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**Article**

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# FDI spillover effect on the green productivity of Vietnam manufacturing firms: the role of absorptive capacity

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**ABSTRACT**

This study examines the contribution of absorptive capacity to the relationship between FDI spillover effects and firm-level green total factor productivity (GTFP) using the Malmquist-Luenberger productivity index approach combined with a threshold regression model. Using firm-level data from annual enterprise surveys in Vietnam's manufacturing and processing industries from 2013 to 2019, the study found that absorptive capacity had an important mediating role in amplifying the beneficial effects of FDI spillover. The magnitude of horizontal FDI spillover varies with absorptive capacity in medium high technology (MHT) sectors, while negative effects are observed in medium low technology (MLT) and low technology (LT) sectors. Firms with HT, MLT, and LT sectors have positive backward effects on productivity if their absorptive capacity exceeds a particular threshold. Furthermore, our findings point to specific factors that may be crucial in improving absorptive capacity, such as internal research and development, process improvement, and export.

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**KEYWORDS**
FDI; absorptive capacity; green total factor productivity; threshold regression

## 1. Introduction

In recent years, many developing countries have relied heavily on foreign direct investment (FDI) (Zhang et al., 2023). One driving force behind FDI-friendly regimes is the expectation that FDI inflows will indirectly boost domestic firm productivity by transferring foreign technologies and manufacturing techniques, as well as administrative practices, expertise, and methods to host country enterprises. As a result, many countries are employing promotional strategies to draw in FDI (Ali et al., 2016). However, a significant and often-discussed concern regarding FDI is its potential negative impact on the environment (Chau, 2022; Sugiharti et al., 2022). The economic benefits linked to increased FDI may be negated by potential environmental costs, given that FDI can coincide with higher environmental emissions.

Regarding environmental issues, rapid economic growth has led to various environmental and resource concerns, prompting governments worldwide to prioritize the

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development of a green economy. Green total factor productivity (GTFP) is widely accepted as a significant and comprehensive measure to reflect sustainable development, emphasizing a win–win situation between economic growth and environmental protection (Luo et al., 2022; Teng et al., 2021). As a result, strengthening GTFP plays an important role in establishing the green economy (Zhao et al., 2015).

With the growing awareness about environmental concerns, several research have evaluated the influence of FDI on GTFP, but no conclusive result has been found. On the one hand, the "Pollution Paradise" argument proposes that governments in developing nations prioritize economic development and remove environmental restrictions, luring foreign direct investment in pollution-intensive businesses, which raises the pressure on national environmental pollution. GTFP expansion has been limited by decreased efficiency and rising pollution (Lin & Chen, 2018). The "pollution halo" argument, on the other hand, proposes that foreign investment has provided enterprises with access to more environmentally friendly technologies. It has also fostered GTFP improvement through the reverse feeding of green technologies and domestic diffusion, absorption, and innovation processes (Xu & Deng, 2012).

Despite the growing FDI spillovers literature, this field of study has some research gaps. *First*, previous research addressed productivity using broad TFP without considering the restrictions of natural resources and the environment (Cheng et al., 2023). Since preserving resources and lowering emissions are the two primary principles of sustainable development, ignoring them may result in an exaggeration of TFP. To this goal, a growing number of scholars are including energy consumption and environmental impacts into the TFP framework by constantly refining their assessment methodologies (Emrouznejad & Yang, 2018). *Second*, prior research has rarely investigated the influence of various types of FDI spillovers on GTFP. Foreign investors have a motive to prevent knowledge leakages that would improve the performance of their local rivals, but they may also desire to pass on knowledge to their local suppliers, so the impacts of productivity spillovers are more pronounced vertically. Ignoring the routes via which spillover effects occur may lead to an overestimation of the impact of FDI on domestic enterprises (Sugiharti et al., 2022). *Third*, whether local firms benefit from the entry of foreign firms depends on their own "absorptive capacity" (Chen et al., 2015; Girma, 2005; Girma et al., 2008; Kokko, 1992). Additionally, the absorptive capacity of domestic firms determines the direction and intensity of vertical and horizontal spillovers (Orlic et al., 2018). Absorptive capacity is even increasingly essential in emerging economies when there is a significant disparity between foreign and domestic enterprises. Although some studies have examined the thresholds of absorptive capacity on the link between FDI spillover and domestic firm productivity (Girma, 2005; Moralles & Moreno, 2020; Vu, 2018), their major concern is still traditional TFP. Finally, a few research considered corporate heterogeneity in technology intensity. Jin et al. (2020) noted that high-technology-intensive firms might benefit from FDI spillovers, whereas lower-tech firms may be negatively affected. Therefore, it is important to consider heterogeneity technological intensity when assessing the impact of FDI spillovers on firms' productivity.

Thus, the main purpose of this paper is to answer the following: (1) Is there an absorptive capacity threshold in the link between various types of FDI spillovers and GTFP? (2) Is there heterogeneity in technological intensity in the influence of FDI spillovers on GTFP? (3) What elements can improve firms' absorptive

capacity? To address this research gap, this paper sets up a Malmquist-Luenberger (ML) index to assess GTFP using panel data from Vietnam Enterprise Surveys and Technology in Production Survey, both conducted by the Vietnam's General Statistics Organization from 2013 to 2019. Several econometric models are then developed to examine the impact of FDI spillovers on GTFP and the importance of absorptive capacity in the relationship between FDI spillover channels (horizontal, backward, and forward linkages) and GTFP change in four technological groups (high (HT), medium (MHT), medium low (MLT), and low (LT)). Furthermore, the study investigates several critical factors that may play an important role in the promotion of absorptive capacity, such as research and development, process improvement, machine, and export. This study also includes robustness checks.

This study focuses on Vietnam for several important reasons. *First*, Vietnam is an emerging economy that has caught the attention of the world for its rapid economic growth performance in the last four decades. In addition, the country ranks among the top 20 host economies for FDI inflows worldwide. *Second*, along with its benefits, FDI has placed negative aspects affecting the economic, political, social, and environmental areas in Vietnam (Chau, 2022). Many environmental pollution accidents and disasters have occurred because of large FDI projects and facilities, including Vedan Vietnam Enterprises Co., Ltd (Taiwan) in 2008, Miwon Vietnam Co., Ltd from 2008 to 2014, and Formosa Ha Tinh Steel Corporation (Taiwan) (Nguyen, 2018). *Third*, the intensive economic development, industrialization and urbanization have substantially augmented the energy consumption and environmental pressures. According to Statista Research Department, the volume of $CO_2$ emissions of Vietnam has increased by nine times in the last four decades (from 14 million tons in 1980 to around 106 million tons in 2021). Consequently, Vietnam's government has issued many relevant environmental policies and regulations in recent years to enhance environmental protection. However, that can affect both FDI flows and firm's productivity because of the rising costs of environmental protection. Therefore, the factors that influence GTFP in the relationship with FDI spillover effects need to be studied further to assist in the formulation of stronger policies for the country's long-term growth.

This study's major contributions can be described as three aspects. *First*, this analysis presents new evidence that supports the presence of absorptive capacity thresholds in different types of FDI spillovers. *Second*, this analysis combines FDI spillovers, absorptive ability, and technology groupings into a single framework for investigation. Specifically, this study captures both specific channels and technical groups in influencing productivity to provide evidence about whether the FDI-specific channels perform differently on technological groups. Such research might investigate the extent to which a group of technologies can influence FDI spillover performance, and which channels contribute the most to company productivity. *Third*, this study addresses productivity by using GTFP, covering both desired and undesired outputs. *Finally*, this research explores several factors that play a significant role in the promotion of absorptive capacity.

The rest of this paper is structured as follows: Section 2 examines the existing literature. Section 3 describes the methodology. Section 4 discusses data and estimated results. Finally, section 5 contains the conclusion.

## 2. Review of literature and development of hypothesis

Kokko (1992) proposes four ways in which foreign enterprises' sophisticated technology spreads to the host country: the demonstration-imitation effect, the competition effect, the foreign linkage effect, and the training effect. However, not all spillovers are advantageous as FDI can result in adverse effects when foreign firms possessing advanced technologies drive domestic firms to leave. These adverse impacts are also known as the competition effect, the crowding-out impact, and the business-stealing effect. The significant empirical literature on FDI spillovers that has emerged over the last 40 years has yielded mixed results. Three major associations have been identified: promoting, inhibitory, and neutral. The discussion on FDI spillovers is mostly concerned with estimates of the extent of intra-industry spillovers in terms of domestic productivity. There is no agreement on the corresponding levels of FDI spillovers (Blomström et al., 2001).

Existing studies have employed traditional total factor productivity (TFP) for their analyses without considering the constraints of environment, potentially leading to considerable differences in their results (Cheng et al., 2023). Since preserving resources and lowering emissions are the two primary principles of sustainable development, ignoring them may result in an exaggeration of TFP. To this goal, a growing number of scholars are including energy consumption and environmental impacts into the TFP framework by constantly refining their assessment methodologies (Emrouznejad & Yang, 2018).

Recently, some research based on the principles of the "Pollution Paradise" and "Pollution Halo" theories, originally proposed by Walter and Ugelow (1979), has evaluated the influence of FDI on firm productivity using the GTFP indicator. However, no conclusive result has been found. Governmentshand, the "Pollution Paradise" argument proposes that governments in developing nations prioritize economic development and remove environmental restrictions, luring foreign direct investment in pollution-intensive businesses, which raises the pressure on national environmental pollution. GTFP expansion has been limited by decreased efficiency and rising pollution (Lin & Chen, 2018). Several empirical studies have supported the hypothesis. For example, using panel data from China's service industry from 2002 to 2014, S. Wang and Wang (2017) discovered that the spillover effects of FDI will diminish the GTFP of service industries. The "Pollution Halo" argument, on the other hand, proposes that foreign investment has provided enterprises with access to internationally sophisticated more environmentally friendly technologies. It has also fostered GTFP improvement through the reverse feeding of green technologies and domestic diffusion, absorption, and innovation processes (Xu & Deng, 2012). Among the research that find a favorable influence of FDI on GTFP, Tong et al. (2022) found that FDI considerably contributes to green manufacturing in China from 2010 to 2021, using the Generalized Method of Moments technique. The disparities in prior studies' conclusions could be attributed to variances in

economic models, research populations, and variable selection. Moreover, earlier studies failed to identify the specific channels through which FDI spillovers influence GTFP. Neglecting to understand the mechanisms through which spillover effects occur could lead to oversimplifying the impact of FDI on domestic firms (Sugiharti et al., 2022).

In accordance with extant literature, FDI spillover is classified into two categories: horizontal and vertical. The first kind happens when local firms operating in the same sector as foreign firms improve their productivity through competition, workforce turnover, and imitation channels. The latter can occur through the customer-supplier interaction among local suppliers and overseas clients, or vice versa. The rationale behind this distinction implies that foreign investors have a motivation to avoid knowledge leaks that could improve the results of their neighboring rivals but may also desire to pass on knowledge to their local suppliers, implying that spillovers may not occur horizontally, but only through FDI-induced vertical integration (Görg & Greenaway, 2001, 2004). So far, few scholars have investigated the influence of different types of FDI spillovers on GTFP.

"Absorptive capacity" was coined to define "the ability to identify the value of external knowledge before assimilating and applying it to commercial ends" (Cohen & Levinthal, 1990, 1994). Previous research has found that firm variation in the field of absorptive capacity could account for a large percentage of the varying effect of FDI on company outcomes. However, no clear result is reached on the significance of absorptive capacity in the productivity growth of enterprises. While Behera (2017) discovered that local firms with higher absorptive capacity (particularly those in high-technology industries) are better able to take advantage of spilled technology from foreign firms, Sokhanvar (2023) discovered that high-growth firms with higher absorptive capacity do not outperform other firms in terms of capacity to absorb FDI spillover. The conflicting results of the preceding empirical studies may indicate that the impact of absorptive ability is nonlinear.

While there is a large body of literature on the impact of absorptive ability on the link between FDI spillovers and domestic company productivity, few studies have looked at absorptive capacity thresholds (except for Duong, 2020; Girma, 2005; Moralles & Moreno, 2020; Sokhanvar, 2023). However, these studies combined enterprises into just one data set to identify organizations based on fewer inconsistent characteristics, this combination is probable to introduce a certain bias. Furthermore, prior research has failed to account for vertical spillover through backward and forward links in homogeneous groupings of enterprises. Importantly, their major concern is still traditional TFP which does not consider the unwanted output in their measurement. A notable exception is a study by You and Xiao (2022), which examines the role of absorptive capacity in the relationship between FDI and GTFP and discovered that the spillover effect of FDI can only have a positive impact on regional GTFP when the levels of innovation, R&D investment, and human capital exceed the threshold values. However, their concentration is on regional productivity rather than business productivity.

Given the discussion above, three hypotheses are proposed:

**H1.** There is a threshold of absorptive capacity in the link between horizontal FDI spillovers and GTFP.

**H2.** There is a threshold of absorptive capacity in the link between backward FDI spillovers and GTFP.

**H3.** There is a threshold of absorptive capacity in the link between forward FDI spillovers and GTFP.

## 3. Methodology

### 3.1. Malmquist – Luenberger productivity index through Data Envelopment Analysis to predict GTFP change

Total factor productivity (TFP) is a residual of a production function that encompasses everything that cannot be measured by physical components (Solow, 1957). To assess the efficiency of green economic development more accurately, Ramanathan (2005) and S. Chen (2009) demonstrated that when assessing the TFP, it is necessary to consider not only the inputs with regards to traditional variables, but also the outputs with regards of energy consumption and environmental damage. The GTFP linear approach incorporates environmental and resource factors into total factor productivity, with economic development representing expected output, pollutant emissions indicating unwanted results, and labor, capital, and fuel representing input. Chung et al. (1997) modified the Malmquist productivity index to assess environmentally sensitive productivity growth by integrating unwanted outputs into the model to address the issue. The updated index was dubbed the Malmquist-Luenberger productivity index (ML index).

Since Chung et al. (1997), the ML technique has increased in popularity and has been used in various studies at both the macro and micro levels in manufacturing sectors (Färe et al., 2001), the public domain (Yu et al., 2008), and nations (Kumar, 2006; Yoruk et al., 2005). Following to H. Wang et al. (2020), this study applies the Malmquist-Luenberger productivity index method (based on Data Envelopment Analysis (DEA)) with selected inputs (capital, labor, and energy consumption TOE) and outputs (Gross Industry Output (GO) and $CO_2$ emissions) to estimate GTFP change of Vietnamese manufacturing and processing firms.

### 3.2. A threshold regression model is used to investigate the role of domestic enterprises' absorptive ability

The threshold regression model proposed by Girma (2005), Huang et al. (2012) and Ubeda and Pérez-Hernández (2017) is used in this study to analyze the effect of domestic enterprises' absorptive capacity (AC) on FDI-related productivity spillovers:

$$\begin{aligned} \Delta GTFP_{ijt} = {} & \alpha + \alpha_i + \beta_1 spillover_{jt} + \beta_2 Z_{ijt} + \rho_1 spillover_{jt} I\left(AC_{ijt} < \gamma_1\right) \\ & + \rho_2 spillover_t I\left(AC_{ijt} \geq \gamma_1\right) + \beta_3 control_{ijt} + \varepsilon_{ijt} \end{aligned} \quad (1)$$

where the variables listed below are defined: $\Delta GTFP_{ijt}$ is change in green total factor productivity (TFP) of firm $i$ in sector $j$ in year $t$; $spillover_{jt}$ denotes horizontal, backward, or forward FDI spillover channels, in sector $j$ in year $t$; $Z_{ijt}$ is a set of company characteristics that influence productivity, such as firm size, firm age, capital intensity; $AC_{ijt}$ is firm $i$'s absorptive capacity in sector $j$ in year $t$; $I(,)$ is an indicator function; $\alpha$ denotes traits that are steady across time (fixed effect); $\gamma_i$ signifies the yet-to-be-determined thresholds; and $\varepsilon$ signifies the random disturbance.

In this study, based on an approach proposed by Hansen (2000) and further evolved by Q. Wang (2015), a fixed-effect panel thresholds model is estimated by matching it to the threshold estimator, which requires balanced panel data. Furthermore, robust estimations for heteroscedasticity and serial correlation are used in the calculations.

The threshold needs to be estimated in conjunction with the slope parameters, $S_n[\beta(\alpha), \gamma(\alpha)]$ indicates the sum of residual squares (SSR) of equation (1). This function can be reduced by ordinary least squares (OLS) with all potential values of $\alpha$ of to select the one with the lowest SSR, as shown in (2).

$$\hat{\alpha} = arg_{\alpha} min S(\alpha) \tag{2}$$

Girma (2005) suggests using threshold variable quantiles of 1%, 1.25%, 1.5%,. . ., 98.75%, and 99% to calculate the threshold values, yielding 393 quantiles. Following the parameter computation, it is critical to evaluate the threshold impact, or whether there are two regimes for the regime-dependent variable based on the threshold variable. This can be done by putting the null hypothesis to the test ($H_0$: $\alpha_1 = \alpha_2$) and employing likelihood ratio test statistics and their bootstrapped p-value for each estimation on 200 replications.

### 3.3. Empirical model adding interaction terms of absorptive capability

Evoluting from the studies of Blalock and Gertler (2009) and Urata and Baek (2022), as shown in equation (3), the study attempts to explore what factors related to firms' absorptive capacity facilitate these effects by adding an interaction term of absorptive capacity with these factors in the model.

$$\Delta GTFP_{ijt} = \alpha + \beta_1 spillover_{jt} + \beta_2 Z_{ijt} + \beta_3 AC_{jt} + \beta_4 AC_{jt} * factor_{ijt} + \beta_5 control_{ijt} + \delta_s + \delta_t + \varepsilon_{it} \tag{3}$$

where $AC_{jt}$*$factor_{ijt}$ is an interaction variables between absorptive capacity and factors impacting on firms' absorptive capacity. $factor_{ijt}$ is defined as follows:

- *Machine* is a dummy variable with the value 1 if the equipment is difficult to use, causing a delay or obstacle in the firm's business operations, and 0 otherwise
- *InternalR&D* is a dummy variable with the value 1 if the corporation performs R&D on its own, and 0 otherwise
- *ExternalR&D* is a dummy variable with the value 1 if the corporation outsources R&D activities, and 0 otherwise
- *Collaborate* is a dummy variable with the value 1 if the company implements the R&D partnership, and 0 otherwise.

- *Patent* is a dummy variable with the value 1 if the company possesses a patent, and 0 otherwise
- *Export1* is a dummy variable with a value of 1 if the company exports goods to developed countries, and 0 otherwise
- *Export2* is a dummy variable with the value 1 if the company exports goods to developing countries, and 0 otherwise
- *Process* is a dummy variable with the value 1 if the firm adopts an improvement approach in production processes, and 0 otherwise
- *Quality* is a dummy variable with a value of 1 if the organization follows an improvement in product quality plan, and 0 otherwise

*The independent variable:* $\Delta GTFP_{ijt}$ is change in green total factor productivity of firm $i$ in sector $j$ in year $t$;

*Spillover variables*: The study employs Javorcik's (2004) technique to determine three FDI spillover effects, namely: Foreign share, Horizontal, Backward, and Forward.

*First, Foreign share* is defined as the share of firm $i$'s total equity owned by foreign investors, is its real output, for $i$ th firms in sector $j$ at time $t$.

*Second*, the level of foreign presence in sector $j$ at time $t$ is measured by *Horizontal*, which is defined as the foreign firm's sales share of total sales in sector $j$. Horizontal FDI is used to study the effects of intra-industry spillovers.

$$Horizontal_{jt} = \frac{\sum_{i\,for\,i\in j} Foreign\,share_{it} * A_{ijt}}{\sum_{i\,for\,i\in j} A_{ijt}} \tag{4}$$

where $A_{ijt}$ can be the income of firm $i$ in industry $j$ at time $t$.

*Third*, *Backward* is defined at time $t$ as the weighted share of foreign firms' participation in downstream sectors of sector $j$. The effect of backward FDI spillover occurs when domestic enterprises offer intermediate items to foreign firms.

$$Backward_{jt} = \sum_{k\,if\,k\neq j} \alpha_{jk} Horizontal_{kt} \tag{5}$$

where $\alpha_{jk}$ is the share of output from industry $j$ consumed by industry $k$. This criterion is derived using Vietnam's Input-Output table in 2012 and assumes no change from 2013 to 2019.

*Fourth*, *Forward* is defined at time $t$ as the weighted share of foreign firms' participation in the upstream sectors of sector $j$. The effect of forward FDI spillover is considered when domestic enterprises purchase intermediate items from foreign firms.

$$Forward_{jt} = \sum_{m\,if\,m\neq j} \beta_{jm} Horizontal_{mt} \tag{6}$$

where $\beta_{jm}$ is the proportion of industry $m$ output utilized by industry $j$ to produce final outputs. Furthermore, because forward and backward FDI are both vertical FDI, intermediate commodities purchased within the same sector are ineligible for both.

### 3.3.1. Absorptive capacity

The research adopts the Girma (2005), Moralles and Moreno (2020) technique, which uses the technological frontier distance (technology gap) as a proxy to quantify the firm's absorptive capacity (AC). However, persistent efficiency (PE) is employed rather than TFP because the former can be a superior proxy if other noises are removed (Duong, 2020).

$$AC_{it} = \frac{PE_{it}}{\max(PE_{it})} \tag{7}$$

where *PE* is firm i's persistent efficiency in year t, estimated based on the study of Kumbhakar et al. (2014) and Colombi et al. (2014); *max (PE)* is the maximum value of a firm's consistent efficiency in the same industry in year t. The higher the value of AC, the greater the firm's absorptive ability.

### 3.3.2. Control variables

*Capital intensity*: is measured by capital stock per employee of the $i^{th}$ firm in the year *t*. An increase in capital intensity is assumed to increase the firm's productivity since more capital per employee is available.

*Human capital*: is approximated by dividing the individual's hourly wage by the highest hourly wage in the same industry.

*Firm size*: is a proxied log transformation of the company's total staff count at time t

*Capital share*: is proxied by firm's external loan share.

*Industry concentration*: It is also beneficial to gain control over the market concentration environment to which a particular firm is exposed.

$$Industry\ concentration = \sum_{i=1}^{N} (S_i)^2 \tag{8}$$

where $S_i$ is the share of the market and N is the number of businesses in a specific industry

*Foreign share*: shows the share of capital of FDI enterprises in the total capital of enterprises in the manufacturing industry.

Finally, the province variable *Institution* is obtained using the Vietnam PCI index. This index allows us to compare the institutional environment in the provinces of Vietnam.

## 4. Data and estimated results

### 4.1. Data

The data utilized in the study came from two surveys done by the General Statistics Office (GSO): the Annual Enterprise Survey and the Technology in Production Survey, both of which were conducted between 2013 and 2019. The database includes 2,770 enterprises and a total of 19,390 observations. Input and output values are calculated in VND millions and corrected for inflation.

In Vietnam, there has been almost no environmental research regarding $CO_2$ emissions. This problem was addressed using energy consumption data collected from the

Vietnamese Annual Enterprise Surveys. Tons of Oil Equivalent (TOE) were calculated from the energy data as the basis for measuring the $CO_2$ emissions of firms.

$CO_2$ emission (*Emis*) is considered as undesirable output. In fact, there is less detailed data of $CO_2$ emission for each firm in Vietnam. Therefore, the calculation of $CO_2$ emissions from firm energy consumption is based on the IPCC reference approach (IPCC, 2006, 2019) and J. Chen et al. (2015). Firm $CO_2$ emission from energy consumption (coal, oil, natural gas, gasoline) is constructed as follows:

$$CO_{2t} = Emis_t = \sum_{i=1}^{4} Emis_{i,t} = \sum_{i=1}^{4} Eng_{i,t} * NCV_i * CEF_i * COF_i * \left(\frac{44}{12}\right) \quad (9)$$

where, $CO_{2t} = Emis_t$ = carbon dioxide flow measured in tons; $NCV_i$ (TJ/Gg) = calorific net value given by the IPCC (2006, 2019) National Greenhouse Gas Inventories; $CEF_i$ (ton/GJ) = carbon oxidization factor provided by IPCC (2006); $COF_i$ is factor of carbon oxidation set to be 1 in the investigation. (44/12) is the $CO_2$ to carbon molecular weight ratio. As a result of equation (9), the calculated $CO_2$ emission for coal is 2.077 (ton $CO_2$/ton coal), for oil 2.514 (tonne $CO_2$/tonne oil), for natural gas 2.704 (tonne $CO_2$/1000 $m^3$ natural gas) and for gasoline 3.145 (ton $CO_2$/1000 liter).

The database is organized by technology intensity and divided into four categories (see Table A1 in Appendix A).

A variable description is summarized in Table 1.

GTFP, capital intensity, human capital, total labor, capital share, industry concentration, institution, and absorptive capacity are among the characteristics of our sample presented in Panel A of Table 1. Panel B of Table 1 provides descriptive statistics for all spillover variables used in this study. oreign firm shares vary per subsector from 0.005% in the HT sector to 0.018% in the LT sector. The horizontal, backward, and forward spillover ratios in the LT sectors are the highest, at 0.5%, 0.895%, and 0.363%,

**Table 1.** Descriptive statistics.

Panel A.

| Variable | Unit | Avg. | Std.dv. | Min. | Max. |
|---|---|---|---|---|---|
| GTFP | % | 1.003 | .051 | .614 | 1.74 |
| Capital intensity | Million VND | 18786.111 | 94708.209 | 4.132 | 6927913.5 |
| Human capital | Million VND | 15.128 | 17.969 | .013 | 1450.483 |
| Total labor | Person | 343.081 | 854.976 | 1 | 19177 |
| Capital share | % | .638 | .734 | 0 | 37.485 |
| Industry concentration | Index | .048 | .057 | .008 | 1 |
| Institution | Index | 59.396 | 3.91 | 45.117 | 70.69 |
| Absorptive capacity | % | 67.212 | 18.668 | 7.536 | 100 |

Panel B.

| | HT | | MHT | | MLT | | LT | |
|---|---|---|---|---|---|---|---|---|
| Variable | Avg. | Std.dv. | Avg. | Std.dv. | Avg. | Std.dv. | Avg. | Std.dv. |
| Foreign Share | 0.005 | 0.068 | 0.013 | 0.21 | 0.012 | 0.113 | 0.018 | 0.191 |
| Horizontal | 0.045 | 0.115 | 0.156 | 0.988 | 0.117 | 0.479 | 0.5 | 2.761 |
| Backward | 0.004 | 0.007 | 0.508 | 0.924 | 0.215 | 0.389 | 0.895 | 1.324 |
| Forward | 0.002 | 0.004 | 0.026 | 0.049 | 0.075 | 0.101 | 0.363 | 0.662 |

Source: Authors' estimates from annual surveys of GSO.

respectively. The Pearson correlation between absorptive capacity and FDI spillover from Table A2 (see Appendix A) shows that a significant relationship exists between two variables. The variable correlations from Table A3 (see Appendix A) shows there is no relationship between two independent variables.

### 4.2. Threshold regression results

Before implementing FEM and threshold regression, the study conducted regressions to identify endogenous variables using the 2SLS method, sequentially testing each suspected independent variable in the model with their respective instrumental variables. And then, the study employed the Durbin-Wu-Hausman test to assess endogeneity. If the model exhibited endogeneity, the GMM method by Arellano and Bond (1991) was used to address the issue. The results of the Durbin-Wu-Hausman test accepted the null hypothesis that there are no endogenous variables in the model (Table 2).

Then, equation (1) was estimated by fixed-effect method. The estimation results from Table A4 (see Appendix A) shows that almost all number of controls were statistically significant, validating the subset of controls. A 1% increase in *human capital*, for example, may result in a 0.107% rise in the GTFP generated by HT firms. In a similar manner the absorptive capacity's value is positive and statistically significant, demonstrating that absorptive capacity influences firm GTFP. Moralles and Moreno (2020) Brazilian FDI investigation yielded comparable results. Meanwhile, the adverse effect of capital intensity is accepted where a one percent (%) rise in capital intensity leads to a 0.206% decrease in MHT enterprises' GTFP.

The coefficients of horizontal and forward are negative and statistically significant for almost all groups (except MHT sectors). This finding, which is consistent with those of Orlic et al. (2018). This implies that foreign corporations are far more competitive than domestic firms.

Backward FDI spillover is significantly positive in MHT and MLT enterprises, but notably negative in HT and LT sectors, according to the estimation findings shown in Table A4. This could imply that numerous foreign firms are involved in final product assembly, and that domestic enterprises supplying parts and components to foreign firms acquire technology through commercial interactions.

To ascertain the impact of absorptive ability on the relationship between FDI spillover and firm GTFP, the study applied threshold regression model. Tables 3, 5, and 7 present three alternative specifications for the threshold model with AC as regime variable. To test the impact of horizontal FDI on GTFP change for high and low AC values, Table 3 adopts the horizontal spillover (*Horizontal*) as the threshold variable, as proposed by

**Table 2.** Endogeneity test results for some suspected independent variables.

| | Test results for some suspected independent variables | | | | | | |
|---|---|---|---|---|---|---|---|
| Test | Capital intensity | Human capital | Foreign share | Horizontal | Forward | Backward | AC |
| Durbin | 1.9937 | 1.3092 | 0.3574 | 0.0811 | 0.0945 | 0.6430 | 0.1609 |
| p-Value (Durbin) | 0.158 | 0.2525 | 0.5500 | 0.7757 | 0.7585 | 0.4226 | 0.6882 |
| Wu-Hausman | 1.9924 | 1.3083 | 0.3571 | 0.0811 | 0.0944 | 0.6426 | 0.1687 |
| p-Value (Wu) | 0.1581 | 0.2527 | 0.5501 | 0.7758 | 0.7586 | 0.4228 | 0.6884 |

Source: Authors estimate from Annual Surveys of GSO.

**Table 3.** Threshold model estimates with horizontal spillover as the threshold variable.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| GTFP | HT | MHT | MLT | LT |
| Capital intensity | −0.1518*** | −0.159*** | −0.159*** | −0.158*** |
| | (0.002) | (0.00202) | (0.00200) | (0.00199) |
| Human capital | 0.1157*** | 0.126*** | 0.124*** | 0.112*** |
| | (0.0058) | (0.00584) | (0.00586) | (0.00585) |
| Firm size | 0.0213*** | 0.0230*** | 0.0186*** | 0.0211*** |
| | (0.0059) | (0.00592) | (0.00598) | (0.00590) |
| Capital share | 0.0123** | 0.0139** | 0.0135** | 0.0127** |
| | (0.0054) | (0.00551) | (0.00553) | (0.00549) |
| Industry concentration | 0.0467*** | 0.0330*** | 0.0362*** | 0.0211*** |
| | (0.0063) | (0.00661) | (0.00633) | (0.00634) |
| Foreign share | −0.0842 | −0.177*** | −0.130*** | −0.316*** |
| | (0.0644) | (0.0273) | (0.0328) | (0.0495) |
| Backward | −12.1489*** | 0.133*** | 0.0254* | −0.0206*** |
| | (1.0457) | (0.0104) | (0.0154) | (0.00377) |
| Forward | −36.112*** | 0.797*** | −0.143*** | −0.129*** |
| | (1.4719) | (0.0651) | (0.0325) | (0.00737) |
| Institution | 1.9764*** | 2.054*** | 2.181*** | 1.962*** |
| | (0.0446) | (0.0477) | (0.0472) | (0.0471) |
| Horizontal (AC<$\gamma_1$) | −0.9725 | 0.00511 | −0.690*** | −0.0193*** |
| | (0.2462) | (0.00750) | (0.0988) | (0.00228) |
| Horizontal (AC ≥ $\gamma_1$) | −0.4714 | 0.0387*** | −0.140*** | −0.00381* |
| | (0.0589) | (0.00672) | (0.0136) | (0.00229) |
| Constant | −6.3452*** | −6.924*** | −7.296*** | −6.375*** |
| | (0.1857) | (0.201) | (0.195) | (0.197) |
| Observations | 19,390 | 19,390 | 19,390 | 19,390 |
| R-squared | 0.3886 | 0.375 | 0.369 | 0.379 |
| Number of firms | 2,770 | 2,770 | 2,770 | 2,770 |

Note: ***, **, * signify significance levels of 1, 5, and 10%, respectively. The standard errors are shown in parenthesis.
Source: The author estimates from annual surveys of GSO.

equation (1). Backward and forward spillovers (*Backward and Forward*) are used as threshold variables in Tables 5 and 7, respectively, to verify the effect of vertical FDI effects on GTFP change, following the logic of equation (1). The threshold effect tests (see Appendix A Table A5) confirm that there are some thresholds in each FDI spillover.

Regarding horizontal FDI spillover, in Table 3, the threshold effect tests confirm that there is a threshold in this spillover. On the one hand, *horizontal* impact varies based on the value of absorptive capacity in MHT sectors. Domestic firms with AC values greater than the threshold 1 can gain positive productivity spillovers as a result of the presence of foreign enterprises in the same industry. If a firm's absorptive capacity is less than one, there is no horizontal spillover. On the other hand, negative horizontal FDI spillovers are found in HT, MLT and LT sectors, regardless of threshold values. Therefore, hypothesis H1 is supported.

Specifically, in MHT industry, the threshold separates AC's value into a pair of quantiles. The first are the smallest AC values (AC < $\gamma_1$; $\gamma_1 = 90.9121$). The second quantile covers enterprises with the highest absorptive capacity score (AC ≥ $\gamma_1$). The horizontal impact does not appear to affect enterprises in the first quantile, but it can be beneficial for firms in the second quantile. Then, the study provides a general view on characteristics of firms in the MHT industry by dividing the mean value of AC by the threshold. The AC is determined using equation (7), and its mean by threshold is shown in Table 4. On the one hand, the most significant impediment to enterprises' absorptive

**Table 4.** Characteristics of firms in MHT industry benefited from FDI horizontal spillover.

| | Mean of threshold value | | |
|---|---|---|---|
| | $< \gamma_1$ | $\geq \gamma_1$ | Scale |
| Mean AC | 64.82 | 94.87 | [0–100] |
| InternalR&D | 0.04 | 0.08 | [0–1], Dummy variable, takes 1 if a firm takes a specific activity, |
| ExternalR&D | 0.03 | 0.07 | |
| Collaborate | 1.00 | 1.00 | |
| Process | 0.67 | 0.73 | |
| Quality | 0.73 | 0.80 | |
| Patent | 0.01 | 0.00 | |
| Export1 | 0.08 | 0.23 | |
| Export2 | 0.33 | 0.49 | |
| Machinery obstacle | 5.61 | 5.43 | [0–10] where 0 is the least important, and 10 is the most importance |
| Finance obstacle | 5.72 | 4.47 | |
| Experience obstacle | 6.05 | 5.61 | |
| Labor obstacle | 5.18 | 4.72 | |
| Horizontal spillover benefit | Unclear | Positive | |

Note: $\gamma_1 = 90.9121$
Source: The author estimates from annual surveys of GSO.

capacity and ability to gain from horizontal FDI spillover is financial hardship. Firms that do not benefit from FDI spillover face more financial difficulties than beneficiaries (5.72/10 in the former and (4.47/10) in the latter); this hinders the ability to apply technology in production. Next is the difficulty in employee number (5.18 versus 4.72); that hinders the capacity of awareness and understanding, so it is difficult to catch up and learn from FDI spillover channels. On the other hand, firms that implement R&D activities (internal (0.08) and/or outsourced (0.07)), and export (to developed (0.23) and/or developing countries (0.49) are more inclined than others to gain from FDI horizontal spillovers.

In comparison to larger or international organizations, LT firms are thought to have limited absorptive capacity because of poor worker skills and less advanced administrative approaches (Sugiharti et al., 2022). Due to a significant knowledge gap, they may be unable to copy superior information and increase production. Similarly, because many developing nations are only interested in copying, the MLT industry is linked with exploitative rather than open innovation (Sugiharti et al., 2022). Meanwhile, as the knowledge gap between high-tech sectors and multinational corporations narrows, domestic enterprises can absorb and imitate MNC practices. Therefore, domestic firms with high absorptive capacity values in MHT sectors can benefit from horizontal FDI spillovers.

Our findings on horizontal FDI spillover (Horizontal) for LT firms are consistent with the results reported by Suyanto et al. (2021), who found that sectors such as food and drinks and textiles (low-tech) suffer from decreased productivity due to increased foreign presence.

Turning to backward FDI spillovers, in Table 4, the threshold effect tests confirm that there are two thresholds in this case. Our results indicate that for the MHT sector, the backward effect is positive and improves the domestic firms' GTFP, regardless of threshold values. In other words, the growing presence of foreign firms in MHT industries has a beneficial impact on enterprises' GTFP levels. Firms in the HT, MLT, and LT sectors, on the other hand, have negative vertical effects on productivity if their absorptive

**Table 5.** Threshold model estimates with backward spillover as the threshold variable.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| GTFP | HT | MHT | MTL | LT |
| Capital intensity | −0.157*** | −0.165*** | −0.162*** | −0.164*** |
| | (0.00205) | (0.00203) | (0.00202) | (0.00202) |
| Human capital | 0.116*** | 0.124*** | 0.122*** | 0.111*** |
| | (0.00577) | (0.00578) | (0.00585) | (0.00583) |
| Firm size | 0.0173*** | 0.0235*** | 0.0126** | 0.0226*** |
| | (0.00586) | (0.00587) | (0.00598) | (0.00587) |
| Capital share | 0.0131** | 0.0147*** | 0.0148*** | 0.0140** |
| | (0.00544) | (0.00546) | (0.00552) | (0.00547) |
| Industry concentration | 0.0460*** | 0.0324*** | 0.0343*** | 0.0175*** |
| | (0.00630) | (0.00655) | (0.00632) | (0.00631) |
| Foreign share | −0.0144 | −0.0840*** | −0.126*** | −0.329*** |
| | (0.0631) | (0.0219) | (0.0327) | (0.0493) |
| Horizontal | −0.375*** | 0.0241*** | −0.0578*** | −0.00866*** |
| | (0.0567) | (0.00587) | (0.0107) | (0.00185) |
| Forward | −35.76*** | 0.811*** | −0.144*** | −0.130*** |
| | (1.469) | (0.0644) | (0.0324) | (0.00733) |
| Institution | 1.996*** | 2.097*** | 2.204*** | 2.005*** |
| | (0.0446) | (0.0473) | (0.0472) | (0.0470) |
| Backward ($AC<\gamma_1$) | −15.82*** | 0.0344*** | −0.243*** | −0.101*** |
| | (1.156) | (0.0118) | (0.0302) | (0.0101) |
| Backward ($\gamma_1 \leq AC < \gamma_2$) | −10.03*** | 0.123*** | −0.113*** | −0.0489*** |
| | (1.278) | (0.0143) | (0.0238) | (0.00452) |
| Backward ($AC \geq \gamma_2$) | −2.313 | 0.193*** | 0.0722*** | 0.000379 |
| | (1.704) | (0.0124) | (0.0177) | (0.00513) |
| Constant | −6.376*** | −7.043*** | −7.335*** | −6.519*** |
| | (0.185) | (0.200) | (0.195) | (0.197) |
| Observations | 19,390 | 19,390 | 19,390 | 19,390 |
| R-squared | 0.391 | 0.387 | 0.372 | 0.384 |
| Number of firms | 2,770 | 2,770 | 2,770 | 2,770 |

Note: ***, **, * signify significance levels of 1, 5, and 10%, respectively. The standard errors are shown in parenthesis.
Source: The author estimates from annual surveys of GSO.

capacities are less than 2. However, if the absorptive capacity is over $\gamma_2$ (in MLT and LT), the positive backward effect is detected. Therefore, hypothesis H2 is supported.

Table 6 shows characteristics of firms in MLT and LT industries benefited from FDI backward spillover.

As shown in Table 6, firms in MLT and LT industries that implement technology transfer within group (0.1 and 0.08 respectively) and export (to developed (0.28 and 0.39 respectively) and/or developing countries (0.43 and 0.41 respectively) are more likely to benefit from FDI backward spillovers than others. Again, financial obstacles are the most important factor that hinders firms from benefiting FDI backward spillovers.

Referring to forward FDI spillovers, in Table 5, the threshold effect tests confirm that there are two thresholds in MLT and LT cases while only one threshold exists in HT and MHT sectors. Our findings show that, similar to the backward impact, the forward impact is favorable for the MHT sector and helps improve domestic company output regardless of threshold values. By contrast, firms in the HT and LT sectors experience negative forward effects on productivity. However, if the absorptive capacity is over $\gamma_2$ (in MLT), the positive forward effect is detected. The estimation results indicate that MNCs hinder productivity growth in the HT and LT industries. Therefore, hypothesis H3 is supported.

**Table 6.** Characteristics of firms in MLT and LT industries benefited from FDI backward spillover.

| | Mean of threshold value in MLT firms | | | Mean of threshold value in LT firms | | | |
|---|---|---|---|---|---|---|---|
| | $< \gamma_1$ | $[\gamma_1 - \gamma_2]$ | $> \gamma_2$ | $< \gamma_3$ | $[\gamma_3 - \gamma_4]$ | $> \gamma_4$ | Scale |
| Mean AC | 49.69 | 75.90 | 91.56 | 27.05401 | 56.50536 | 83.75783 | [0–100] |
| InternalR&D | 0.02 | 0.03 | 0.05 | 0.01 | 0.01 | 0.02 | Dummy variable, takes 1 if a firm takes a specific activity, |
| ExternalR&D | 0.02 | 0.02 | 0.03 | 0.01 | 0.01 | 0.02 | |
| Collaborate | 0.99 | 0.98 | 1 | 0.99 | 0.99 | 1 | |
| Process | 0.67 | 0.67 | 0.67 | 0.57 | 0.67 | 0.70 | |
| Quality | 0.78 | 0.75 | 0.79 | 0.79 | 0.77 | 0.71 | |
| Patent | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | |
| Export1 | 0.05 | 0.20 | 0.28 | 0.05 | 0.15 | 0.39 | |
| Export2 | 0.13 | 0.33 | 0.43 | 0.07 | 0.26 | 0.41 | |
| Skill_transfer | 0.29 | 0.17 | 0.17 | 0.33 | 0.19 | 0.17 | |
| Intra_tranfer | 0.04 | 0.07 | 0.10 | 0.04 | 0.05 | 0.08 | |
| Machinery obstacle | 6.49 | 6.15 | 6.31 | 6.25 | 6.27 | 6.01 | [0–10] where 0 is the least important, and 10 is the most importance |
| Finance obstacle | 6.48 | 5.60 | 5.39 | 6.53 | 6.35 | 5.28 | |
| Experience obstacle | 6.25 | 5.97 | 5.90 | 5.99 | 6.09 | 6.00 | |
| Labor obstacle | 5.38 | 5.24 | 5.4 | 5.49 | 5.67 | 5.66 | |
| Backward spillover benefit | Negative | Negative | Positive | Negative | Negative | Positive | |

Note: $\gamma_1 = 65.9494$; $\gamma_2 = 86.6571$; $\gamma_3 = 34.9751$; $\gamma_4 = 71.8511$.
Source: The author estimates from annual surveys of GSO.

As shown in Table 8, firms in MLT industry that implement technology transfer within group (0.08) and export (to developed (0.22) and/or developing countries (0.46) are more inclined than others to gain from FDI forward spillovers. Again, financial obstacles are the most important factor that hinders firms from benefiting FDI forward spillovers.

### 4.3. The results of models adding interactive variables

Table 9 shows the estimation results of the influence interactive terms with absorptive capacity on GTFP change. Except for external R&D and patent, almost all other interaction terms' coefficients are statistically significant. The estimated coefficients of internal R&D, process, and export are positive and statistically significant, indicating the importance of developing internal R&D, process enhancement programs and export for the promotion and acceleration of absorptive capacity and thereby improve GTFP. The finding on internal R&D highlights the importance of developing new technology through research and development, which in turn increases the firm's internal knowledge. The process finding emphasizes the need of participating in process enhancement to lower costs because the process demonstrates a firm's capabilities in the use of technology. At the same time, the positive and significant export coefficient underscores the importance of exporting as a means of acquiring technology.

In contrast, the estimated parameters of the cooperate R&D, quality and machine are negative and statistically significance indicating that R&D cooperation, quality enhancement programs and machinery difficulties are obstacles for absorptive capacity. These

**Table 7.** Threshold model estimates with forward spillover as the threshold variable.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| GTFP | HT | MHT | MTL | LT |
| Capital intensity | −0.154*** | −0.160*** | −0.165*** | −0.165*** |
| | (0.00200) | (0.00203) | (0.00206) | (0.00197) |
| Human capital | 0.117*** | 0.125*** | 0.123*** | 0.109*** |
| | (0.00577) | (0.00584) | (0.00585) | (0.00576) |
| Firm size | 0.0196*** | 0.0200*** | 0.0170*** | 0.0246*** |
| | (0.00587) | (0.00594) | (0.00597) | (0.00581) |
| Capital share | 0.0128** | 0.0139** | 0.0151*** | 0.0129** |
| | (0.00544) | (0.00551) | (0.00552) | (0.00541) |
| Industry concentration | 0.0451*** | 0.0337*** | 0.0369*** | 0.0211*** |
| | (0.00631) | (0.00662) | (0.00631) | (0.00624) |
| Foreign share | −0.0202 | −0.0983*** | −0.130*** | −0.332*** |
| | (0.0631) | (0.0222) | (0.0327) | (0.0487) |
| Horizontal | −0.403*** | 0.0281*** | −0.0639*** | −0.00873*** |
| | (0.0567) | (0.00593) | (0.0107) | (0.00183) |
| Backward | −12.32*** | 0.137*** | 0.00163 | −0.0240*** |
| | (1.045) | (0.0104) | (0.0154) | (0.00372) |
| Institution | 1.990*** | 2.031*** | 2.184*** | 1.976*** |
| | (0.0446) | (0.0479) | (0.0471) | (0.0464) |
| Forward ($AC<\gamma_1$) | −50.09*** | 0.285** | −0.398*** | −0.431*** |
| | (2.579) | (0.132) | (0.0512) | (0.0175) |
| Forward ($\gamma_1 \leq AC < \gamma_2$) | −40.33*** | 0.633*** | −0.125*** | −0.207*** |
| | (1.887) | (0.0931) | (0.0409) | (0.0112) |
| Forward ($AC \geq \gamma_2$) | −31.66*** | 0.885*** | 0.566*** | −0.120*** |
| | (1.623) | (0.121) | (0.0745) | (0.00907) |
| Constant | −6.378*** | −6.805*** | −7.267*** | −6.377*** |
| | (0.186) | (0.202) | (0.195) | (0.194) |
| Observations | 19,390 | 19,390 | 19,390 | 19,390 |
| R-squared | 0.390 | 0.375 | 0.373 | 0.398 |
| Number of firms | 2,770 | 2,770 | 2,770 | 2,770 |

Note: ***, **, * signify significance levels of 1, 5, and 10%, respectively. The standard errors are shown in parenthesis.
Source: The author estimates from annual surveys of GSO.

**Table 8.** Characteristics of firms in MLT industry benefited from FDI forward spillover.

| | Mean of threshold value | | | |
|---|---|---|---|---|
| | $< \gamma_1$ | $[\gamma_1 - \gamma_2]$ | $> \gamma_2$ | Scale |
| Mean AC | 53.85 | 79.99 | 94.06 | [0–100] |
| InternalR&D | 0.02 | 0.04 | 0.04 | [0–1], dummy variable, takes 1 if a firm takes a specific activity, |
| ExternalR&D | 0.01 | 0.03 | 0.01 | |
| Collaborate | 0.99 | 1 | 1 | |
| Process | 0.66 | 0.68 | 0.65 | |
| Quality | 0.77 | 0.76 | 0.79 | |
| Patent | 0.00 | 0.00 | 0.01 | |
| Export1 | 0.078 | 0.23 | 0.22 | |
| Export2 | 0.16 | 0.37 | 0.46 | |
| Skill_transfer | 0.27 | 0.16 | 0.19 | |
| Intra_tranfer | 0.05 | 0.07 | 0.08 | |
| Machinary obstacle | 6.39 | 6.25 | 6.18 | [0–10] where 0 is the least important, and 10 is the most importance |
| Finance obstacle | 6.30 | 5.57 | 5.4 | |
| Experience obstacle | 6.15 | 6.04 | 5.84 | |
| Labor obstacle | 5.31 | 5.32 | 5.49 | |
| Forward spillover benefit | Negative | Negative | Positive | |

Note: $\gamma_1 = 72.5443$; $\gamma_2 = 90.1359$.
Source: The author estimates from annual surveys of GSO.

**Table 9.** Effects of firm's characteristics on absorptive capacity.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| GTFP | HT | MHT | MTL | LT |
| Capital intensity | −0.197*** | −0.205*** | −0.202*** | −0.203*** |
| | (0.00212) | (0.00216) | (0.00214) | (0.00213) |
| Human capital | 0.0989*** | 0.105*** | 0.105*** | 0.0965*** |
| | (0.00545) | (0.00549) | (0.00555) | (0.00553) |
| Firm size | 0.00234 | 0.00596 | 0.000560 | 0.00424 |
| | (0.00557) | (0.00560) | (0.00570) | (0.00561) |
| Capital share | 0.0197*** | 0.0210*** | 0.0202*** | 0.0198*** |
| | (0.00512) | (0.00516) | (0.00521) | (0.00518) |
| Industry concentration | 0.0291*** | 0.0230*** | 0.0206*** | 0.00838 |
| | (0.00594) | (0.00620) | (0.00597) | (0.00598) |
| Foreign share | −0.0296 | −0.0719*** | −0.0653** | −0.270*** |
| | (0.0594) | (0.0207) | (0.0309) | (0.0466) |
| Horizontal | −0.296*** | 0.0266*** | −0.0569*** | −0.00732*** |
| | (0.0534) | (0.00555) | (0.0101) | (0.00175) |
| Backward | −10.08*** | 0.123*** | 0.0198 | −0.0246*** |
| | (0.984) | (0.00979) | (0.0145) | (0.00356) |
| Forward | −34.15*** | 0.962*** | −0.134*** | −0.106*** |
| | (1.385) | (0.0611) | (0.0307) | (0.00699) |
| Institution | 1.998*** | 2.020*** | 2.195*** | 2.000*** |
| | (0.0434) | (0.0459) | (0.0458) | (0.0457) |
| AC | 0.0152*** | 0.0159*** | 0.0156*** | 0.0151*** |
| | (0.000598) | (0.000603) | (0.000609) | (0.000605) |
| Machine*AC | −0.00174*** | −0.00186*** | −0.00184*** | −0.00164*** |
| | (0.000123) | (0.000124) | (0.000125) | (0.000125) |
| InternalR&D*AC | 0.000483* | 0.000570** | 0.000512* | 0.000531** |
| | (0.000261) | (0.000263) | (0.000266) | (0.000264) |
| ExternalR&D*AC | −0.000280 | −0.000382 | −0.000415 | −0.000420 |
| | (0.000303) | (0.000305) | (0.000308) | (0.000306) |
| Collaborate*AC | −0.000976* | −0.00106** | −0.00108** | −0.000903* |
| | (0.000520) | (0.000524) | (0.000529) | (0.000526) |
| Patent*AC | 0.000612 | 0.000536 | 0.000497 | 0.000388 |
| | (0.000554) | (0.000558) | (0.000564) | (0.000560) |
| Process*AC | 0.000156* | 0.000207** | 0.000206** | 0.000171** |
| | (8.29e-05) | (8.35e-05) | (8.44e-05) | (8.38e-05) |
| Quality*AC | −0.000414*** | −0.000437*** | −0.000421*** | −0.000401*** |
| | (8.77e-05) | (8.84e-05) | (8.93e-05) | (8.87e-05) |
| Export1*AC (developed) | 0.00141*** | 0.00137*** | 0.00142*** | 0.00136*** |
| | (0.000182) | (0.000183) | (0.000185) | (0.000184) |
| Export2*AC (developing) | 0.00106*** | 0.000991*** | 0.00105*** | 0.00103*** |
| | (0.000149) | (0.000150) | (0.000152) | (0.000151) |
| Constant | −6.840*** | −7.160*** | −7.763*** | −6.938*** |
| | (0.182) | (0.194) | (0.191) | (0.193) |
| Observations | 19,390 | 19,390 | 19,390 | 19,390 |
| R-squared | 0.461 | 0.452 | 0.441 | 0.449 |
| Number of firms | 2,770 | 2,770 | 2,770 | 2,770 |

Note: ***, **, * signify significance levels of 1, 5, and 10%, respectively. The standard errors are shown in parenthesis. Due to space constraints, the coefficients of input variables are not displayed (see Appendix A, Table A1).
Source: Authors'estimates from annual surveys of GSO.

findings are not surprising as machinery difficulties hinders firm's capacity to absorbing technology while ineffective R&D cooperation and quality enhancement programs increase production cost, which in turn reduces firm's productivity.

Overall, our findings suggest certain aspects that could play a crucial role in the promotion of absorptive ability, notably internal R&D, process enhancement, and export. Meanwhile, machinery difficulties, cooperated R&D, and quality enhancement are obstacles to absorptive capacity.

### 4.4. Robustness analysis

Additionally, in this study, a robustness test is carried out by substituting research method. The study calculates Green Total Factor Productivity using an alternative method, the Global Malmquist-Luenberger Productivity Index (GMLPI), for a robustness test (Oh, 2010) (see Tables 10 and 11).

The results indicate that no matter what GTFP methods are employed, the regression coefficients of Absorptive Capacity (AC) and the regression coefficients of FDI spillover variables on green technology TFP using the FEM model (Table 10 and Appendix A Table A4) resemble the findings of the original model.

In the sample of threshold model estimates using Global MLPI (Table 11), the significance of nearly all variables remains consistent, except for the significance of *Forward* variable in Model 4 of Table 11. This supports the robustness of the research conclusions in this study.

### 4.5. Sensitivity analysis

To assess how the coefficients of Absorptive Capacity (AC) and the regression coefficients of FDI spillover through a threshold model change with a reduced sample, we diminished the sample size and re-evaluated the models. Our dataset was sorted, all extreme values were withdrawn, and some were decreased randomly. Subsequently, the

**Table 10.** Fixed effect results on global Malmquist-Luenberger productivity index (GMLPI).

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| GTFP_Global | HT | MHT | MTL | LT |
| Capital intensity | −0.172*** | −0.181*** | −0.178*** | −0.178*** |
| | (0.00287) | (0.00291) | (0.00288) | (0.00288) |
| Human capital | 0.124*** | 0.132*** | 0.132*** | 0.122*** |
| | (0.00736) | (0.00740) | (0.00743) | (0.00745) |
| Firm size | 0.0639*** | 0.0588*** | 0.0638*** | 0.0607*** |
| | (0.00749) | (0.00751) | (0.00758) | (0.00751) |
| Capital share | 0.0199*** | 0.0213*** | 0.0206*** | 0.0201*** |
| | (0.00694) | (0.00698) | (0.00701) | (0.00699) |
| Industry concentration | 0.0338*** | 0.0240*** | 0.0226*** | 0.0106 |
| | (0.00805) | (0.00837) | (0.00802) | (0.00807) |
| Foreign share | 0.00658 | −0.0609** | −0.0670 | −0.266*** |
| | (0.0805) | (0.0280) | (0.0415) | (0.0630) |
| Horizontal | −0.273*** | 0.0141* | −0.0624*** | −0.00525** |
| | (0.0724) | (0.00750) | (0.0136) | (0.00237) |
| Backward | −12.84*** | 0.131*** | −0.0149 | −0.0206*** |
| | (1.334) | (0.0132) | (0.0194) | (0.00480) |
| Forward | −33.83*** | 0.911*** | −0.187*** | −0.102*** |
| | (1.875) | (0.0825) | (0.0412) | (0.00938) |
| Institution | 1.542*** | 1.585*** | 1.784*** | 1.548*** |
| | (0.0571) | (0.0605) | (0.0601) | (0.0602) |
| Absorptive capacity (AC) | 0.0109*** | 0.0113*** | 0.0111*** | 0.0110*** |
| | (0.000396) | (0.000398) | (0.000399) | (0.000398) |
| Constant | −4.818*** | −5.255*** | −5.939*** | −4.957*** |
| | (0.239) | (0.256) | (0.250) | (0.254) |
| Observations | 19,390 | 19,390 | 19,390 | 19,390 |
| R-squared | 0.369 | 0.361 | 0.354 | 0.358 |
| Number of iddn | 2,770 | 2,770 | 2,770 | 2,770 |

Note: ***, **, * signify significance levels of 1, 5, and 10%, respectively. The standard errors are shown in parenthesis.
Source: The author estimates from annual surveys of GSO.

**Table 11.** Sample of threshold model estimates with spillovers as the threshold variable using global MLPI.

| | Horizontal | | Forward | | Backward | |
|---|---|---|---|---|---|---|
| GTFP_Global | MHT (1) | MTL (2) | MHT (3) | MTL (4_ | MHT (5) | MTL (6) |
| Capital intensity | −0.135*** | −0.141*** | −0.142*** | −0.147*** | −0.144*** | −0.146*** |
| | (0.00255) | (0.00258) | (0.00262) | (0.00266) | (0.00261) | (0.00263) |
| Human capital | 0.129*** | 0.130*** | 0.142*** | 0.140*** | 0.139*** | 0.129*** |
| | (0.00748) | (0.00760) | (0.00756) | (0.00757) | (0.00757) | (0.00759) |
| Firm size | 0.0474*** | 0.0513*** | 0.0525*** | 0.0558*** | 0.0602*** | 0.0502*** |
| | (0.00760) | (0.00766) | (0.00768) | (0.00773) | (0.00774) | (0.00765) |
| Capital share | 0.0146*** | 0.0148*** | 0.0143** | 0.0160** | 0.0159** | 0.0146** |
| | (0.00125) | (0.00126) | (0.00713) | (0.00715) | (0.00715) | (0.00713) |
| Industry concentration | 0.0472*** | 0.0199** | 0.0294*** | 0.0339*** | 0.0312*** | 0.0172** |
| | (0.00816) | (0.00824) | (0.00857) | (0.00817) | (0.00817) | (0.00823) |
| Foreign share | −0.201** | −0.290*** | −0.0761*** | −0.114*** | −0.109*** | −0.306*** |
| | (0.0831) | (0.0644) | (0.0287) | (0.0423) | (0.0423) | (0.0642) |
| Horizontal | | | 0.0153** | −0.0671*** | 0.0615*** | −0.00601** |
| | | | (0.00768) | (0.0139) | (0.0138) | (0.00241) |
| Backward | −14.64*** | −0.0169*** | 0.146*** | −0.0403** | | |
| | (1.351) | (0.00490) | (0.0135) | (0.0199) | | |
| Forward | −34.58*** | −0.111*** | | | −0.198*** | −0.112*** |
| | (1.901) | (0.00957) | | | (0.0420) | (0.00955) |
| Institution | 1.402*** | 1.397*** | 1.464*** | 1.635*** | 1.657*** | 1.430*** |
| | (0.0576) | (0.0612) | (0.0619) | (0.0610) | (0.0610) | (0.0613) |
| Hor/For/Back (AC<$\gamma_1$) | −0.526*** | −0.0231*** | −0.480 | −0.401*** | 0.285*** | −0.0843*** |
| | | | (0.353) | (0.0580) | (0.0391) | (0.0125) |
| Hor/For/Back ($\gamma_1 \leq$ AC < $\gamma_2$) | (0.0760) | (0.00373) | 1.557*** | −0.141** | 0.145*** | −0.0382*** |
| | | | (0.292) | (0.0584) | (0.0308) | (0.00577) |
| Hor/For/Back (AC $\geq \gamma_2$) | −0.136* | −0.00383 | 0.565*** | 0.442*** | 0.0261 | 0.00160 |
| | (0.0804) | (0.00273) | (0.0950) | (0.0967) | (0.0228) | (0.00692) |
| Constant | −3.885*** | −3.979*** | −4.397*** | −4.917*** | −4.987*** | −4.084*** |
| | (0.240) | (0.256) | (0.261) | (0.252) | (0.252) | (0.256) |
| Observations | 19,390 | 19,390 | 19,390 | 19,390 | 19,390 | 19,390 |
| R-squared | 0.348 | 0.327 | 0.327 | 0.325 | 0.325 | 0.329 |
| Number of iddn | 2,770 | 2,770 | 2,770 | 2,770 | 2,770 | 2,770 |

Note: ***, **, * signify significance levels of 1, 5, and 10%, respectively. The standard errors are shown in parenthesis.
Source: The author estimates from annual surveys of GSO.

dataset was restructured to form a new balanced panel spanning from 2013 to 2019, resulting in a decreased sample size from 19,390 to 16,940 observations. With this updated dataset, Table 12 displays the same estimations as those in Appendix A - Tables 4A, and 13 reproduces the same estimations (sample for MHT and MTL models) from Tables 3, 5, and 7.

Although the dataset is reduced in the sample, the significance of all variables presented in Table 12 are similar to the original model found in Appendix A - Table A4. The estimation results of threshold model in Table 13 using MLPI remains consistent, with the exception that one threshold in Model 5 and Model 6 of Table 13 having no statistical significance.

Despite the differences in absolute values, they generally had a similar trend, as expected. Therefore, it can be concluded that the results are not influenced by outliers.

**Table 12.** Fixed effect results on Malmquist-Luenberger productivity index (MLPI) for new sample data (sensitivity analysis).

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| GTFP | HT | MHT | MTL | LT |
| Capital intensity | −0.197*** | −0.208*** | −0.204*** | −0.203*** |
| | (0.00234) | (0.00237) | (0.00236) | (0.00234) |
| Human capital | 0.112*** | 0.119*** | 0.120*** | 0.107*** |
| | (0.00589) | (0.00594) | (0.00600) | (0.00597) |
| Firm size | 0.00802 | 0.0146** | 0.00853 | 0.0101* |
| | (0.00602) | (0.00605) | (0.00616) | (0.00605) |
| Capital share | 0.0217*** | 0.0235*** | 0.0222*** | 0.0216*** |
| | (0.00535) | (0.00539) | (0.00545) | (0.00539) |
| Industry concentration | 0.0338*** | 0.0347*** | 0.0271*** | 0.0101 |
| | (0.00654) | (0.00679) | (0.00656) | (0.00656) |
| Foreign share | −0.0184 | −0.165*** | −0.0799** | −0.264*** |
| | (0.0610) | (0.0348) | (0.0318) | (0.0494) |
| Horizontal | −0.294*** | 0.0334*** | −0.0549*** | −0.00947*** |
| | (0.0572) | (0.00618) | (0.0109) | (0.00190) |
| Backward | −9.007*** | 0.110*** | 0.0559*** | −0.0309*** |
| | (1.068) | (0.0110) | (0.0163) | (0.00400) |
| Forward | −37.59*** | 1.165*** | −0.100*** | −0.130*** |
| | (1.537) | (0.0682) | (0.0327) | (0.00739) |
| Institution | 2.006*** | 1.988*** | 2.191*** | 1.954*** |
| | (0.0480) | (0.0511) | (0.0511) | (0.0510) |
| Absorptive capacity (AC) | 0.0130*** | 0.0135*** | 0.0133*** | 0.0131*** |
| | (0.000323) | (0.000325) | (0.000329) | (0.000325) |
| Constant | −6.928*** | −7.064*** | −7.818*** | −6.786*** |
| | (0.201) | (0.216) | (0.213) | (0.215) |
| Observations | 16,940 | 16,940 | 16,940 | 16,940 |
| R-squared | 0.432 | 0.423 | 0.410 | 0.423 |
| Number of iddn | 2,420 | 2,420 | 2,420 | 2,420 |

Note: ***, **, * signify significance levels of 1, 5, and 10%, respectively. The standard errors are shown in parenthesis.
Source: The author estimates from annual surveys of GSO.

## 5. Conclusion

This study, based on a sample of Vietnamese manufacturing and processing enterprises, gives new insights into how firm managers might increase GTFP productivity through foreign direct investment. This study contributes to the literature on FDI by differentiating three channels of FDI spillovers and analyzing the independent effects of FDI spillovers on local business productivity. More crucially, this analysis evaluates the level of absorptive capacity required by local enterprises in distinct homogenous groups to profit from FDI spillovers. It also identifies absorptive capacity and its learning process (exploration, transformation, and exploitation) as a trigger that must be created to maximize FDI spillover.

Our findings reveal that the impact of *horizontal* FDI spillover in MHT sectors changes depending on the value of absorptive capacity, but negative effects are detected in MLT and LT sectors regardless of threshold values. Regarding backward FDI spillover, for the MHT sector, the effect is positive and helps boost the domestic firms' production, regardless of threshold values. By contrast, firms with HT, MLT, and LT sectors have positive backward effects on productivity if their absorptive capacity is over a certain amount. Our findings show that, similar to the backward impact, the forward impact is favorable for the MHT sector and helps improve domestic company output regardless of threshold values. By

**Table 13.** Threshold model estimates with spillovers as the threshold variable using Malmquist-Luenberger productivity index (MLPI) for new sample data (sensitivity analysis).

| | Horizontal | | Forward | | Backward | |
|---|---|---|---|---|---|---|
| GTFP | MHT (1) | MTL (2) | MHT (3) | MTL (4_ | MHT (5) | MTL (6) |
| Capital intensity | −0.161*** | −0.160*** | −0.162*** | −0.167*** | −0.167*** | −0.163*** |
| | (0.00219) | (0.00219) | (0.00221) | (0.00225) | (0.00220) | (0.00220) |
| Human capital | 0.132*** | 0.131*** | 0.132*** | 0.130*** | 0.130*** | 0.129*** |
| | (0.00626) | (0.00630) | (0.00626) | (0.00628) | (0.00620) | (0.00628) |
| Firm size | 0.0248*** | 0.0189*** | 0.0210*** | 0.0161** | 0.0255*** | 0.0142** |
| | (0.00639) | (0.00646) | (0.00640) | (0.00644) | (0.00633) | (0.00645) |
| Capital share | 0.0166*** | 0.0159*** | 0.0167*** | 0.0176*** | 0.0175*** | 0.0172*** |
| | (0.00569) | (0.00573) | (0.00569) | (0.00571) | (0.00563) | (0.00571) |
| Industry concentration | 0.0397*** | 0.0383*** | 0.0416*** | 0.0399*** | 0.0392*** | 0.0377*** |
| | (0.00718) | (0.00689) | (0.00717) | (0.00687) | (0.00710) | (0.00687) |
| Foreign share | −0.170*** | −0.114*** | −0.188*** | −0.136*** | −0.172*** | −0.133*** |
| | (0.0368) | (0.0347) | (0.0367) | (0.0333) | (0.0364) | (0.0333) |
| Horizontal | | | 0.0378*** | −0.0630*** | 0.0324*** | −0.0515*** |
| | | | (0.00653) | (0.0114) | (0.00646) | (0.0114) |
| Backward | 0.127*** | 0.0557*** | 0.131*** | 0.0272 | | |
| | (0.0116) | (0.0172) | (0.0116) | (0.0172) | | |
| Forward | 0.995*** | −0.117*** | | | 0.999*** | −0.117*** |
| | (0.0719) | (0.0344) | | | (0.0711) | (0.0343) |
| Institution | 1.816*** | 1.974*** | 1.786*** | 1.975*** | 1.862*** | 2.002*** |
| | (0.0538) | (0.0534) | (0.0539) | (0.0532) | (0.0533) | (0.0533) |
| Hor/For/Back ($AC<\gamma_1$) | 0.0287*** | −0.175*** | 0.403*** | −0.338*** | 0.0153 | −0.166*** |
| | | | (0.152) | (0.0548) | (0.0133) | (0.0242) |
| Hor/For/Back ($\gamma_1 \leq AC < \gamma_2$) | (0.00673) | (0.0249) | 0.817*** | −0.0955** | 0.123*** | 0.0287 |
| | | | (0.0902) | (0.0427) | (0.0149) | (0.0249) |
| Hor/For/Back ($AC \geq \gamma_2$) | 0.0570*** | −0.0934*** | 1.402*** | 0.605*** | 0.187*** | 0.135*** |
| | (0.0124) | (0.0132) | (0.193) | (0.0861) | (0.0139) | (0.0220) |
| Constant | −5.951*** | −6.474*** | −5.790*** | −6.424*** | −6.079*** | −6.532*** |
| | (0.227) | (0.221) | (0.227) | (0.220) | (0.224) | (0.220) |
| Observations | 16,940 | 16,940 | 16,940 | 16,940 | 16,940 | 16,940 |
| R-squared | 0.356 | 0.349 | 0.357 | 0.353 | 0.370 | 0.353 |
| Number of iddn | 2,420 | 2,420 | 2,420 | 2,420 | 2,420 | 2,420 |

Note: ***, **, * signify significance levels of 1, 5, and 10%, respectively. The standard errors are shown in parenthesis.
Source: The author estimates from annual surveys of GSO.

contrast, firms with HT and LT sectors have negative forward effects on productivity. However, if the absorptive capacity is over $\gamma_2$ (in MLT), the positive forward effect is detected.

Furthermore, our findings point to specific factors that may be crucial in improving absorptive capacity, such as internal research and development, process improvement, and export. The study contributes to the existing body of knowledge by demonstrating the importance of estimating spillovers at disaggregated groupings of enterprises. Because firms' absorptive capacity vary, broad generalizations about the effects of FDI spillovers in the industry may be inaccurate. Using the idea of absorptive capacity, discrepancies in worker skills, technological intensity, and resource access all play critical roles in an organization's ability to profit from external knowledge and technologies. The benefits of FDI spillover are expected to be mediated by firms' ability to utilise knowledge and technology in their business practices and innovation activities.

In conclusion, some suggestions on enhancing absorptive capability, encouraging FDI spillover and then improving GTFP in the Vietnamese manufacturing and processing industry are given as follows:

Firstly, policy design and implementation should take into consideration the need for technology transfer and imported technology especially from developed countries. Firms should be encouraged to access environmentally friendly technology and prevent the import of technology harmful to the environment.

Secondly, the government should continue to issue policies to encourage FDI funds but must also issue environmental policies to improve national technical regulations on safety, energy conservation, and environmental protection to be on par with global standards, as well as support or guarantee loans for imported advanced machinery to promote cleaner production.

Thirdly, firms should be encouraged to regularly implement innovation and improvement process by themselves to increase the quality of products, apply advanced process and tools into the production. Some solutions which can be applied are efficiency improvement in the internal cooperation process, continuously improve the production process, the receptive capabilities, promotion of cooperation with other firms and institutions especially FDI firms via conferences, seminars, training courses and consultations.

Finally, enhancing businesses' absorptive ability should take into account the wide range of their capacity as well as stimulate the process of upgrading not only their technology adoption but also their capacity to combine and internalize new knowledge and transfer it into performance outcomes.

This study has some drawbacks, which could be addressed in future research. First, the study is restricted to a sample of manufacturing enterprises. Subsequent research could look at the influence of FDI spillover on GTFP for both manufacturing and service firms. Second, more research is needed to understand the dynamic impact of FDI spillovers on GTFP. Finally, this research focuses on firm-level analysis. Future studies may investigate the impact of FDI spillovers on GTFP across industries and regions.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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# Appendix A

**Table A1.** High and low technology classification based on vsic 2007.

| High Technology | Medium-High Technology | Medium-Low Technology | Low-Technology |
|---|---|---|---|
| **Code/Subsector** | **Code/Subsector** | **Code/Subsector** | **Code/Subsector** |
| 21. Pharmaceutical | 27. Electrical Equipment | 19. Coke & refined petroleum | 10. Food |
| 26. Computers & Peripheral Equipment | 28. Machinery | 20. Chemicals | 11. Beverages |
| | 29. Motor and Trailers | 22. Rubber & Plastic | 12. Tobacco |
| | 30. Other Transport Equipment | 23. Other non-metallic minerals | 13. Textile |
| | | 24. Basic Metals | 14. Apparel |
| | | 25. Fabricated Metal | 15. Leather & Footwear |
| | | 33. Repair & Installation of Machinery and Equipment | 16. Wood |
| | | | 17. Paper & Printing |
| | | | 18. Printing & Media |
| | | | 31. Furniture |
| | | | 32. Other Manufacturing |

Source: OECD, 2011, ISIC REV.3 Technology Intensity Definition.

**Table A2.** Pearson correlation between absorptive capacity and FDI spillovers.

| | Horizontal | Backward | Forward |
|---|---|---|---|
| AC (in HT firms) | –0.0962*** | –0.1072*** | –0.0376*** |
| AC (in MHT firms) | –0.0244*** | 0.0512*** | –0.0648*** |
| AC (in MLT firms) | 0.0904*** | 0.0717*** | –0.0078 |
| AC (in LT firms) | 0.0480*** | 0.0002 | 0.1411*** |

Source: Authors.

**Table A3.** Variable correlations.

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) GTFP | 1.000 | | | | | | | | | | | | | |
| (2) Capital intensity | −0.283 | 1.000 | | | | | | | | | | | | |
| (3) Human capital | 0.137 | 0.320 | 1.000 | | | | | | | | | | | |
| (4) Firm size | −0.021 | 0.559 | 0.226 | 1.000 | | | | | | | | | | |
| (5) Capital share | 0.018 | −0.006 | 0.003 | 0.023 | 1.000 | | | | | | | | | |
| (6) Industry concen … | 0.028 | −0.044 | −0.001 | −0.160 | 0.011 | 1.000 | | | | | | | | |
| (7) ×k1 | 0.001 | 0.189 | 0.113 | 0.377 | 0.010 | −0.128 | 1.000 | | | | | | | |
| (8) ×k2 | 0.004 | 0.183 | 0.195 | 0.211 | 0.017 | −0.040 | −0.325 | 1.000 | | | | | | |
| (9) Foreign share | −0.002 | 0.093 | 0.051 | 0.074 | −0.010 | −0.009 | −0.015 | 0.055 | 1.000 | | | | | |
| (10) Horizontal | −0.017 | −0.018 | −0.089 | −0.077 | −0.025 | −0.058 | −0.137 | −0.101 | 0.175 | 1.000 | | | | |
| (11) Backward | −0.016 | −0.101 | −0.080 | −0.115 | −0.025 | 0.009 | −0.034 | −0.002 | −0.040 | −0.232 | 1.000 | | | |
| (12) Forward | −0.089 | −0.003 | 0.027 | −0.043 | −0.023 | −0.159 | 0.057 | −0.034 | −0.032 | −0.187 | −0.224 | 1.000 | | |
| (13) Institution | 0.214 | 0.071 | 0.081 | −0.028 | 0.048 | 0.028 | −0.010 | −0.006 | −0.009 | 0.050 | 0.039 | −0.061 | 1.000 | |
| (14) AC | −0.000 | 0.669 | 0.500 | 0.655 | −0.009 | −0.086 | 0.275 | 0.263 | 0.065 | −0.096 | −0.107 | −0.038 | −0.024 | 1.000 |

**Table A4.** Fixed effect results.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| GTFP | HT | MHT | MTL | LT |
| Capital intensity | –0.197*** | –0.206*** | –0.203*** | –0.203*** |
| | (0.00214) | (0.00217) | (0.00216) | (0.00215) |
| Human capital | 0.107*** | 0.114*** | 0.114*** | 0.103*** |
| | (0.00548) | (0.00552) | (0.00558) | (0.00556) |
| Firm size | 0.00775 | 0.0127** | 0.00746 | 0.00990* |
| | (0.00557) | (0.00561) | (0.00569) | (0.00561) |
| Capital share | 0.0201*** | 0.0215*** | 0.0207*** | 0.0202*** |
| | (0.00517) | (0.00521) | (0.00526) | (0.00522) |
| Industry concentration | 0.0316*** | 0.0272*** | 0.0238*** | 0.00958 |
| | (0.00599) | (0.00625) | (0.00602) | (0.00602) |
| Foreign share | –0.0150 | –0.0813*** | –0.0752** | –0.281*** |
| | (0.0599) | (0.0209) | (0.0312) | (0.0470) |
| Horizontal | –0.296*** | 0.0269*** | –0.0589*** | –0.00778*** |
| | (0.0538) | (0.00560) | (0.0102) | (0.00177) |
| Backward | –9.854*** | 0.118*** | 0.0306** | –0.0248*** |
| | (0.992) | (0.00987) | (0.0146) | (0.00358) |
| Forward | –35.25*** | 0.993*** | –0.132*** | –0.118*** |
| | (1.395) | (0.0617) | (0.0309) | (0.00700) |
| Institution | 2.155*** | 2.185*** | 2.358*** | 2.144*** |
| | (0.0425) | (0.0452) | (0.0451) | (0.0449) |
| Absorptive capacity (AC) | 0.0130*** | 0.0134*** | 0.0132*** | 0.0130*** |
| | (0.000295) | (0.000297) | (0.000300) | (0.000297) |
| Constant | –7.511*** | –7.864*** | –8.470*** | –7.550*** |
| | (0.178) | (0.191) | (0.187) | (0.189) |
| Observations | 19,390 | 19,390 | 19,390 | 19,390 |
| R-squared | 0.451 | 0.441 | 0.430 | 0.440 |
| Number of firms | 2,770 | 2,770 | 2,770 | 2,770 |

Note: ***, **, * signify significance levels of 1, 5, and 10%, respectively. The standard errors are shown in parenthesis.
Source: Authors estimate from Annual Surveys of GSO.

**Table A5.** Threshold effect tests.

Panel A. Threshold models with horizontal spillover as the threshold variable

| | Probability | | |
|---|---|---|---|
| Threshold | MHT | MLT | LT |
| Single | 0.0133 | 0.0000 | 0.0000 |
| Double | 0.1200 | 0.1400 | 0.1133 |
| Triple | 0.8333 | 1.0000 | 0.1667 |

Panel B. Threshold models with backward spillover as the threshold variable

| | Probability | | | |
|---|---|---|---|---|
| Threshold | HT | MHT | MLT | LT |
| Single | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Double | 0.0400 | 0.0000 | 0.0267 | 0.0400 |
| Triple | 0.9667 | 0.9933 | 1.0000 | 1.0000 |

Panel C. Threshold models with forward spillover as the threshold variable

| | Probability | | | |
|---|---|---|---|---|
| Threshold | HT | MHT | MLT | LT |
| Single | 0.0000 | 0.0133 | 0.0000 | 0.0000 |
| Double | 0.0000 | 0.2867 | 0.0000 | 0.0000 |
| Triple | 0.9467 | 1.0000 | 1.0000 | 1.0000 |

Source: Authors.