	(0.717)	(0.492)
Treatment ×Post06	0.00489**	0.00452*	0.00586**	0.00560**
	(0.00193)	(0.00260)	(0.00220)	(0.00258)
Herfindal Index	−0.0250	0.0153	−0.0244	0.0161
	(0.0277)	(0.0519)	(0.0278)	(0.0530)
Observations	1,230,432	1,229,072	1,230,432	1,229,072
R-squared	0.046	0.053	0.045	0.052
Time Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Industry control	No	Yes	No	Yes

Note: Standard errors in parentheses, clustered at industry level. Industry control includes the number of foreign firms in an industry (in log form) and industry-level capital ratio of state-owned firms.

Abbreviations: DID, difference-in-difference; FE, fixed effects; TFP, total factor productivity.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

3.4 | Other robustness checks

Several issues are worth extra care to confirm the robustness of our findings. One might argue that the differing spillover impact is due to geographical heterogeneity. For instance, Vietnam has close business connections with Japan and China, and this bond can enhance the interaction between investors from these countries and local suppliers. However, this is not the case for investors from other Asian countries. If the distribution of Asian investors within the 35%–80% range is not random, then it will contaminate our estimation of the sole influence of the technology gap on vertical spillover.

To alleviate this concern, we decompose Asian investors in the "middle" subgroup. We find that investors with middle-level TFP are not limited to a particular country; rather, they are scattered, ranging from East Asia to South Asia. This gives us a reason to believe that geographical (or cultural) differences might not be as serious as we considered though we should take further effort to justify this point.

Another issue is that foreign investors' ownership can affect the spillover they induce to domestic firms because joint ventures may face a lower cost to find local suppliers of intermediates, and thus be more likely to engage in local sourcing than wholly owned foreign subsidiaries (Javorcik & Spatareanu, 2008). We thus generate the new vertical spillover indexes based on foreign investors' ownership (full or partial ownership) and reestimate Equation 6. The inclusion of the new indexes does not change our prediction.

In addition, there might be a concern with measurement error for the TFP thresholds. To confirm this, we use 25% or 50% TFP cutoffs to replace 35% when dividing the <80% group. We still come up with the same results, regardless of the threshold value we use.

4 | A SIMPLE MODEL

We have found that the effect of foreign presence on the local firms' productivity differs depending on the productivity of foreign investors. We here provide a simple theoretical model to explain the potential mechanism of our empirical findings. Our emphasis is on the local firm's choice of productivity-enhancing investment. We are exclusively concerned with vertical spillovers; see Appendix B for an extended model that explains negative horizontal spillovers.

Consider a partial-equilibrium Cournot model with upstream and downstream sectors. In a host country, there are one local upstream firm and $N^* > 1$ number of symmetric foreign downstream firms, each of which produces a homogeneous intermediate and final good, respectively.[21] N^* represents the presence of foreign firms or the variable Vertical_Asia in the empirical section. Foreign firms source $1/\varphi$ units of a homogeneous input per unit of production from a local supplier at the price of w. φ captures their productivity or a theoretical counterpart of their TFP. In addition to input production, the local supplier makes a cost-reducing investment, which can be thought of as an R&D. His or her marginal cost, denoted by c^U, is thus endogenously determined. The inverse of the marginal cost, $1/c^U$, corresponds to the productivity (or TFP) of the local supplier, which is the dependent variable of our empirical specification.

The timing of actions proceeds as follows. First, the local suppliers decide on how much they invest in marginal cost reduction. Second, they sell inputs to foreign firms, and finally they serve the final-good market. The problem is solved backward.

We will illustrate how the effect of foreign presence in the downstream sector on the local supplier's productivity, that is, $d\left(1/c^U\right)/dN^*$, varies with the productivity of foreign firms φ.

4.1 | Final stage: Downstream sector

Let us first see the decision of foreign firms in the final stage. They face the linear demand of $p = a - Q$, where p is the price of the final good and Q is the total demand. Letting q_i^* be the quantity supplied by foreign firm i, the market-clearing condition implies $Q = \sum_{i=1}^{N^*} q_i^*$.

The profit of foreign firm i is the sales from selling the final product minus the input cost:

$$\pi_i^* = pq_i^* - (w/\varphi)\, q_i^*,$$

where $1/\varphi$ is the unit input requirement and thus φ is the TFP of foreign firm i.

The optimal output that maximizes π_i is given by

$$q_i^* = \frac{a - w/\varphi}{N^* + 1}.$$

The total output is then

$$\begin{aligned} Q = N^* q_i^* &= \frac{N^*(a - w/\varphi)}{N^* + 1}, \\ \rightarrow w &= \varphi\left[a - \frac{(N^*+1)Q}{N^*}\right]. \end{aligned} \tag{11}$$

Accordingly, the total input demand is Q/φ.

4.2 | Second stage: Upstream sector

We turn to the second stage, where the local supplier chooses quantity Q. His or her gross profit is

$$\frac{(w - c^U)Q}{\varphi} = \left[a - \frac{(N^*+1)Q}{N^*} - \frac{c^U}{\varphi}\right] Q,$$

where w is given in Equation 11. c^U is the marginal cost, exogenously given at this stage. The supplier maximizes the gross profit to obtain

$$\frac{Q}{\varphi} = \frac{N^*\left(a\varphi - c^U\right)}{2\varphi^2\left(N^*+1\right)}. \tag{12}$$

It is worth noting that this input demand has an inverted U-shaped relationship with the foreign productivity φ. Foreign firms with very low φ produce little and do not need many inputs. Those with very high φ can produce much from a tiny amount of inputs. It is foreign firms with middle φ that demand inputs most. This nonmonotonic relationship translates into interesting interactions between the foreign productivity and the supplier's investment and productivity, as shown in the following sections.

4.3 | First stage: Productivity-enhancing investment

In the first stage, the supplier engages in productivity-enhancing investment or R&D investment. The marginal cost, c^U, or the inverse measure of productivity depends on the investment level x. We simply specify c^U as a decreasing function of x:

$$c^U = \bar{c} - x,$$

where $\bar{c}$ is a positive constant.

The supplier chooses x to maximize the net profit of a quadratic investment cost:

$$\pi^U = w(Q/\varphi) - c^U(Q/\varphi) - (x^2/2).$$

The optimal investment level and the resulting marginal cost are, respectively,

$$x = \frac{N^*\left(a\varphi - \bar{c}\right)}{2\varphi^2\left(N^*+1\right) - N^*} \tag{13}$$

and

$$c^U = \frac{\varphi\left[2\bar{c}\varphi\left(N^*+1\right)-N^*a\right]}{2\varphi^2\left(N^*+1\right)-N^*}.$$

The second-order condition (SOC) requires $2\varphi^2\left(N^*+1\right)-N^*<0$ or $\varphi>\sqrt{N^*/\left[2\left(N^*+1\right)\right]}$. To ensure both $x>0$ and $c^U>0$, as well as the SOC, we assume (1) $\varphi>\varphi_{min}\equiv\bar{c}/a$ and (2) $\bar{c}/a>\sqrt{N^*/\left[2\left(N^*+1\right)\right]}$. x has an inverted U-shaped relationship with φ because the same relationship holds between φ and the input demand Q/φ, as indicated earlier.

4.4 | Inverted U-shaped relationship

We see that the foreign presence N^* in the downstream sector increases the supplier's productivity $1/c^U$:

$$\begin{aligned}\frac{\partial\left(\frac{1}{c^U}\right)}{\partial N^*} &= \frac{1}{(\bar{c}-x)^2}\frac{\partial x}{\partial N^*}\\ &= \frac{2\left(a\varphi-\bar{c}\right)}{\left[2\bar{c}\varphi\left(N^*+1\right)-N^*a\right]^2}>0,\end{aligned} \tag{14}$$

where x is given in Equation 13. An increase in the foreign presence increases the input demand and makes R&D investment more rewarding.

The magnitude of the previous effect, however, depends on the productivity of foreign firms, φ:

$$\frac{d}{d\varphi}\left[\frac{\partial\left(1/c^U\right)}{\partial N^*}\right] = \frac{2\left[4\bar{c}^2\left(N^*+1\right)-N^*a^2-2a\bar{c}\varphi\left(N^*+1\right)\right]}{\left[2\varphi^2\left(N^*+1\right)-N^*\right]^3}\begin{cases}\geq 0 & \text{if}\varphi\leq\hat{\varphi}\\ <0 & \text{if}\varphi>\hat{\varphi}\end{cases},$$

$$\text{where}\hat{\varphi}\equiv\frac{4\bar{c}^2\left(N^*+1\right)-N^*a^2}{2a\bar{c}\left(N^*+1\right)},$$

noting $\varphi^*>0$ because of assumption (2). The positive effect of foreign presence on the local supplier's productivity first increases and then decreases as the foreign firms' productivity rises.

An increase in foreign productivity, φ, leads to an inverted U-shaped effect on the degree of spillovers $\partial\left(1/c^U\right)/\partial N^*$ in the following steps, as illustrated in quadrant I in Figure 3. As the second-stage result suggests, foreign productivity has an inverted U-shaped relationship with the input demand Q/φ (quadrant IV). A larger input demand makes the local supplier's incentive stronger to improve productivity and thus leads to more R&D investment x (quadrant III).[22] A higher level of investment then magnifies the degree of vertical spillovers $\partial\left(1/c^U\right)/\partial N^*$ (quadrant II).[23] In sum, the degree of vertical spillovers is linked with the foreign productivity through investment decisions in response to input demand.

The empirical implication key to our theory is that foreign productivity also has an inverted U-shaped relationship with the optimal R&D investment level, as shown in quadrant I of Figure 4. The local suppliers invest most at the intermediate value of φ, which gives the highest input demand.

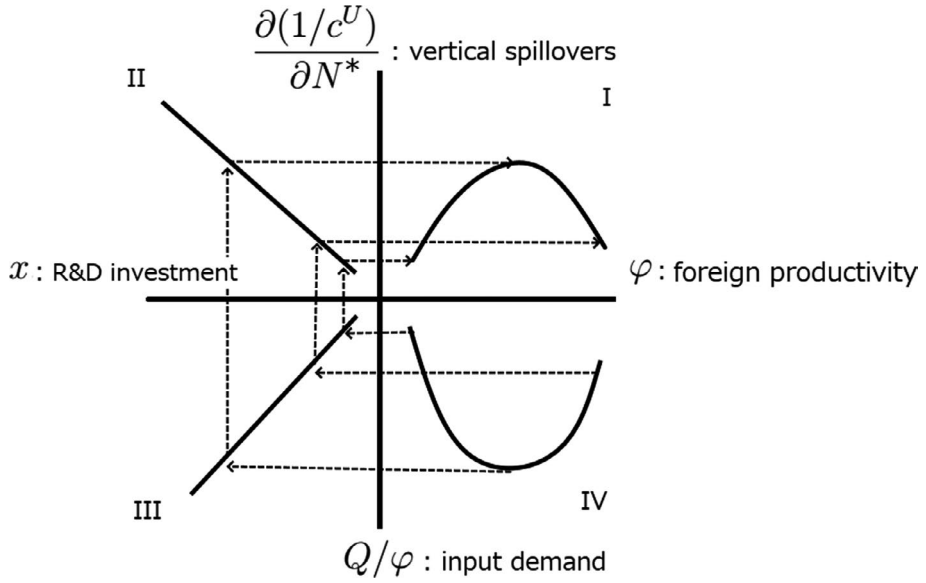

FIGURE 3 Foreign productivity and vertical spillovers

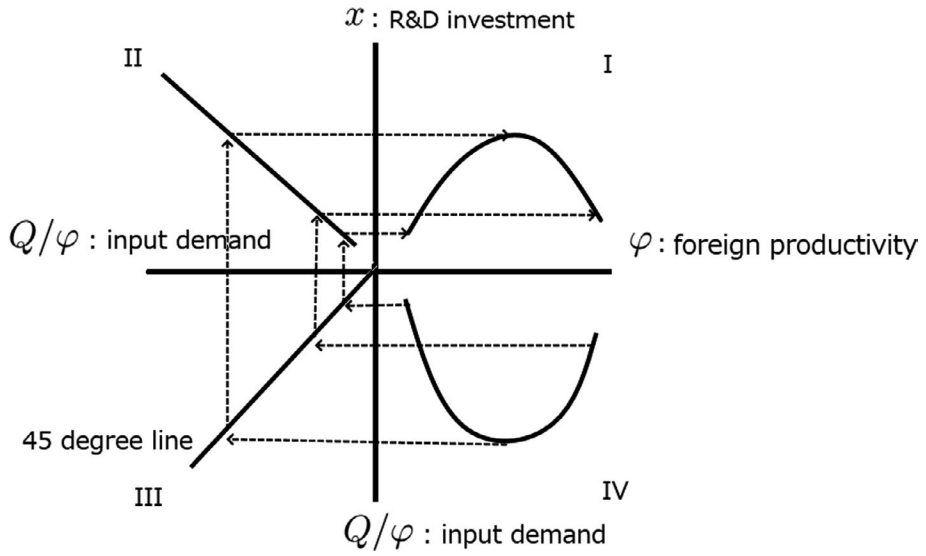

FIGURE 4 Foreign productivity and research and development (R&D) investment

4.5 | Empirical evidence on the mechanism

The mechanism illustrated in our model implies that downstream foreign investors with different productivities have different demands for local inputs: Foreign firms with very low productivity produce little and thus demand few inputs, and those with very high productivity can produce much from a tiny amount of inputs. Foreign firms with intermediate productivity demand input the most. As such, foreign customers increase their presence, and local suppliers engage in R&D investment and thus improve their productivity most effectively.

TABLE 6 Results using the DID method (35% and 80% TFP cutoffs)

	(1)	(2)
Dependent Variable	**Investment_machinery**	**Investment_fixed_assets**
Horizontal_total (lag 1)	0.112	−0.0211
	(0.0986)	(0.457)
Vertical_Asia (lag 1) (<35%)	−6.750***	−27.36**
	(1.931)	(13.67)
Vertical_Asia (lag 1) (35%~80%)	0.590***	3.563***
	(0.190)	(1.109)
Vertical_Asia (lag 1) (>80%)	−0.0311	1.553*
	(0.0946)	(0.917)
Vertical_Europe (lag 1)	−2.436**	0.731
	(1.158)	(6.082)
Vertical_NorthAme (lag 1)	13.79*	84.54***
	(7.235)	(22.30)
Herfindal Index	0.965	17.70***
	(1.289)	(2.226)
Observations	418,655	53,440
R-squared	0.010	0.150
Time Fixed Effects	Yes	Yes
Firm Fixed Effects	Yes	Yes
Industry control	No	No

Note: Robust standard errors in parentheses, clustered at industry level. Industry control includes the number of foreign firms in an industry (in log form) and industry-level capital ratio of state-owned firms.

Abbreviations: DID, difference-in-difference; FE, fixed effects; TFP, total factor productivity.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

To verify whether local suppliers increase the productivity through the channel of R&D investment, as in quadrant I of Figure 4, we conduct the following analysis:

$$\ln \mathrm{RD}_{ijt} = \mathrm{Horizontal\_total}_{jt-1} + \sum_{\varphi \in \{\mathrm{low,\ middle,\ high}\}} \beta^{\varphi} \mathrm{Vertical\_Asia}^{\varphi}_{jt-1} + \mathrm{Vertical\_Europe}_{jt-1} + \mathrm{Vertical\_North\ America}_{jt-1} + \mathrm{Herfindal}_{jt-1} + \alpha_i + \eta_t + u_{ijt},$$

where the coefficients of explanatory variables except for Vertical_Asia are omitted for brevity. We use two variables—a firm's own investment in machinery and its investment in repairing fixed assets alternatively as a proxy for their effort on R&D—and regress them on the same set of spillover variables. As shown in Table 6, the coefficient of Vertical_Asia (35%−80%), β^{middle}, has the most significant and positive result. This indicates that the presence of Asian invesrs with the middle TFP level is driving up the local firms' own investment in R&D, and this effort, in turn, will lead to an increase in the productivity. In contrast, the groups of Asian investors with low- and high-TFP levels do not induce as much vertical spillover as the group with a middle-TFP level does.

5 | CONCLUSION

The spillover impact of FDI has been widely investigated in the existing literature. In this study, we examine how the productivity gap and vertical spillover are correlated in the context of Vietnam. In particular, we focus on Asian investors, which are most likely to induce vertical spillover to local suppliers, as shown in the literature. After applying a statistical method, the endogenous structural break approach, to divide Asian investors by different TFP thresholds, we showed that the relationship between the productivity gap and the vertical spillover has an inverted U shape; that is, Vietnamese suppliers can achieve the most TFP gains from the diffusion of Asian investors with middle-level TFP.

We use the economic shock of Vietnam's entry to the WTO in 2007 to conduct a DID estimation to identify the spillover effect further, which did not change the predictions. The empirical results are also robust to several sensitivity checks, thus providing evidence that not all the foreign investors with the most advanced technology can benefit local firms in Vietnam. To understand the empirical findings better, we proposed a simple theoretical model to highlight a possible mechanism. The model focuses on local firms' own efforts on R&D, and it is affected by the TFP level of Asian investors located in the downstream sectors. Consequently, middle-productive Asian investors induce local firms to exert the most effort on R&D-related activities and thus increase local firms' productivity. Such a mechanism is also verified empirically. Nevertheless, there might be other channels through which the presence of foreign investors can induce different levels of spillover, and we will leave the verification for our future study.

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DATA AVAILABILITY STATEMENT

The data are not publicly available due to privacy or ethical restrictions.

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ENDNOTES

[1] By contrast, the literature reports mixed evidence on spillovers within an industry or horizontal spillovers. In firm-level studies, Kokko (1994) found negative horizontal spillovers in Mexico, whereas Aitken and Harrison (1999) found positive spillovers in Venezuela. See Gorg and Greenaway (2004), Smeets (2008), and Demena and van Bergeijk (2017) for comprehensive surveys.

[2] According to the Foreign Investment Agency in Vietnam, in terms of value, the FDI inflow from Asia has reached 74% among all investments, and the second is from the EU with 15%, by the end of 2017.

[3] For cross-country analysis, see Borensztein, De Gregorio, and Lee (1998), Xu (2000), Li and Liu (2005), Shen, Lee, and Lee (2010), and Baltabaev (2014). Theoretical explanations are given by Findlay (1978), Wang and Blomstrom (1992), and Glass and Saggi (1998).

[4] For the determinants of foreign investors' local procurement in the host country, see Alfaro and Rodriguez-Clare (2004) for multinationals in Latin America and Kiyota, Matsuura, Urata, and Wei (2008) and Baldwin and Okubo (2014) for Japanese multinationals across the world.

[5] Although we focus on the manufacturing sector, these two events also had significant impacts on the agricultural sector. See Cazzuffi, McKay, and Perge (2018) for the welfare implications of agricultural commercialization.

[6] In the apparel industry, for example, the average wage in Vietnam is approximately half of that in China (*The Wall Street Journal*, May 1, 2013. http://www.wsj.com/public/page/archive-2013-5-01.html, accessed October 25, 2017). UNCTAD (2008) evaluates the impacts of the Doi Moi policy and the WTO accession on FDI.

[7] Apart from these firm-level studies, there are also studies using more aggregate data. Anwar and Nguyen (2010b) used province-level panel data from 1996 to 2005 to examine the effect of (aggregate) FDI on regional economic growth. They found that FDI contributes to the regional economy in general, but the contribution becomes smaller if the region is not equipped with a good financial system. Anwar and Nguyen (2010a) distinguished between vertical and horizontal FDIs and looked at their impact on the growth rate of local manufacturing sectors.

[8] Nguyen (2008), Anwar and Nguyen (2014), and Le and Pomfret (2011); and we use the Vietnam Enterprise Survey data, which will be explained in the next section. However, our data span a longer period and cover more recent years, that is, from 2002 to 2011. The data source is used in other recent studies on Vietnam, for example, Ha, Kiyota, and Yamanouchi (2016) on resource misallocation; Trinh and Ha (2018) on small- and medium-sized firms; Nguyen, Tran, Pham, and Nguyen (2020) for employment.

[9] Van Biesebroeck (2007) took five TFP estimation methods including OLS, the stochastic frontier approach, and the semiparametric approach (Levinsohn & Petrin, 2003; Olley & Pakes, 1996), and checked their robustness to measurement error and to differences in production technology using simulated data. He concluded that "given the well-known simultaneity problem between inputs and unobserved productivity, estimating a production function by least squares (OLS) is generally not advisable" (p. 531). See also Van Beveren (2012) for the recent development of TFP estimation.

[10] We use the first two digits indicated in the VSIC coding system. There are two types of codes, namely, VSIC code 2007 and VSIC code 1993, where the former has been applied since 2007. We also construct a concordance table to unify these two systems. For simplicity, we aggregate some sectors.

[11] Although producer price index in the sector level is a preferred deflator, such data are not available for Vietnam.

[12] In the standard FDI literature, foreign firms are defined as the ones whose foreign share is more than 10%. We stick to the definition by the GSO.

[13] Meanwhile, the Levinsohn and Petrin's (2003) method has been considered a standard procedure to calculate the TFP because it alleviates the bias caused by the correlation between unobservable productivity shocks and input levels. However, the lack of information on the intermediate input, which is essential for the calculation, prevents us from applying the approach.

[14] For detailed discussion, please refer to the original contents in Kumbhakar and Lovell (2003).

[15] When we calculate γ_{jkt}, sector j's output sold for final consumption was excluded.

[16] The table is formed based on the content description of the sector.

[17] In the sample, we have firms from 32 different Asian countries, excluding Vietnam. The countries with the largest numbers of investors are Taiwan, South Korea, Japan, Singapore, China, Hong Kong, and Malaysia (more than 1,000 firms throughout the period).

[18] Vietnam excluded certain products from its WTO distribution services commitments, including rice, sugar, tobacco, and crude and processed oil (UNCTAD, 2008). The distribution of alcohol, cement and concrete, fertilizers, iron and steel, paper, tires, and audiovisual equipment was opened to foreign investors by 2010.

[19] The timing of the FDI deregulation can be considered as random because the negotiation of the Vietnam's WTO accession went for many years (11 years) and uncertain prior to 2006. See Hanh (2011) for details.

[20] In place of $\text{Treatment}_j \times \text{Post06}_t$, we use $\text{mean\_capital\_labor\_ratio(35\%−80\% Asian)}_j \times \text{Treatment}_j \times \text{Post06}_t$. The new interaction term remains positively significant. We do not present these results in the paper, but they are available upon request.

[21] Because competition among local suppliers would not change our qualitative results, we assume that the number of local firms is 1. In Appendix B, we introduce foreign firms into the upstream sector and examine the intra-industry spillover effect from them.

[22] We can check that the incentive to invest increases with the input demand. In the first stage, the first-order condition is $\partial \pi^U / \partial x = \partial \left(wQ/\varphi - c^U Q/\varphi - x^2/2 \right) / \partial x = Q/\varphi - x$, which increases with.

[23] Using Equations 13 and 14, we have $\partial \left(1/c^U\right) / \partial N^* = 2x \left[2\varphi^2 \left(N^* + 1\right) - N^*\right] / [2\bar{c}\varphi \left(N^* + 1\right) - N^* a]^2$, which increases with.

[24] Using the optimal quantities in the second stage, we have $\max \left(w - c^U\right) q^U = \left(w - c^U\right) q^U |_{x=\bar{c}} = a\varphi \left[1 + (\varphi - 1) N^{U*}\right] / (N^{U*} + \varphi + 1)$. A sufficient condition for this to be positive is $\varphi > 1$.

[25] The condition is given by $N^* \left(N^{U*} - 2\right) - (N^{U*} + 2)^2 < 0$ and obtained as follows. First, we can see that $\partial^2 \pi^U / \partial x^2$ decreases with φ, implying that it takes the infimum at $\varphi = 1$. We then check under what condition the infimum takes a negative value, which is a sufficient condition for the SOC, that is, $\partial^2 \pi^U / \partial x^2 < 0$.

REFERENCES

Aitken, B. J., & Harrison, A. E. (1999). Do domestic firms benefit from direct foreign investment? Evidence from Venezuela. *American Economic Review*, *89*(3), 605–618.

Alfaro, L., & Rodriguez-Clare, A. (2004). Multinationals and linkages: An empirical investigation. *Economica*, *4*(2), 113–169.

Antras, P. (2003). Firms, contracts, and trade structure. *Quarterly Journal of Economics*, *118*(4), 1375–1418.

Anwar, S., & Nguyen, L. P. (2010a). Absorptive capacity, foreign direct investment-linked spillovers and economic growth in Vietnam. *Asian Business & Management*, *9*(4), 553–570.

Anwar, S., & Nguyen, L. P. (2010b). Foreign direct investment and economic growth in Vietnam. *Asia Pacific Business Review*, *16*(1–2), 183–202.

Anwar, S., & Nguyen, L. P. (2014). Is foreign direct investment productive? A case study of the regions of Vietnam. *Journal of Business Research*, *67*(7), 1376–1387.

Baldwin, R., & Okubo, T. (2014). Networked FDI: Sales and sourcing patterns of Japanese foreign affiliates. *The World Economy*, *37*(8), 1051–1080.

Baltabaev, B. (2014). Foreign direct investment and total factor productivity growth: New macro-evidence. *World Economy*, *37*(2), 311–334.

Blalock, G., & Gertler, P. J. (2008). Welfare gains from foreign direct investment through technology transfer to local suppliers. *Journal of International Economics*, *74*(2), 402–421.

Blalock, G., & Gertler, P. J. (2009). How firm capabilities affect who benefits from foreign technology. *Journal of Development Economics*, *90*(2), 192–199.

Borensztein, E., De Gregorio, J., & Lee, J.-W. (1998). How does foreign direct investment affect economic growth? *Journal of International Economics*, *45*(1), 115–135.

Cazzuffi, C., McKay, A. D., & Perge, E. (2018). *The impact of commercialization of rice on household welfare in rural Viet Nam* (WIDER Working Paper 2018/130).

Demena, B. A., & van Bergeijk, P. A. (2017). A meta-analysis of FDI and productivity spillovers in developing countries. *Journal of Economic Surveys*, *31*(2), 546–571.

Findlay, R. (1978). Relative backwardness, direct foreign investment, and the transfer of technology: A simple dynamic model. *Quarterly Journal of Economics*, *92*(1), 1–16.

Glass, A. J., & Saggi, K. (1998). International technology transfer and the technology gap. *Journal of Development Economics*, *55*(2), 369–398.

Gorg, H., & Greenaway, D. (2004). Much ado about nothing? Do domestic firms really benefit from foreign direct investment? *The World Bank Research Observer*, *19*(2), 171–197.

Ha, D. T. T., Kiyota, K., & Yamanouchi, K. (2016). Misallocation and productivity: The case of Vietnamese manufacturing. *Asian Development Review*, *33*(2), 94–118.

Hanh, P. T. H. (2011). Does WTO accession matter for the dynamics of foreign direct investment and trade? Vietnam's new evidence. *Economics of Transition*, *19*(2), 255–285.

Javorcik, B. S. (2004). Does foreign direct investment increase the productivity of domestic firms? In search of spillovers through backward linkages. *American Economic Review*, *94*(3), 605–627.

Javorcik, B. S., & Spatareanu, M. (2008). To share or not to share: Does local participation matter for spillovers from foreign direct investment? *Journal of Development Economics*, *85*(1), 194–217.

Javorcik, B. S., & Spatareanu, M. (2011). Does it matter where you come from? Vertical spillovers from foreign direct investment and the origin of investors. *Journal of Development Economics*, *96*(1), 126–138.

Kiyota, K., Matsuura, T., Urata, S., & Wei, Y. (2008). Reconsidering the backward vertical linkages of foreign affiliates: Evidence from Japanese multinationals. *World Development*, *36*(8), 1398–1414.

Kohler, W., & Smolka, M. (2015). *Global sourcing of heterogeneous firms: Theory and evidence* (CESifo Working Paper Series, 5184).

Kokko, A. (1994). Technology, market characteristics, and spillovers. *Journal of Development Economics*, *43*(2), 279–293.

Kumbhakar, S. C., & Lovell, C. K. (2003). *Stochastic frontier analysis*. Cambridge: Cambridge University Press.

Lai, M., Wang, H., & Zhu, S. (2009). Double-edged effects of the technology gap and technology spillovers: Evidence from the Chinese industrial sector. *China Economic Review*, *20*(3), 414–424.

Lall, S. (1996). *Learning from the Asian tigers: Studies in technology and industrial policy*. London: Macmillan.

Le, H. Q., & Pomfret, R. (2011). Technology spillovers from foreign direct investment in Vietnam: Horizontal or vertical spillovers? *Journal of the Asia Pacific Economy*, *16*(2), 183–201.

Levinsohn, J., & Petrin, A. (2003). Estimating production functions using inputs to control for unobservables. *Review of Economic Studies*, *70*(2), 317–341.

Li, X., & Liu, X. (2005). Foreign direct investment and economic growth: An increasingly endogenous relationship. *World Development*, *33*(3), 393–407.

Liu, Z. (2008). Foreign direct investment and technology spillovers: Theory and evidence. *Journal of Development Economics*, *85*(1), 176–193.

Lu, Y., Tao, Z., & Zhu, L. (2017). Identifying FDI spillovers. *Journal of International Economics*, *107*, 75–90.

Markusen, J. R., & Venables, A. J. (1999). Foreign direct investment as a catalyst for industrial development. *European Economic Review*, *43*(2), 335–356.

Newman, C., Rand, J., Talbot, T., & Tarp, F. (2015). Technology transfers, foreign investment and productivity spillovers. *European Economic Review*, *76*, 168–187.

Nguyen, L. P. (2008). *Productivity spillovers from foreign direct investment: Evidence from Vietnamese firm data*. Unpublished manuscript. School of Commerce, University of South Australia.

Nguyen, T. Q., Tran, L. T. K., Pham, P. L., & Nguyen, T. D. (2020). Impacts of foreign direct investment inflows on employment in Vietnam. *Institutions and Economies*, *12*(1), 37–62.

Ni, B. & Kato, H. (2017). *Productivity gaps and vertical technology spillovers from foreign direct investment: Evidence from Vietnam*, Keio-IES Discussion Paper Series 2017-022. Institute for Economics Studies, Keio University.

Ni, B., Spatareanu, M., Manole, V., Otsuki, T., & Yamada, H. (2017). The origin of FDI and domestic firms' productivity: Evidence from Vietnam. *Journal of Asian Economics*, *52*, 56–76.

Olley, G. S., & Pakes, A. (1996). The dynamics of productivity in the telecommunications equipment industry. *Econometrica*, *64*(6), 1263–1297.

Rodriguez-Clare, A. (1996). Multinationals, linkages, and economic development. *American Economic Review*, *86*(4), 852–873.

Shen, C.-H., Lee, C.-C., & Lee, C.-C. (2010). What makes international capital flows promote economic growth? An international cross-country analysis. *Scottish Journal of Political Economy*, *57*(5), 515–546.

Smeets, R. (2008). Collecting the pieces of the FDI knowledge spillovers puzzle. *The World Bank Research Observer*, *23*(2), 107–138.

Trinh, L. Q., & Ha, D. T. T. (2018). Internationalization and the growth of Vietnamese micro, small, and medium sized enterprises: Evidence from panel quantile regressions. *Journal of Asian Economics*, *55*, 71–83.

UNCTAD (2008). *Investment policy review: Viet Nam*. New York: UNCTAD.

Van Beveren, I. (2012). Total factor productivity estimation: A practical review. *Journal of Economic Surveys*, *26*(1), 98–128.

Van Biesebroeck, J. (2007). Robustness of productivity estimates. *Journal of Industrial Economics*, *55*(3), 529–569.

Wang, J.-Y., & Blomstrom, M. (1992). Foreign investment and technology transfer: A simple model. *European Economic Review*, *36*(1), 137–155.

Wooster, R. B., & Diebel, D. S. (2010). Productivity spillovers from foreign direct in-vestment in developing countries: A meta-regression analysis. *Review of Development Economics*, *14*(3), 640–655.

Xu, B. (2000). Multinational enterprises, technology diffusion, and host country productivity growth. *Journal of Development Economics*, *62*(2), 477–493.

Zhang, Y., Li, H., Li, Y., & Zhou, L.-A. (2010). FDI spillovers in an emerging market: The role of foreign firms' country origin diversity and domestic firms' absorptive capacity. *Strategic Management Journal*, *31*(9), 969–989.

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APPENDIX A

TABLE A1 Statistical summary

Main Variables	Obs	Mean	S.D.	Min	Max
Firm level					
Total number of labor	1,681,667	43.31377	389.4886	1	88275
Net turnover	1,272,073	22495.07	369967.2	1	1.85E+08
Fixed assets	1,681,667	7421.772	317678	0	2.16E+08
Foreign capital	1,780,508	1143772	6374559	0	1.61E+08
TFP_SF	1,272,073	0.577142	0.119471	0.043346	0.7869591
Total investment	5,025,76	4906.839	324552.3	0	224000000
Investment for capital	3,912,06	2214.798	361815.3	0	2.24E+08
Investment for machinery	4,371,19	548.7237	22750.51	0	5620648
Invest for fixed assets	3,606,11	93.01869	11582.92	0	6.70E+06
Industry level					
Horizontal spillover_total	1,272,073	0.142614	0.17438	0	0.9757611
Backward vertical spillover_Asia	1,272,092	0.168748	0.093517	0.005015	0.4736987
Backward vertical spillover_EU	1,272,092	0.042771	0.018266	0.001202	0.1525457
Backward vertical spillover_North America	1,272,092	0.007068	0.003548	0.000148	0.046097
Backward vertical spillover_Asia (TFP<35%)	1,272,092	0.008674	0.006718	0.000176	0.1645835
Backward vertical spillover_Asia (TFP∈[35%, 80%])	1,272,092	0.23291	0.093561	0.016153	0.7696869
Backward vertical spillover_Asia (TFP>80%)	1,272,092	0.451289	0.181828	0.015756	0.8360114
Herfindal Index	1,780,508	1.68E-05	0.002019	0	0.9940184
Number of foreign firms by industry	1,780,508	39265.88	37088.49	2	125166
SOE capital share by industry	1,270,713	0.132711	0.118129	0	0.8

Abbreviations: S.D., standard deviation; TFP, . total factor productivity.

TABLE A2 Categories of industries by FDI regulation as of 2005 Investment law in Vietnam

No.	Industry name	Category
1	Agriculture	The others
2	Mining	Encouraged
3	Food	The others
4	Beverages	The others
5	Tobacco	The others
6	Textiles	Encouraged
7	Apparel	Encouraged
8	Leather products	Encouraged
9	Wood products	Encouraged
10	Paper products	The others
11	Printing products	The others
12	Coke products	The others
13	Chemical products	Encouraged
14	Pharmaceuticals	The others
15	Rubber and plastic	Encouraged
16	Non-metallic products	The others
17	Metals	The others
18	Electronics	Encouraged
19	Electrical equipment	Encouraged
20	Machinery	Encouraged
21	Vehicles	Encouraged
22	Transportation equipment	Encouraged
23	Furniture	The others
24	Other manufacturing	The others
25	Repair and installation	The others
26	Electricity and water	Encouraged
27	Construction	Encouraged
28	Wholesale and retail	The others
29	Transportation	Encouraged
30	Accommodation and restaurants	The others
31	Information	The others
32	Finance	The others
33	Real estate	The others
34	Professional activity	The others
35	Support services	The others
36	Communist party	The others
37	Education	The others
38	Hospital and social work	The others
39	Arts and entertainment	The others

(Continues)

TABLE A2 (Continued)

No.	Industry name	Category
40	Lottery	The others
41	Other services	The others
42	Household services	The others

Source: Vietnamese Enterprise Survey, GSO, and Investment Promotion Center for Central Vietnam.

A ADDITIONAL TABLES

APPENDIX B

AN EXTENDED MODEL WITH HORIZONTAL SPILLOVERS

We here examine horizontal spillovers by modifying the model developed in the main text. We consider foreign firms in the upstream industry as well as in the downstream industry. There are $N^{U*}>1$ number of symmetric foreign upstream firms with zero marginal cost. Each of them, indexed by j, produces q_j^{U*} units of inputs, while the local supplier does q^U. The input market must clear, implying that $Q/\varphi = q^U + \sum_j q_j^{U*}$. In the following, we will show that the presence of foreign firms in the upstream industry has a negative effect on the productivity of the local firm in the same industry, that is, $\partial\left(1/c^U\right)/\partial N^{U*}<0$.

In the second stage, we solve for optimal levels of inputs that foreign and local suppliers produce. The profit of foreign supplier j is

$$\begin{aligned}\pi_j^{U*} &= wq_j^{U*}\\ &= \left[a-\frac{(N^*+1)Q}{N^*}\right]q_j^{U*}.\end{aligned}$$

The first-order condition gives its best response function:

$$\begin{aligned}&\frac{\partial \pi_j^{U*}}{\partial q_j^{U*}}=0,\\ &\rightarrow \varphi\left[a-(N^*+1)\left(q^U+\sum_j q_j^{U*}\right)\right]q_j^{U*}-\frac{\varphi^2(N^*+1)q_j^{U*}}{N^*}=0.\end{aligned}$$

Similarly, the best-response function of the local supplier is given by

$$\begin{aligned}&\frac{\partial \pi^U}{\partial q^U}=0,\\ &\rightarrow \varphi\left[a-(N^*+1)\left(q^U+\sum_j q_j^{U*}\right)\right]q^U-c^U-\frac{\varphi^2(N^*+1)q^U}{N^*}=0.\end{aligned}$$

We exploit the symmetry of foreign suppliers, that is, $q_j^{U*}=q_k^{U*}=q^{U*}$ for all $j\neq k$ and solve these equations to obtain

$$\begin{aligned}q^{U*} &= \frac{N^*\left(a\varphi^2-c^U\right)}{\varphi^2(N^*+1)\left(\varphi+N^{U*}+1\right)},q^U\\ &= \frac{N^*\left[a\varphi^2-\left(\varphi+N^{U*}\right)c^U\right]}{\varphi^2(N^*+1)\left(\varphi+N^{U*}+1\right)}.\end{aligned}$$

As can be seen, the larger number of foreign suppliers makes competition tougher, thereby reducing the quantity of the local supplier: $\partial q^U/\partial N^{U*}<0$. We assume $\varphi>1$ to ensure that the local supplier's gross profit is nonnegative at the maximum level of R&D.[24]

The optimal investment level x can be obtained by solving the local supplier's maximization problem in the first stage, as we did in the main text. The SOC is satisfied as long as the number of foreign downstream firms is not extremely large.[25] To show $\partial\left(1/c^U\right)/\partial N^{U*}<0$ (or equivalently $\partial x/\partial N^{U*}<0$), however, we need not solve for optimal x itself. Instead, we only should check whether the incentive of investment responds negatively to the intra-industry foreign presence:

$$\frac{\partial}{\partial N^{U*}}\left(\frac{\partial \pi^U}{\partial x}\right)=\frac{N^*\left(\Gamma x-\Theta\right)}{\varphi^2\left(N^*+1\right)\left(N^{U*}+\varphi+1\right)^3}$$
$$<-\frac{aN^*\left[\varphi^3+\left(N^{U*}-1\right)\varphi^2+\left(2N^{U*}+1\right)\varphi-N^{U*}-1\right]}{\varphi\left(N^*+1\right)\left(N^{U*}+\varphi+1\right)^3}<0,$$

where

$$\Gamma\equiv 2\left(\varphi^2+N^{U*}\varphi+N^{U*}+1\right)>0,$$
$$\Theta\equiv a\left(1-N^{U*}\right)\varphi^3+\left(2aN^{U*}+2\bar{c}+a\right)\varphi^2+\left[\left(a-2\bar{c}\right)N^{U*}+a\right]\varphi-2\bar{c}\left(N^{U*}+1\right).<0.$$

That is, the greater presence of foreign suppliers discourages the investment of the local supplier and thus decreases his or her productivity, which corresponds to negative horizontal spillovers.