Discussion Papers In Economics And Business

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Discussion Paper 20-05

February 2020

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

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February 18, 2020

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 affects 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: FDI spillovers; Heterogeneous productivity; Firm-level data; Endogenous structural break; Vertical Cournot model

JEL classification: D22; F21; F64; Q56

*This article is a substantially revised version of the paper previously circulated under the title "Productivity gaps and vertical technology spillovers from foreign direct investment: Evidence from Vietnam" (Ni and Kato, 2017). We are grateful to two anonymous referees, the editor Andy McKay, as well as Mi Dai, Hiro Ishise, Naoto Jinji, Fukunari Kimura, Eric Ramstetter and Shuichiro Urata for valuable suggestions. Our thanks also go to the seminar and conference participants at the East Asian Economic Association (Bandung) and the Asia Pacific Trade Seminars (Foreign Trade U) for their helpful comments. This research received financial support from JSPS KAKENHI (JP16H07279; JP19K13693) and MEXT-Supported Program for the Strategic Research Foundation at Private Universities (JPS1391003), which we gratefully acknowledge.

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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 thereby improve productivity. One notable example is a US sewing-machine company, Singer, which started operations in Taiwan in 1964, where there were small sewing-machine manufacturers with poor technology (Lall, 1996). To meet the local-content requirement forced by the government, the company sent several technical and management stuff 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 and Venables, 1999).

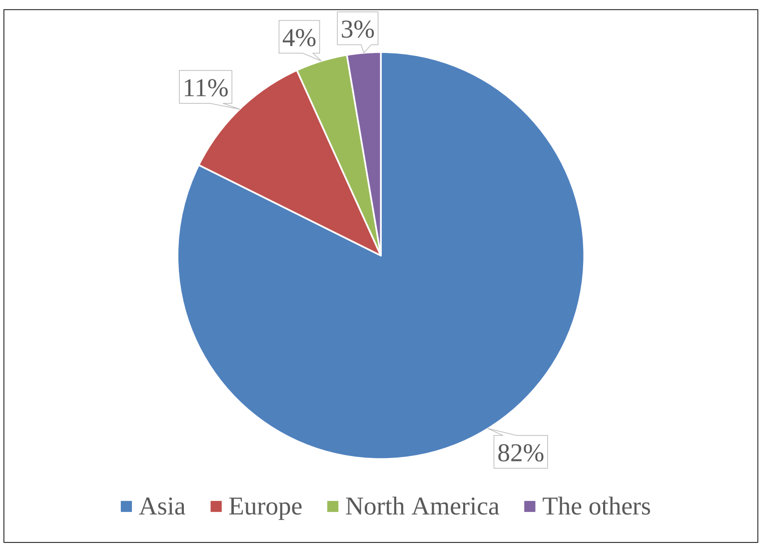
Previous studies on FDI spillovers have shown evidence of positive spillovers from backward industrial linkages (Javorcik, 2004; Blalock and Gertler, 2008; Liu, 2008; Wooster and Diebel, 2010 for meta-analysis).[1] Specifically, an increase in FDI in downstream industries improves the productivity of 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 one-standard-deviation increase in the foreign presence is associated with a 15-percent rise in 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 show that the degree of vertical spillovers depends on both characteristics of local firms and those of foreign investors (Blalock and Gertler, 2009; Javorcik and Spatareanu, 2008, 2011; Ni et al., 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 and Gertler, 2009 for Indonesia). Turning to foreign investors' aspects, the ownership structure in FDI projects (100% foreign ownership vs. joint

[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, while Aitken and Harrison (1999) found positive ones in Venezuela. See Görg and Greenaway (2004); Smeets (2008); and Demena and van Bergeijk (2017) for comprehensive surveys.

domestic and foreign ownership) does matter (Javorcik and Spatareanu, 2008 for Romania). Another important feature of foreign investors is their origin; those from particular source countries bring more positive vertical spillovers (Javorcik and 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. Specifically, we decompose downstream foreign investors into subgroups depending on their total factor productivity (TFP). We mainly focus on Asian investors, along with the two facts that (i) Asian investors have a larger presence in Vietnam than others (Figure 1) and that (ii) they tend to have a more significant effect (Ni et al., 2017).[2] The grouping is not arbitrary but is based on a statistical method using endogenous structural breaks (Lai et al., 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, i.e., the most significant positive spillovers coming from the intermediate group.



Source: General Statistics Office, Vietnam.

FIGURE 1 Share of FDI firms by country of origin (years 2002-2011)

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 A2 for

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

an extended model for horizontal spillovers). Before producing an intermediate good, the local supplier invests in reducing 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 her marginal cost thus changes in response to changes in the number of foreign firms through her investment, which we regard 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 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 (Kokko, 1994 for Mexico; Blalock and Gertler, 2009 for Indonesia; Zhang et al., 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 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 Rodríguez-Clare (1996): hosting downstream FDI would increase the productivity of local suppliers if the number of locally produced input variety is close to the one produced in the origin country. His emphasis is on the foreign investors' input substitution between local and imported inputs, which is distinct from ours on their productivity-enhancing investment.[4] We think that 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 data on input sourcing patterns.

Finally, it is worth noting our methodological contribution to identifying spillover effects. Inspired by the identification strategy of Lu et al. (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

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

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

Vietnam's WTO accession. We did 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 one of its kind.

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 thanks 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 et al. (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 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

[5] Although we focus on the manufacturing sector, these two events also had significant impacts on the agricultural sector. See Cazzuffi et al. (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 1st, 2013: `http://www.wsj.com/public/page/archive-2013-5-01.html`, accessed on 25 October 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 FDI and looked at their impact on the growth rate of local manufacturing sectors.

[8] Nguyen (2008); Anwar and Nguyen (2014); Le and Pomfret (2011); and we use the Vietnam Enterprise

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 the above-mentioned studies highlight the characteristics of local firms such as their location (Nguyen, 2008; and Anwar and Nguyen, 2014), they did not look at 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. The final section concludes the paper.

Survey data, which will be explained in the next section. However, our data span a longer period and cover more recent years, i.e., from 2002 to 2011. The data source is used in other recent studies on Vietnam, e.g., Ha et al. (2016) on resource misallocation; Trinh and Ha (2018) on small and medium-sized firms; Nguyen et al. (2020) for employment.

[9]Van Biesebroeck (2007) took five TFP estimation methods including OLS, the stochastic frontier approach and the semiparametric approach (Olley and Pakes, 1996; Levinsohn and Petrin, 2003), and checked their robustness to measurement error and to differences in production technology using simulated data. He concluded that "(G)iven 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.

2 Data and estimation strategy

2.1 Data

This paper applies a firm-level panel dataset 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 (i) to collect the business information needed to compile national accounts, (ii) to gather up-to-date information on business registrations, and (iii) to develop a statistical database of enterprises. The majority of the firms in the dataset 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, materials 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 GDP.[11]

This panel dataset 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 dataset is that for foreign-owned firms, 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 dataset (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 one 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

[10] We use the first 2-digits indicated in the VSIC coding system. There are two types of codes, namely VSIC code 2007 and VSIC code 1993, where VSIC code 2007 is applied since the year 2007. We also construct a concordance table to unify these two systems. For simplicity we aggregate some sectors. See Appendix Table A2 for detailed categorization of industries.

[11] Even though Producer Price Index in the sector level is a preferred deflator, such data are not available for Vietnam.

[12] Though 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 GSO.

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:

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

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 genuine productivity from statistical noise.

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

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

where x_{ni} is a vector of inputs. v_i is the noise component and u_i is the nonnegative technical inefficiency component. Here, 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 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 (i) $v_i \sim i.i.d.\ N(0, \sigma_v^2)$, (ii) $u_i \sim i.i.d.\ N^+(0, \sigma_v^2)$, and (iii) v_i and u_i are distributed independently of each other, and of the regressors.

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

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:

$$TE_i = \exp(-\widehat{u}_i), \tag{3}$$

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

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:

$$\begin{aligned} \ln TFP_{ijt} = Horizontal\_Origin_{jt-1} + \beta Vertical\_Origin_{jt-1} + Herfindal_{jt-1} \\ +\alpha_i + \eta_t + u_{ijt}, \end{aligned} \tag{4}$$

where the coefficients of explanatory variables except for $Vertical\_Asia$ are omitted for brevity. In (4), the dependent variable $\ln TFP_{ijt}$ 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 $Horizontal\_Origin_{jt}$ 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 $Horizontal\_NorthAmerica$. If we want to explore the horizontal spillover impact by all the foreign firms, then $Horizontal\_Origin$ will be replaced with $Horizontal\_total$.

In the meantime, $Vertical\_Origin_{jt}$ measures the foreign presence in downstream industries. Following the literature, vertical spillovers in this study refer only to backward

[14] $E(u_i \mid \varepsilon_i) = \mu_i^* + \sigma^* \frac{\phi(-\mu_i^*/\sigma^*)}{1-\Phi(-\mu_i^*/\sigma^*)} = \sigma^*[\frac{\phi(\varepsilon_i\lambda/\sigma)}{1-\Phi(\varepsilon_i\lambda/\sigma)} - \frac{\varepsilon_i\lambda}{\sigma}]$, σ and λ are σ_u and λ_v ; ϕ and Φ are density and cumulative density functions respectively.

spillovers to upstream suppliers. In addition, we include in the regression the Herfindahl index of industry concentration. 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 $Vertical\_Origin_{jt}$ is defined as:

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

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 have to match the industries in our dataset with those used in the IO Table (see Ni et al., 2017 for the detailed matching procedure). We end up with 42 two-digit industries, which are listed in the Appendix Table A2. Furthermore, the VSIC code system changed from VSIC code1993 to VSIC code 2007 in the year 2007, and therefore, the industry codes prior to 2007 are converted in accordance with VSIC code 2007 by using a 1993-2007 concordance table.[16]

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	×
total Asia	0.594	○
ASEAN	0.637	×
Japan & Korea	0.592	×
other Asia	0.586	○

Source: Ni et al. (2017)

$Vertical\_Origin_{jt}$, 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

[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.

spillovers, we include $Vertical\_Asia$, $Vertical\_Europe$ and $Vertical\_NorthAmerica$ 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 dataset 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:

$$\ln TFP_{ijt} = Horizontal\_total_{jt-1} + \sum_{\varphi=\varphi_0}^{P} \beta^{\varphi} Vertical\_Asia^{\varphi}_{jt-1} + Vertical\_Europe_{jt-1} \\ + Vertical\_NorthAmerica_{jt-1} + Herfindal_{jt-1} + \alpha_i + \eta_t + u_{ijt}, \quad (6)$$

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 the next section, we will elaborate on the procedure of how to determine φ and P.

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.

[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).

Then the next question is: how can we determine the number of thresholds, or P as noted previously? Rather than choosing the thresholds arbitrary, 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:

$$\ln TFP_{ijt} = \delta_0 + \delta_1 Vertical\_Asia_{jt-1} + u_{ijt}. \tag{7}$$

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:

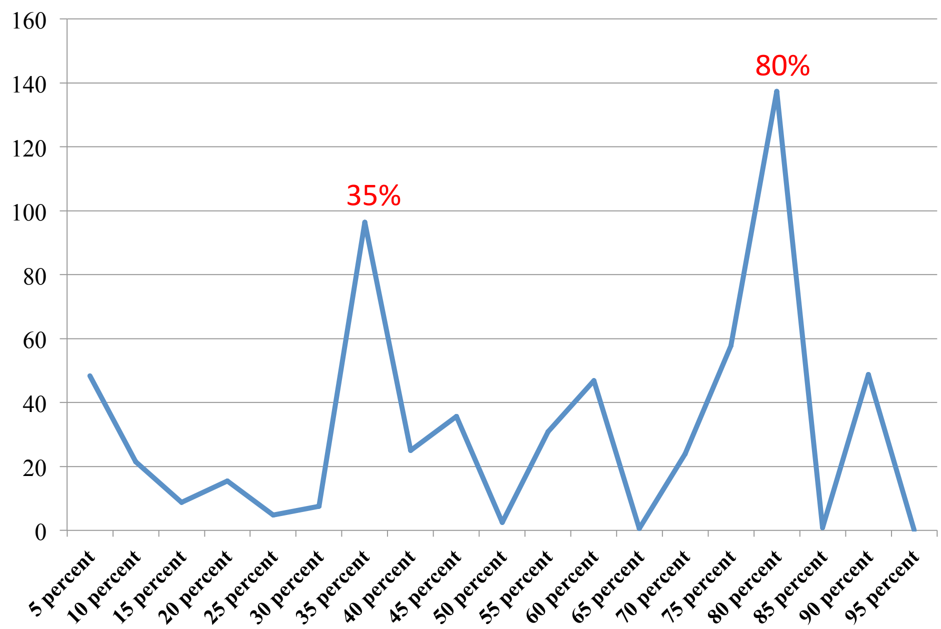
$$\ln TFP_{ijt} = \delta_0 + \delta_1 Vertical\_Asia_{jt-1} + \delta^{\varphi} Vertical\_Asia^{\varphi}_{jt-1} + u_{ijt}, \tag{8}$$

$Vertical\_Asia^{\varphi}$ 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, (a) we use the lowest 5% of the samples to calculate $Vertical\_Asia^{\varphi_{5\%}}$; (b) we estimate (7) and (8), retrieve the sum of squared residuals from each result to test the null hypothesis $H_0 : \delta^{\varphi} = 0$; (c) during this process, we calculate the F-statistics as follows:

$$F = \frac{SSR_1 - SSR_2}{SSR_1} \cdot \frac{N-k}{q}. \tag{9}$$

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

We then repeat the process of (a)-(c) introduced above, except that we replace $Vertical\_Asia^{\varphi_{5\%}}$ with $Vertical\_Asia^{\varphi_{10\%}}$, i.e., 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.



Source: Author's own calculation based on Vietnamese Enterprise Survey data.

FIGURE 2 F-statistics by TFP level (the lowest % of all Asian samples)

As we can see, at the 80% threshold there is a huge spike, which indicates that the inclusion of $Vertical\_Asia^{\varphi_{80\%}}$ brings about the most structural variation compared with the original specification (see (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 at the 80% threshold. This guides us to use the 35% cutoff further to divide the "<80%" group of Asian investors into "<35%" and "35%<80%" subgroups. We will show the results for both practices in the following section.

3 Estimation results

3.1 Results using the 80% TFP cutoff

Table 2 shows the baseline estimation results using (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 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.

TABLE 2 Baseline grouping (80% TFP cutoff)

	(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 FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry control	No	No	Yes	Yes

Note: Robust standard errors in parentheses, clustered at industry level.
*** p<0.01, ** p<0.05, * p<0.1
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.

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 FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry control	No	No	Yes	Yes

Note: Standard errors in parentheses, clustered at industry level.
*** p<0.01, ** p<0.05, * p<0.1
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.

3.3 Endogeneity

Identification strategy.

A crucial assumption for obtaining an unbiased estimate as in (6) is that the regressor of interest, namely, the vertical spillover variables, are 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 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. Though 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, for example, includes high-technology, agriculture, labor-intensive industries (employing 5000 or more employees), and infrastructure development (for the detailed categorization, please refer to Appendix Table A2). 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 above; while the control group contains the sectors that were already encouraged prior to WTO entry. We then apply firm-level data covering 2002 to 2011 to compare the spillover effect between the treatment group and control group, before and after Vietnam's entry into the WTO.

[18]Vietnam excluded certain products from its WTO distribution services commitments, including rice, sugar, tobacco, and crude and processed oil (UNCTAD (2008)). Distribution of alcohol, cement and concrete, fertilizers, iron and steel, paper, tires, and audiovisual equipment had 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 was a lengthy way (11 years) and uncertain prior to 2006. See Hanh (2011) for details.

Estimation specification.

We adopt an augmented version of (6):

$$\ln TFP_{ijt} = Treatment_j \times Post06_t + Horizontal\_total_{jt-1} + Vertical\_Origin_{jt-1} + Herfindal_{jt-1} + \alpha_i + \eta_t + u_{ijt}, \quad (10)$$

where the coefficients of explanatory variables are omitted for brevity. Our main interest lies in the coefficient of the interaction term in (10). $Treatment_j$ indicates whether industry j belongs to the treatment group, as we defined before. $Post06_t$ is a dummy variable indicating the post-WTO period, that is, $Post06_t = 1$ 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 $Treatment_j \times Post06_t$ 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. Antràs (2003) argued that the costs of physical capital are easier to share than the costs 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 and 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 $Treatment_j \times Post06_t$, and use it as a robustness for our DID verification.[20]

Estimation results.

As the results in Table 4 show, the $Horizontal\_total$ is always negative, which is consistent with the previous findings that foreign investors have an even more substantial replacement

[20] In place of $Treatment_j \times Post06_t$, we use $mean\_capital\_labor\_ratio(35\% - 80\% Asian)_j \times Treatment_j \times Post06_t$. The new interaction term remains positively significant. We do not present these results in the paper, but they are available upon request.

impact on domestic firms in the same industry after Vietnam's entry to the WTO. In the case of vertical spillovers, when we divide Asian firms into low- and high-TFP groups, our regressor of interest, $Treatment_j \times Post06_t$, 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, the results shown in Table 5 show a similar trend as in the previous ones. $Horizontal\_total$ still has negative signs, as expected. On the other hand, regardless of whether we include $Vertical\_Asia(35\% - 80\%)$ or not, the variable of interest, $Treatment_j \times Post06_t$, is positive and significant in all specifications. Combining the results from Table 4, we can infer that among the low-TFP group of investors, it is Asian firms in the middle-TFP range (35%-80%) that 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 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 FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry control	No	Yes	No	Yes

Note: Robust standard errors in parentheses, clustered at industry level.
*** p<0.01, ** p<0.05, * p<0.1
Industry control includes the number of foreign firms in an industry (in log form) and industry-level capital ratio of State-owned firms.

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 FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry control	No	Yes	No	Yes

Note: Standard errors in parentheses, clustered at industry level.
*** p<0.01, ** p<0.05, * p<0.1
Industry control includes the number of foreign firms in an industry (in log form) and industry-level capital ratio of State-owned firms.

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 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 and Spatareanu, 2008). We thus generate the new vertical spillover indexes based on foreign investors' ownership (full or partial ownership) and re-estimate (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 a 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 A2 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 whom 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. 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

[21] Because competition among local suppliers would not change our qualitative results, we assume that the number of local firms is one. In Appendix A2, we introduce foreign firms into the upstream sector and examine the intra-industry spillover effect from them.

empirical specification.

The timing of actions proceeds as follows. First, the local supplier decides on how much they invest in marginal-cost reduction. Second, she sells 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, i.e., $d(1/c^U)/dN^*$, 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

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

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. Her gross profit is

$$w(Q/\varphi) - c^U(Q/\varphi)$$
$$= [a - (N^* + 1)Q/N^* - c^U/\varphi]Q,$$

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

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

It is worth noting here that the above 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 who demand inputs most. This nonmonotonic relationship translates into interesting interactions between the foreign productivity and the supplier's investment and productivity, as we will see below.

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 an decreasing function of x:

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

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

The supplier chooses x to maximize the profit net 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

$$\begin{aligned} x &= \frac{N^*(a\varphi - \overline{c})}{2\varphi^2(N^* + 1) - N^*}, \\ c^U &= \frac{\varphi[2\overline{c}\varphi(N^* + 1) - N^* a]}{2\varphi^2(N^* + 1) - N^*}. \end{aligned} \tag{13}$$

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

4.4 Inverted-U-shaped relationship

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

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

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

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

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

noting $\varphi^* > 0$ because of assumption (b). 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 $\partial(1/c^U)/\partial N^*$ 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 stronger the local supplier's incentive 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

[22]We can check that the incentive to invest increases with the input demand. In the first stage, the FOC is

$$\begin{aligned}\frac{\partial \pi^U}{\partial x} &= \frac{\partial}{\partial x}[w(Q/\varphi) - c^U(Q/\varphi) - x^2/2] \\ &= Q/\varphi - x,\end{aligned}$$

which increases with Q/φ.

$\partial(1/c^U)/\partial N^*$ (quadrant II).[23] In sum, the degree of vertical spillovers is linked with the foreign productivity through investment decisions in response to input demand.

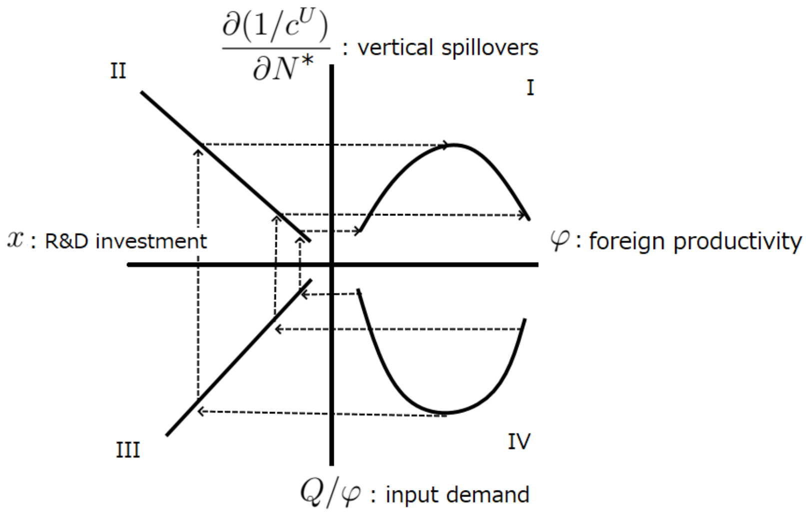


FIGURE 3 Foreign productivity and vertical spillovers

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 quadrant I in Figure 4 shows. The local suppliers invest most at the intermediate value of φ, which gives the highest input demand.

[23]Using (13) and (14), we have

$$\frac{\partial(1/c^U)}{\partial N^*} = \frac{2[2\varphi^2(N^*+1) - N^*]}{[2\bar{c}\varphi(N^*+1) - N^* a]^2} \cdot x,$$

which increases with x.

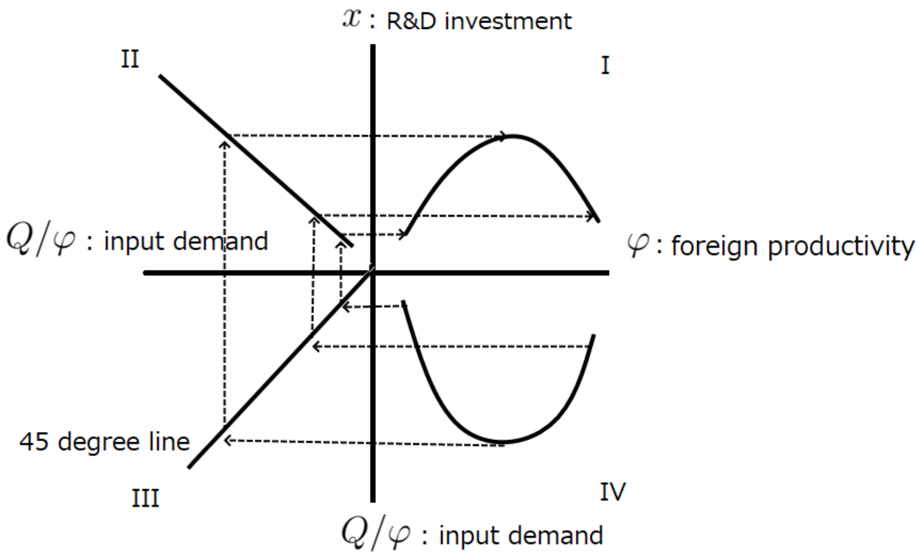


FIGURE 4 Foreign productivity and R&D investment

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, local suppliers engage in R&D investment and thus improve their productivity most effectively.

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

$$\ln R\&D_{ijt} = Horizontal\_total_{jt-1} + \sum_{\varphi \in \{low,\ middle,\ high\}} \beta^{\varphi} Vertical\_Asia^{\varphi}_{jt-1} + Vertical\_Europe_{jt-1} + Vertical\_NorthAmerica_{jt-1} + Herfindal_{jt-1} + \alpha_i + \eta_t + u_{ijt},$$

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 or its investment in repairing fixed assets alternatively as a proxy for their effort on R&D—and regress it on the same set of spillover variables. As we can see from the results 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 investors 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 productivity. In contrast, the groups of Asian investors with low- and high-TFP levels are not inducing as much vertical spillover as the group with a middle-TFP level does.

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 FE	Yes	Yes
Firm FE	Yes	Yes
Industry control	No	No

Note: Robust standard errors in parentheses, clustered at industry level.
*** p<0.01, ** p<0.05, * p<0.1
Industry control includes the number of foreign firms in an industry (in log form) and industry-level capital ratio of State-owned firms.

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 previous 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 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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Appendix

A1. Additional tables

TABLE A1 Statistical summary

Main Variables	Obs	Mean	S.D.	Min	Max
Firm level					
Total number of labor	1681667	43.31377	389.4886	1	88275
Net turnover	1272073	22495.07	369967.2	1	1.85E+08
Fixed assets	1681667	7421.772	317678	0	2.16E+08
Foreign capital	1780508	1143772	6374559	0	1.61E+08
TFP_SF	1272073	0.577142	0.119471	0.043346	0.7869591
Total investment	502576	4906.839	324552.3	0	224000000
Investment for capital	391206	2214.798	361815.3	0	2.24E+08
Investment for machinery	437119	548.7237	22750.51	0	5620648
Invest for fixed assets	360611	93.01869	11582.92	0	6.70E+06
Industry level					
Horizontal spillover_total	1272073	0.142614	0.17438	0	0.9757611
Backward vertical spillover_Asia	1272092	0.168748	0.093517	0.005015	0.4736987
Backward vertical spillover_EU	1272092	0.042771	0.018266	0.001202	0.1525457
Backward vertical spillover_North America	1272092	0.007068	0.003548	0.000148	0.046097
Backward vertical spillover_Asia (TFP<35%)	1272092	0.008674	0.006718	0.000176	0.1645835
Backward vertical spillover_Asia (TFP∈[35%, 80%])	1272092	0.23291	0.093561	0.016153	0.7696869
Backward vertical spillover_Asia (TFP>80%)	1272092	0.451289	0.181828	0.015756	0.8360114
Herfindal Index	1780508	1.68E-05	0.002019	0	0.9940184
Number of foreign firms by industry	1780508	39265.88	37088.49	2	125166
SOE capital share by industry	1270713	0.132711	0.118129	0	0.8

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
40	Lottery	The others
41	Other services	The others
42	Household services	The others

Source: Vietnamese Enterprise Survey, GSO & Investment promotion center for central Vietnam

A2. 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, i.e., $\partial(1/c^U)/\partial N^{U*} < 0$.

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

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

The FOC gives his best-response function:

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

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

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

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

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

As can be seen, the larger number of foreign suppliers makes competition tougher, thereby reducing the quantity of the local supplier: $\partial q^U/\partial N^{U*}$. We assume $\varphi > 1$ to ensure that the local supplier's gross profit is non-negative 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 $\partial(1/c^U)/\partial N^{U*} < 0$ (or equivalently $\partial x/\partial N^{U*} < 0$), however, we do not have to solve for optimal x itself. Instead, wee only have to check whether the incentive of investment responds negatively to the intra-industry foreign presence:

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

where

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

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

[24]Using the optimal quantities in the second stage, we have

$$\max\ (w - c^U)q^U = (w - c^U)q^U|_{x=\bar{c}} = \frac{a\varphi[1 + (\varphi - 1)N^{U*}]}{N^{U*} + \varphi + 1}.$$

A sufficient condition for this to be positive is $\varphi > 1$.

[25]The condition is given by $N^*(N^{U*} - 2) - (N^{U*} + 2)^2 < 0$ 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 i.e., $\partial^2\pi^U/\partial x^2 < 0$.