Journal of Open Innovation:
Technology, Market, and Complexity

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MDPI

https://doi.org/10.3390/joitmc8020099

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The FDI Spillover Effect on the Efficiency and Productivity of Manufacturing Firms: Its Implication on Open Innovation

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Abstract: In this study, we investigated the effects of foreign direct investment (FDI) spillovers on firm production and technical efficiency in Indonesia's manufacturing sector from 2010 to 2015. We scrutinized three different channels of horizontal spillover, namely, demonstration, technology adoption, and competition channels. We also captured the heterogeneous effect of firms by categorizing them based on their technological intensity (low, medium, or high). Using time-varying stochastic production frontier analysis, we found that manufacturing firms in each technological group benefit from FDI, either from productivity improvement or technical efficiency improvement. High-technology firms mainly benefit from FDI due to their high technological absorption capability. Meanwhile, medium-high and medium-low tech firms increase productivity through the demonstration effect and the technology adoption channel, despite underperforming in technical efficiency. Finally, low-tech firms, which primarily employ unskilled workers, suffer from large inefficiency. We found that increased FDI, combined with improvements in technology absorption capacity, can help revitalize the productivity of low-tech firms. FDI, firm size, and access to foreign inputs all support production effects but have no direct positive impact on firms' technical efficiency. The results of this study suggest that the government should ensure that domestic firms can absorb the technical capability of a foreign presence. Open innovation can help strengthen foreign–domestic linkages to contribute to growth through the transfer of knowledge, skills, and technologies.

Keywords: FDI; spillovers; technology adoption; market competition; demonstration effects; technical efficiency; local economic development; economic globalization; open innovation

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Citation: Sugiharti, L.; Yasin, M.Z.; Purwono, R.; Esquivias, M.A.; Pane, D. The FDI Spillover Effect on the Efficiency and Productivity of Manufacturing Firms: Its Implication on Open Innovation. *J. Open Innov. Technol. Mark. Complex.* **2022**, *8*, 99. https://doi.org/10.3390/joitmc8020099

Received: 29 April 2022
Accepted: 30 May 2022
Published: 2 June 2022

1. Introduction

The spillover effects of foreign direct investment (FDI) have captivated researchers and policy makers for the past two decades. Earlier studies on FDI spillovers have identified positive externalities in host countries in the form of efficiency and productivity gains [1–4]. Other studies argue that FDI can help local firms increase productivity by serving as new sources of funding for industrial development, assisting in improving their management systems, providing access to global markets, generating innovations, and creating technological spillovers in domestic firms [5–7].

However, earlier studies failed to identify the specific channels through which FDI spillovers influence efficiency and productivity [8,9]. Overlooking the channels through which spillover effects operate may lead to overgeneralizing the impact of FDI on domestic firms. Incoming FDI may increase competition among domestic players. Foreign-owned firms may benefit from higher technology, knowledge, and more efficient practices, driving small local firms (often less efficient) out of the industry [10,11]. Foreign players may also crowd out the labor and capital markets by attracting the most skilled workers and efficient resources, resulting in higher production costs and lower profits for domestic firms [12].

Moreover, a few studies have accommodated the heterogeneity of the firms, such as technological groups [11,13–16]. Jin et al. [17] noted that high-technology-intensive firms might benefit from FDI spillovers, whereas lower-tech firms may be negatively affected. In these regards, a study of FDI spillover effects that captures both specific channels and technological groups in affecting efficiency and productivity is essential to provide evidence about whether the FDI-specific channels perform differently on technological groups. Such a study can explore the extent to which the group of technology can determine the FDI spillover performance and which channels contribute the most to the firms' efficiency and productivity. Nguyen et al. [4] investigated the transmission mechanisms in which foreign firms and small domestic firms in Vietnam interact, finding that firms embrace different technology adoption strategies. However, the impact considers vertical linkages, but little is said on how horizontal linkages occur.

Among Southeast Asia's developing countries, Indonesia successfully attracted FDI inflows in the early 2000s. Since the 1980s, when trade and industrial policies provided stronger incentives for investment and innovation, FDI inflows into Indonesia's manufacturing sector have gradually increased [18]. According to Suyanto et al. [11], FDI increased more than 90 times from the mid-1980s to 2019, reaching nearly USD 25 billion in 2019. The rising FDI inflows in Indonesia are widely regarded as a factor supporting innovation, firm productivity, and technical efficiency gains [8,9,19]. Studies in Indonesia, similar to the case of Vietnam [4], generally conclude that FDI has primarily benefited the manufacturing industry via upstream and downstream sectors (vertical spillovers) [16,20–22], with mixed evidence of impacts on recipient sectors (horizontal spillovers). The specific channels through which such FDI effects are transmitted to domestic firms, particularly within the industry in which investment takes place, are often overlooked in FDI literature in Indonesia.

Four previous studies focus on FDI spillover effects using the stochastic production frontier for the Indonesian manufacturing industry [8,11,19,23]. However, only Sari et al. [8] employed a simultaneous model through which FDI spillovers affect both efficiency and productivity, whereas some authors [11,19,23] focused on the FDI spillover effect on a firm's efficiency. Most importantly, none of these studies distinguish between the channels and the firms' heterogeneous technological groups, potentially leading to over-generalized FDI spillovers. Little is known about whether specific horizontal linkages via demonstration effects, labor mobility, and absorption capacity serve as transmission channels for spillover effects from foreign to domestic firms.

This study contributes to the existing literature in several ways. First, this is the first study on FDI spillovers that scrutinizes the firm heterogeneity based on technological intensity in production function estimation in Indonesia. We employed the classification based on their products, which follow the Organization for Economic Cooperation and Development's technological intensity categories (low, medium-low, medium-high, and high) (OECD, 2011). The estimates were conducted by analyzing more than 10,000 firms over the period 2011–2015. Second, we extend earlier studies on the FDI spillover effects on productivity and efficiency [8,11,19,23] by explaining three channels in which spillovers may be occurring within the manufacturing industry. The first channel is the demonstration channel that stems from pure horizontal spillovers. As explained by Orlic et al. [15], the second channel is labor mobility, which is defined as an interaction of horizontal spillovers and absorptive capacity. We proxy the absorptive capacity based on the assumption that more skilled labor has lower mobility costs and is more likely to move to higher-paying jobs [24–26]; therefore, firms that pay higher wages have higher absorptive capacity than firms that do not. The competition is the third channel, which we define as the interaction of horizontal spillover and market concentration. Identifying the role of each channel in the transmission of spillover effects from FDI is crucial for the proposal of policies toward an open innovation system in which the interaction of foreign and domestic firms is maximized.

The remainder of this paper is structured as follows. Section 2 discusses the theoretical setting in which the spillovers occur. Section 3 explains the data, methodology, and econometric specification of spillover measurements. Section 4 presents the findings of this study and offers further discussion. Finally, Section 5 presents the conclusion and policy implications.

2. Theoretical Frameworks

2.1. FDI Spillover and Its Channels

The presence of multinational corporations (MNCs) in a host country is primarily associated with incoming FDI. The existing literature on FDI supports the notion that MNCs are generally more productive than domestic firms are, benefiting from advantages in technology, market reach, and managerial processes, especially when entering an emerging market where they can fully leverage their capabilities [15,27]. Local firms can benefit both directly and indirectly from FDI when an MNC implements advanced technology in a host country, thus increasing productivity [4,8]. Direct effects occur when the MNC provides subsidiaries with open access to advanced technology, knowledge, high-quality intermediate inputs, and markets. Moreover, domestic firms apply superior technology by imitating, replicating, or adapting advanced products and practices, resulting in indirect effects. MNC can then help domestic firms gain open access to advanced technologies, innovative practices, organizational expertise, and other resources.

To explain productivity spillovers, the main theoretical literature on FDI identifies three mechanisms: demonstration, labor mobility, and competition effects. These spillovers take the form of knowledge diffusion generated by non-market and non-rivalry processes within the FDI recipient sector [28,29]. The imitation and reverse engineering associated with MNCs, such as expertise and organization and marketing practices, result in demonstration effects [15,23]. When MNCs enter the market with advanced technology and best production practices, local firms may imitate their technology and methodology, boosting industry efficiency and productivity.

Hypothesis 1. *FDI spillovers from demonstration effects encourage productivity.*

Hypothesis 2. *FDI spillovers from demonstration effects encourage efficiency.*

The second channel is labor mobility, which is still underdeveloped due to a lack of proxy at the firm level. Orlic et al. [15] used the interaction of horizontal spillover and absorptive capacity calculated from labor cost per worker to proxy for this channel. However, other studies did not employ a similar proxy, as it hardly captures how labor mobility occurs, such as labor movements from local to foreign firms [30].

Although absorptive capacity is hardly proximate empirically [31], prior studies have linked labor cost per worker to relative absorptive capacity, with the assumption that a higher labor cost per worker corresponds to a higher skill level of the labor [8,32]. This assumption is consistent with other studies, which assert that MNCs mainly promote further education in workers, assist in developing technical expertise, and foster the transfer of best practices that benefit the local workforce [33,34]. As inward MNCs bring new advanced technology, technology spillover in which the absorptive capacity is primarily accounted for may exist. In this regard, rather than labor mobility, as proposed by Orlic et al. [15], the interaction of horizontal spillover and absorptive capacity represents the rate at which new technology adoption spreads [8], allowing open innovation to occur [35]. When MNCs' larger skilled workers interact with technology spillover, local firms may either adopt similar technology to increase output and efficiency, thereby improving performance, or, conversely, fail to catch up with advanced technology, thereby decreasing output and diminishing performance. Hence, the interaction of horizontal spillover and absorptive capacity can be recognized as a "technology adoption channel", because technology spillover can encourage or discourage efficiency and productivity in industries.

Hypothesis 3. *FDI spillovers from technology adoption encourage productivity.*

Hypothesis 4. *FDI spillovers from technology adoption encourage efficiency.*

The competition channel is the third mechanism. Orlic et al. [15] employed the Herfindahl Index to estimate the proximate competition effect of FDI spillover. However, we contend that this proxy fails to account for FDI spillover. Instead, we argue that the interaction of market concentration and horizontal spillover will be a better proxy for inward FDI-induced competition. In theory, the presence of MNCs can increase market competition, forcing domestic firms to improve resource utilization to defend their market share [21,36]. In this regard, a larger share of output from MNCs, which implies higher market concentration and less competition, indicates how local firms will be affected by the competition channel.

Hypothesis 5. *FDI spillovers from competition encourage productivity.*

Hypothesis 6. *FDI spillovers from competition encourage efficiency.*

2.2. FDI Spillovers in the Indonesian Manufacturing Industry

Several studies [8,15], some of which used panel data models, have provided practical frameworks for investigating the channels through which FDI spillovers occur. The evidence is somewhat mixed in the context of Indonesia. Some studies have discovered positive externalities from foreign to domestic firms [37,38]. Others have found that FDI does not benefit all industries [11]. Some sectors, such as wood, paper, chemicals, and non-metal minerals, which are primarily capital-intensive, benefit from positive FDI spillover effects, whereas others, such as food and textiles, which are primarily labor-intensive, do not. In Indonesia, the evidence remains inconclusive because foreign firms mainly create significant externalities with upstream or downstream players across industries [16], but not clearly within the sector in which the MNCs operate.

In Indonesia, inconclusive evidence may be due to several aspects. First, firm heterogeneity may explain the mixed evidence; thus, a more detailed analysis may yield clearer results. Some studies have used sectoral analysis [11,39], or incorporated firm characteristics [36] to reduce estimate bias. Second, most studies used the share of FDI in an industry's output as an indicator of horizontal FDI [40], which is primarily a proxy for demonstration effects [9,23,37]. Nonetheless, demonstration effects are likely to have moderate effects on labor and firm absorptive capability [15], which have not previously been analyzed in Indonesia. Another source of variation is that estimations can employ either productivity level or productivity growth approaches. Studies that used productivity estimates find little evidence of FDI spillovers, most likely because productivity estimates only capture short-run effects [41]. Different approaches to productivity growth include the use of production functions [9,16,37,40] or decomposition approaches [23,38]. The conventional production function mainly captures technological progress as it commonly assumes full efficiency and full capacity—an assumption that appears to be unsuitable for the real world.

In this study, we neglect the standard assumption that firms operate at full efficiency, recognizing possible slack in production due to different levels of managerial expertise across firms. Although companies may use similar technologies, they may be unable to maintain equal levels of efficiency in their use of inputs, most likely because they operate at different economies of scale. As such, differences in slack emerge between them. Prior studies have identified foreign companies performing at higher efficiency levels than domestic players [9,36,42,43]. In this sense, domestic firms will adjust production following best practices, avoiding slack and producing at higher output levels [44]. We answer whether such adjustments (seen via externalities) occur across different industries.

3. Data and Econometric Specifications

3.1. Data

We employed firm-level data obtained from the national survey for the large and medium manufacturing sector by the Indonesian Central Bureau of Statistics (BPS) from 2011 to 2015. The representation level of the data in 2011 reached 74 percent. BPS refers to firms as large when they report employing more than 100 laborers and as a medium when they employ between 20 and 99 workers. The number of firms may change over time; for example, they may close or move to other subsectors. However, to obtain a larger sample of firms, we employed unbalanced panel data covering 2011–2015. The number of observations per year is different. The lowest number is 12,894 firms for 2015, and the highest number is 13,199 firms for 2011.

There are two sets of variables of interest in this study (Table 1). The first division includes output and input variables needed to estimate the production function, such as total output, capital (estimated by a firm's fixed assets such as land, building, machinery, equipment, and vehicles), number of laborers, energy (approximated by fuel and lubricants used in a year), and raw materials. With the exception of the number of employees, all variables are reported in Indonesian rupiah (IDR). The second set of variables is divided into two parts: variables of interest for estimating various aspects of horizontal spillovers and control variables. Horizontal spillover is measured by the proportion of total output produced by foreign firms in the total subsector (*HSpill*). We follow Javorcik [40] in the formulation of horizontal spillover as follows:

$$HSpill_{jt} = \frac{\Sigma_{i\epsilon j} FSh_{it} * Y_{it}}{\Sigma_{i\epsilon j} Y_{it}} \quad (1)$$

where i denotes the firm and j indicates the subsector. $HSpill$ denotes the horizontal spillover effect, FSh is the share of firm's foreign capital ownership, and Y_{it} is the total output in the manufacturing sector. Orlic et al. [15] noted that *HSpill* mainly captures overall demonstration effects, interpreting that an increase in output share of foreign firms might stimulate the firms' outputs or efficiency within the industry.

Table 1. Employed variables.

Variable	Measurement
Output (Y)	Total outputs produced in a year (IDR)
Capital (K)	Total fixed capital including land, building, machinery, equipment, and vehicles (IDR)
Labor (L)	Number of workers in a year
Energy (E)	Total utilization of fuel and lubricant (IDR)
Raw Material (R)	Total utilization of raw material (IDR)
Market Concentration	Herfindahl–Hirschman Index (HHI)
Imported Material Intensity	Ratio of imported raw material with total raw material
Absorptive Capacity (Absp)	Ratio of total workers' expense with total workers, in natural logarithm
Foreign Company (FOR)	Dummy equals 1 for foreign company, 0 otherwise
Horizontal Spillover (Demonstration Effect)	Ratio of output share of the foreign firms and the total output in the industry
Technology Adoption	Interaction of horizontal spillover and absorptive capacity
Market Competition	Interaction of horizontal spillover and market concentration

We used a proxy of an interaction between absorptive capacity and horizontal spillover to estimate the technology adoption channel. Meanwhile, we used the average cost per worker to calculate labor absorption capacity. Le and Pomfret [32] suggest that higher labor costs per person (wages and training expenditure) indicate that a firm employs highly skilled laborers, who are more likely to absorb technology resourcefully and achieve higher efficiency. This term indicates that a higher labor cost per worker indicates a greater ability to adopt new technology in foreign-owned firms, which may boost output and efficiency in the industry. According to Javorcik et al. [33], workers in foreign-owned firms in Indonesia receive nearly 40 percent higher wage premia than workers in domestic firms because they are more productive. This empirical finding lends support to the theoretical assumption that employees are compensated based on their marginal productivity [24].

Meanwhile, the market competition channel results from the interaction between the market concentration index and horizontal spillover. The Herfindahl–Hirschman index (HHI) is proposed to capture market concentration [15,36].

Other variables are also included, as in Esquivas and Harianto [36] and Sari [9]. The intensity of imported raw materials accounts for the ratio of imported raw materials to total materials. Firm size quantifies a firm's share of sector output [45]. Meanwhile, foreign capital ownership (FOR) denotes a foreign firm's share of capital. In this study, we refer to a firm as foreign-owned when a foreign investor owns at least 10 percent of the capital, as is more commonly used in Indonesian studies. Table 1 summarizes the variables used in this study.

If monetary value variables, such as output, capital, and energy, are used directly, the analysis may be skewed. To make the data consistent, we adjusted monetary variables by the price index. We employed the deflating methodology, with the Wholesale Price Indices of Indonesia of 2010 serving as the base year.

We categorized firms based on their technology intensity, as defined by the OECD (2011). The two digits of the 2009 Indonesia Standard Industrial Classification (ISIC) are used to identify the classification. Industries are classified into four types: high technology (HT), medium-high technology (MHT), medium-low technology (MLT), and low technology (LT). Table 2 summarizes the classification.

Table 2. Classification of high technology and low technology.

High Technology	**Medium-High Technology**	**Medium-Low Technology**	**Low Technology**
Code/Subsector	**Code/Subsector**	**Code/Subsector**	**Code/Subsector**
21 Pharmaceutical	20 Chemical	23 Fabricated Metal	10 Food
26 Computers, Electronics, and Optics	27 Electrical Equipment	24 Metal Base	11 Beverage
	28 Machinery	25 Metals	12 Tobacco
	29 Motor and trailers	22 Rubber and Plastic	13 Textile
	30 Other Transport Equipment	19 Products from Coal and Oil Refinery	14 Apparel
			15 Leather and Footwear
			16 Wood
			17 Paper and Printing
			18 Printing and Recording Media
			31 Furniture
			32 Other Manufacturing

Source: OECD, 2011. ISIC REV. 3 Technology Intensity Definition, https://www.oecd.org/sti/ind/48350231.pdf (accessed on 28 April 2022)

To reduce the data's noise, we removed observations that appear as non-reporting, misreporting, and keypunch errors. Some firms documented missing output values or inputs, such as capital, material, energy, and labor costs, in a given year. Observations with missing production values are intolerable, so they are excluded from our estimation. Similarly, because noises from inputs, such as negative amounts of energy and raw materials, are implausible, they are omitted from the data and recognized as non-reporting.

Table 3 reports the descriptive statistics of all variables that are employed in this study. The highest average of total output is identified within MHT sectors. The possible reason for these data is that MHT has large research and development (R&D) activities, and HT has the second-largest outputs. According to the United Nations Industrial Development Organization [46], R&D plays a critical role in boosting productivity through innovation. Similarly, Tutak and Brodny [47] argued that the launch of Industry 4.0 in 2011 encourages the production process from the HT and MHT, which are more exposed to foreign companies. MHT firms account for 7.91 percent of all observations. Similarly, MHT firms have the highest average capital value, which is nearly 403 percent higher than the average capital of all observations. Meanwhile, HT has the highest average number of workers, with 362 on average. MHT firms consume the most raw materials and energy, with 5.38 billion and 104.13 billion IDR, respectively. Foreign firm (FOR10) shares in each subsector range from 6 to 31 percent in the LT and HT sectors, respectively. The MHT sectors have the highest horizontal spillovers ratio, at more than 48 percent. However, HT firms account for approximately 34 percent of all imported materials. The MHT sectors have the highest market concentration (HHI) of about 11 percent, whereas the LT sectors have the lowest concentration (5 percent).

Table 3. Descriptive statistics.

Variables (Unit)	High Technology (HT)		Medium-High Technology (MHT)		Medium-Low Technology (MLT)		Low Technology (LT)	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Outputs (Billion Rupiah)	121.86	506.31	273.63	1515.50	62.87	486.59	51.37	494.97
Capital (Billion Rupiah)	531.83	9536.20	757.19	19,296.23	102.96	1925.10	138.22	7185.15
Labor (Workers)	362.95	651.93	271.71	713.31	157.14	656.53	185.18	720.87
Energy (Billion Rupiah)	1.84	14.87	5.38	56.18	2.64	37.85	0.97	11.31
Raw Material (Billion Rupiah)	70.90	447.83	104.13	559.67	34.07	342.17	29.57	305.38
Horizontal (*HSpill*)—Ratio	0.46	0.33	0.48	0.15	0.22	0.12	0.27	0.11
Imported Intensity (Ratio)	0.34	0.42	0.22	0.34	0.09	0.25	0.05	0.18
Foreign Ownership (Dummy)	0.31	0.46	0.25	0.43	0.09	0.29	0.06	0.24
Absorptive Capacity (Ratio)	16.81	0.98	16.87	1.02	16.12	1.28	15.86	1.33
Firm Size (Ratio)	0.01	0.02	0.00	0.02	0.00	0.01	0.00	0.01
Market Concentration HHI (Ratio)	0.06	0.04	0.11	0.07	0.07	0.07	0.05	0.09
Technology Adoption (*HSpill* × Abs)	7.81	5.64	8.11	2.65	3.58	1.94	4.36	1.89
Competition Effects (*HSpill* × HHI)	0.04	0.05	0.06	0.06	0.01	0.02	0.01	0.01

Observations: HT 1286; MHT 5318; MLT 13,409; LT 47,181.

3.2. Method

We employed the time-varying stochastic production function (SF) of Battese and Coelli [48], estimated using maximum likelihood. We used transcendental logarithmic (Translog) as the primary stochastic production frontier model. Translog is preferred as it is more flexible for recognizing non-fixed substitution elasticity. Similarly, the Translog function imposes fewer constraints than a general logarithm linear model (e.g., Cobb–Douglas [49]). Moreover, the Translog function does not inflict constant elasticity of substitution, as the Cobb–Douglas does [50,51], often delivering more appropriate estimations. Employing the SF allows for estimating the parameters of the stochastic frontier and the inefficiency function simultaneously in a panel data setting, making it possible for exogenous factors to be included [8]. Our baseline Translog model is in the following form:

$$\begin{aligned} y_{it} = \beta_0 + \beta_1 k_{it} + \beta_2 l_{it} + \beta_3 e_{it} + \beta_4 r_{it} + \tfrac{1}{2}\beta_5 (k_{it})^2 + \tfrac{1}{2}\beta_6 (l_{it})^2 + \tfrac{1}{2}\beta_7 (e_{it})^2 + \tfrac{1}{2}\beta_8 (r_{it})^2 + \beta_9 (k_{it} \times l_{it}) \\ + \beta_{10}(k_{it} \times e_{it}) + \beta_{11}(k_{it} \times r_{it}) + \beta_{12}(l_{it} \times e_{it}) + \beta_{13}(l_{it} \times r_{it}) + \beta_{14}(e_{it} \times r_{it}) + \beta_{15} t \\ + \tfrac{1}{2}\beta_{16}(t^2) + \beta_{17}(k_{it} \times t) + \beta_{18}(l_{it} \times t) + \beta_{19}(e_{it} \times t) + \beta_{20}(r_{it} \times t) + \sum_{k=1}^{K} \beta_k Z k_{it} + v_{it} - u_{it} \end{aligned} \quad (2)$$

where y is the total output, and inputs consist of capital (k), labor (l), energy (e), and raw materials (r). All output and inputs are expressed in the natural logarithm (ln) and as a deviation from their geometric means. Subscripts i and t denote the i-th firm and t-th year, respectively. Zk represents K exogenous variables associated with the inefficiency function. The Zk vector includes horizontal spillover, import intensity, foreign ownership, absorptive capacity, firm size, HHI, and the interaction between horizontal spillover and absorptive capacity. v_{it} is the SF model's random variable assumed as $iid.\ N(0, \sigma_v^2)$, and u_{it} is a non-negative random variable assumed as the truncated half-normal $N^+(\mu_i,\ \sigma_u^2)$ in distribution. The assumption of the truncated half-normal distribution adheres to the model of [48], with a more flexible assumption on the distribution (see [52]). u_{it} is also the inefficiency parameter that captures the inefficiency effects specified as follows:

$$u_{it} = \delta_0 + \sum_{k=1}^{K} \delta_k Zk_{it} + \omega_{it} \tag{3}$$

where δ_k represents the coefficients of inefficiency effects that consist of K exogenous variables, and ω_{it} is an error term in the inefficiency equation.

Applying the stochastic frontier approach limits stringent mechanisms because it requires precise specification forms and causes numerical and statistical samples in infinite samples to be unstable [9]. An additional test, such as the generalized log-likelihood test [53], is required to select the proper specification form to maintain the numerical and statistical samples' stability. Our baseline model is Translog (Model 1). Meanwhile, we refer to two alternative production functions: Hicks-neutral technological progress (HN, Model 2) and Cobb–Douglas (CB, Model 3). A null hypothesis (H_0) posits that the CD model omits the coefficients of time-squared and excludes coefficients related to time ($\beta_{nm} = \beta_{nt} = \beta_{tt} = 0$). The HN model omits the coefficients of interacting input with time ($\beta_{nt} = 0$).

The appropriate log-likelihood approach is chosen by comparing the likelihood ratio statistics from each model. The log-likelihood statistic is determined from $\lambda = -2[l(H_0) - l(H_1)]$, where $l(H_0)$ is the log-likelihood statistic of the CD and HN models. $l(H_1)$ is the log-likelihood value of the Translog. We reject the null hypothesis if the λ statistic is less than the χ^2 table with degrees of freedom equal to the number of parameters involved in the restrictions.

4. Empirical Findings

This section presents the estimation results as follows. The first consideration is to run the log-likelihood test on the proposed models (Models 1–3) to determine the preferable production frontier. Second, two approaches are used to investigate the impact of FDI spillover effects: (i) through production effects and (ii) through inefficiency effects. The production effects indicate the expansion or contraction of the production frontier, which will be interpreted as productivity effects. Furthermore, coefficients show whether the variables have a positive or negative impact on output growth. Meanwhile, the inefficiency effects indicate whether the variables are associated with higher or lower inefficiency in firms.

Table 4 illustrates each group's generalized log-likelihood test decision to choose the preferable production frontier in this study [8,9]. By referring to α =1 percent in χ^2, we show in Table 4 that $\lambda > \chi^2$ for the MHT and LT group, suggesting the suitability of the baseline Model 1 (Translog). Meanwhile, HT, MLT, and LT groups are ideal for Model 2 (Hicks-neutral, HN).

Table 4. Hypothesis testing of production functions.

Technology Intensity	Log-Likelihood Ratio		Decision
	Model 2 (df = 4)	Model 3 (df = 16)	
High Technology	7.20	296.39	Model 2
Medium-High Technology	19,589.09	21,250.95	Model 1
Medium-Low Technology	−79.12	3427.83	Model 2
Low Technology	566.56	9704.43	Model 1
Chi-Square	13.27	31.99	

Note: Model 1 serves as the baseline.

Table 5 reports the estimated coefficients of the production function (upper section) and the exogenous variables' inefficiency effects (lower section). Complete estimates of the production function are presented in the Appendix A (Table A1). Due to space constraints, only the variables of interest and the results based on the preferred model are displayed for each group (Table 5). The results are organized into groups based on technological intensity: (1) HT, (2) MHT, (3) MLT, and (4) LT. Furthermore, the spillover effects for domestic firms are estimated separately from all firms (including from foreign firms) in Table 5. In this regard, we only capture the effects of domestic firms, dividing the effects captured by MNCs within the same sector [29]. For instance, the coefficient FOR is excluded, but horizontal spillovers and their interactions are calculated from the original samples.

Table 5. The estimation of stochastic production frontier.

Variables	HT		MHT		MLT		LT	
Production Function	**All Firms**	**Local Firms**	**All Firms**	**Local Firms**	**All Firms**	**Local Firms**	**All Firms**	**Local Firms**
Demonstration Effect (Horizontal Spillover)	0.547	1.137	4.201 ***	3.636 ***	4.009 ***	4.011 ***	−2.150 ***	−3.221 ***
	(0.918)	(0.934)	(1.263)	(0.709)	(0.471)	(0.528)	(0.374)	(0.406)
Absorptive Capacity (Average labor Cost)	0.088 ***	0.094 ***	0.247 ***	0.217 ***	0.124 ***	0.118 ***	0.043 ***	0.044 ***
	(0.030)	(0.029)	(0.038)	(0.022)	(0.008)	(0.009)	(0.007)	(0.007)
Technology Adoption Effect (Labor Mobility)	−0.028	−0.068	−0.235 ***	−0.174 ***	−0.175 ***	−0.165 ***	0.117 ***	0.167 ***
	(0.055)	(0.055)	(0.073)	(0.047)	(0.028)	(0.031)	(0.023)	(0.026)
Market Concentration (HHI)	2.498	−0.413	0.631	1.508 ***	0.442 ***	0.466 ***	0.016	−0.029
	(1.797)	(0.899)	(0.548)	(0.587)	(0.139)	(0.139)	(0.053)	(0.052)
Competition Effect (HHI × *HSpill*)	1.222	0.193	−1.983 ***	−3.327 ***	−5.242 ***	−5.589 ***	8.116 ***	10.734 ***
	(2.089)	(0.991)	(0.776)	(0.822)	(0.644)	(0.686)	(0.515)	(0.636)
Import Material	0.200 ***	0.192 ***	0.115 ***	0.110 ***	0.148 ***	0.217 ***	0.099 ***	0.183 ***
	(0.049)	(0.057)	(0.036)	(0.039)	(0.024)	(0.031)	(0.018)	(0.024)
FOR	0.291 ***		0.237 ***		0.245 ***		0.168 ***	
	(0.054)		(0.029)		(0.021)		(0.015)	
Firm Size	40.410 ***	33.086 ***	74.306 ***	61.242 ***	15.311 ***	13.481 ***	290.890 ***	196.846 ***
	(2.546)	(2.343)	(5.410)	(3.292)	(1.270)	(1.246)	(4.364)	(41.804)
Inefficiency Effects								
Demonstration Effect (Horizontal Spillover)	2.954	−23.704 ***	53.768 ***	49.613 ***	31.422 ***	26.857 ***	−12.899 ***	−40.922 ***
	(2.878)	(1.136)	(12.073)	(6.170)	(2.060)	(1.017)	(1.051)	(1.584)
Absorptive Capacity (Average labor Cost)	−0.737 ***	−0.873 ***	1.490 ***	0.839 ***	0.214 ***	−0.056	−0.102 ***	−0.145 ***
	(0.166)	(0.088)	(0.368)	(0.216)	(0.091)	(0.016)	(0.015)	(0.028)
Technology Adoption Effect (Labor Mobility)	0.291 **	1.301 ***	−2.964 ***	−2.277 ***	−0.430 ***	−0.105 ***	0.645 ***	2.162 ***
	(0.153)	(0.071)	(0.657)	(0.376)	(0.132)	(0.065)	(0.063)	(0.113)
Market Concentration (HHI)	−24.916 ***	15.370 ***	6.209 **	3.015 ***	16.882 ***	7.528 ***	−0.140	−0.998 ***
	(7.374)	(1.727)	(2.738)	(0.937)	(0.865)	(0.733)	(0.134)	(0.188)
Competition Effect (HHI × *HSpill*)	−34.698 ***	−13.196 ***	−23.362 ***	−27.087 ***	−127.991 ***	−102.852 ***	22.849 ***	42.166 ***
	(11.815)	(0.972)	(4.506)	(3.523)	(2.212)	(2.475)	(1.665)	(5.098)
Import Material	2.181 ***	−0.493 *	0.207	1.165 ***	2.074 ***	2.819 ***	0.399 ***	1.004 ***
	(0.791)	(0.285)	(0.192)	(0.357)	(0.087)	(0.214)	(0.054)	(0.134)
FOR	4.202 ***		0.985 ***		3.989 ***		0.311 ***	
	(0.789)		(0.125)		(0.106)		(0.041)	
Firm Size	81.364 ***	72.881 ***	74.577 ***	80.476 ***	43.973 ***	40.402 ***	286.411 ***	195.251 ***
	(13.279)	(4.482)	(5.124)	(4.272)	(1.524)	(1.498)	(4.349)	(40.908)
Observations	1286	885	5318	3974	13,409	12,177	47,181	44,155

Note: ***, **, and * denote significance at 1, 5, and 10 percent, respectively. Standard errors are in parenthesis. Coefficients of input variables are not displayed due to space limitations (see Appendix A Table A1). Coefficients for the production function (upper panel) and inefficiency function (lower panel).

4.1. Demonstration Effect (HSpill)

Demonstration effects stem from the imitation and reverse engineering linked to MNCs, such as expertise and organization and marketing practices. The capability of workers to understand and apply such practices can lead to productivity and efficiency gains. Our results indicate that for both MHT and MLT sectors, demonstration effects (*HSpill*) are positive and help boost the domestic firms' production. In other words, the increasing presence of foreign companies within the MHT and MLT sectors positively affects the productivity level of firms, thereby supporting H1. By contrast, firms within LT sectors have a negative demonstration effect (*HSpill*) on productivity, suggesting that MNCs are detrimental to productivity gains in LT industries, thus rejecting H1. Orlic et al. [15] discovered negative *HSpill* in the European transition countries' manufacturing sector. However, by aggregating manufacturing firms into a single group [15], they may have failed to capture positive *HSpill* impacts in specific sectors.

It is frequently stated that LT firms have low absorptive capacity due to low skills among workers and less sophisticated managerial practices when compared to MNCs or large firms [9,33,54]. A significant knowledge gap between domestic and MNC firms may also explain why domestic firms (in the LT sectors) are unable to imitate advanced knowledge and increase productivity [11]. Similarly, LT sectors are associated with exploitative innovation rather than open innovation because most developing countries are only concerned with the imitation process. Meanwhile, domestic firms are able to absorb and replicate MNC practices as the knowledge gap between higher-tech sectors and MNCs narrows.

However, demonstration effects have the opposite impact on the technical efficiency of firms. MHT and MLT firms report higher inefficiency levels due to higher participation of foreign firms in the sector (horizontal spillover), thereby rejecting H2 for MHT and MLT firms. By contrast, LT firms gained technical efficiency from horizontal spillovers (demonstration effect), suggesting that larger FDI in LT sectors has a benefit on technical efficiency of LT firms, supporting H2. Technical efficiency may derive from improvements in managerial practices and organizational arrangements that local firms imitate from MNCs. Although LT firms may not be able to imitate advanced technological progress from MNCs, LT firms may be able to apply managerial and organizational practices that result in higher efficiency.

According to Jin et al. [17], FDI in LT sectors may harm domestic firms' production through demonstration effect. Our findings on demonstration effects (*HSpill*) for low-tech are similar to those of Suyanto et al. [11], who discovered that sectors such as food and beverages and textiles (low-tech) gained technical efficiency but not productivity spillovers as a result of increased foreign presence. Other studies in Indonesia [8,36] found that demonstration effects (*HSpill*) positively affect firm efficiency. However, we contend that the impact of *HSpill* is felt primarily in the LT and HT sectors, but not in MHT and MLT. Increased worker absorption capacity in domestic firms can aid the process of open innovation by allowing domestic firms to learn from more technologically advanced firms [55]. Policies and firms should work on detailed identification of workers' skills, competencies, and capabilities across sectors needed to support innovation and technological change [56].

4.2. Technology Adoption Effect

The interaction of absorptive capacity and horizontal spillovers, which illustrates the effects of labor mobility, is used to estimate technology adoption. Before discussing technology adoption, we first discuss absorptive capacity. The empirical findings show that all groups improve productivity, implying that skills (human resources) positively affect firm performance, which is consistent with the literature on FDI spillovers [8,15,57]. Adoptive capacity denotes a firm's ability (via labor) to comprehend and implement novel technologies [37]. Furthermore, both HT and LT sectors improve efficiency through absorptive capacity. A rise in average wages per worker frequently demonstrates workers' increasing ability to absorb external open knowledge and technologies [15]. According to our estimates, a 1 percent increase in workers' wages is associated with a 0.043 percent to 0.247 percent increase in their productivity.

As skilled professionals are required for R&D, a higher-skilled labor allocation in the HT group unsurprisingly leads to greater efficiency. The spillover effects (absorptive capacity) from efficiency are more extensive than those from production growth in the LT group, possibly indicating that LT firms are less engaged in R&D and advanced production activities than higher-tech firms. Because R&D requires resources and is fraught with uncertainty, less technologically capable firms may adopt open technologies, selecting those that best suit their capabilities and needs [4]. As demonstrated in the case of Mexico [54], the introduction of open innovation practices can enable small firms (or LT firms) to access external resources from various partners (e.g., buyers, clients, competitors, and government) at a lower cost, reducing risk and increasing the impact of external sources of knowledge.

Only HT firms report significant and positive effects on productivity and efficiency via the absorptive capacity channel, suggesting that larger participation of skilled workers increases firms' performance, mainly in HT sectors. The findings indicate that FDI benefits may be gained mainly by firms with sizable absorptive capacity (often high-tech or large), as they can capitalize on the presence of MNCs to increase productivity and lower inefficiency. This finding is in line with Jin et al. [17].

Regarding the technology adoption effect, we found that the effects of FDI through the technology adoption channel harm firms' productivity within MHT and MLT (accept H3) but have a positive effect on the productivity of LT firms (reject H3). However, our results on the impact of technology adoption on a firm's efficiency suggest that it can play a positive role in the technical efficiency of MHT and MLT firms, but it has a dampening effect on the efficiency of HT and LT firms. The results suggest accepting H4 for MHT and MLT, but rejecting H4 for LT firms. As noted in the literature, workforce skills, capabilities, and competencies are diverse, complex, and dynamic [55], suggesting that the MHT and MLT sectors may lack complementary skills among workers to tackle the productivity and efficiency challenges that their sector demands.

Our findings support previous work [37,58] stating that foreign firms partnering with domestic firms may provide access to higher technology and knowledge merely to apply and adapt advanced technology, but not to support total technological transfers. Meanwhile, the parent company continues to develop core technology at its headquarters. In this sense, technological spillover helps firms improve their performance (efficiency), but it does not support technological transformation of firms. Our findings back up previous research claiming that foreign firms can prevent knowledge and technology leakage to domestic competitors [15,57,59].

Furthermore, although experienced personnel (skilled workers) may successfully learn and apply foreign technology in local firms [56], resulting in technical efficiency, they may be unable to enhance their technological progress. Meanwhile, for LT firms, absorptive capacity and technology adoption processes support firm productivity. This finding is consistent with previous arguments that LT sectors in developing countries can improve productivity by absorbing basic technologies brought by MNCs, even if they are inefficient. The majority of LT subsectors are classified as unskilled labor-intensive. The findings suggest that workers may lack complementary skills and capabilities [56] to successfully learn, implement, and deploy MNC-provided technologies, which can affect both efficiency and productivity. Companies should invest in human resource practices such as training to develop more innovative employees, to increase relationships with external partners (e.g., MNCs), and to emphasize collaboration to participate in knowledge sharing.

4.3. Competition Effect

The spillover effects on firm productivity and efficiency through the competition channel differ in sign and magnitude across sectors. We found that the competition does not contribute to productivity improvement in the HT and LT sectors, thus rejecting H5 for HT and LT firms. In contrast, the competition effect on MHT and MLT indicates that higher market competition leads to productivity gains, as we initially proposed in H5. A larger market concentration hints at less competition. As foreign firms increase output and gain a share of the total market, they discourage productivity gains by domestic firms, thus depressing competition. When the market competition is fair, the presence of MNCs can benefit the recipient sector, as noted in earlier studies [4]. By contrast, when the concentration is high, firms holding a large market share (HHI) report gains in productivity at the expense of smaller firms.

Despite this, increased market share is associated with lower levels of efficiency for HT, MHT, and MLT. This argument is consistent with the hypothesis of the market-stealing phenomenon, which has been noted in previous studies [9,10,36,39]. Foreign firms tend to escalate market power by utilizing superior technology and practices, thereby taking market share from less competitive domestic firms [15,36]. On the contrary, encouraging a more competitive environment (lower market concentration) is linked to more efficient production in the HT, MHT, and MLT sectors, thus accepting H6. These findings imply that investment policies should encourage a more open system of technologies and knowledge access, allowing all players to compete on equal footing, and that the presence of MNCs leads to a more competitive landscape, not a less competitive one. Previous research [4] also suggests that more competitive environments help in increasing spillover effects from MNCs. Previous research in Indonesia has mostly found a negative spillover effect on efficiency via the competition channel (similar to our estimates for LT firms). However, earlier studies pooled firms in a single panel data set to group firms according to more homogenous characteristics [36] and to observe the positive impact of MNCs on efficiency in higher-tech firms (HT, MHT, and MLT).

4.4. Control Variables (Import Material, FOR, and Firm Size)

Regarding other controlled variables, we identified somewhat similar effects in the production and the inefficiency functions across groups of firms. Foreign ownership (FOR) positively contributes to production growth, although it negatively affects the technical efficiency of recipient firms. Firms with larger sizes can achieve higher production capacity but lower efficiency. Moreover, foreign companies have relatively higher output in all subsectors than purely domestic firms, by about 16.8 percent to 29.1 percent. Meanwhile, we found that foreign companies tend to have lower technical efficiency. This finding is relatively similar to those of earlier studies [8,11,29,33], suggesting that foreign firms mainly outperform domestic firms via productivity and scale.

Large firms are more productive than their smaller counterparts, benefiting from size via productivity, scale, and technical change [60]. Still, large firms seem to record lower efficiency, as inputs (resources) management may be more complex to run. This finding is unsurprising, as larger firms have higher technology and capital to produce more output [45], although it does not mean they operate at a higher efficiency level [8,61,62]. This finding suggests that although large firms allocate more resources for R&D, as noted in Avalos-Quispe [54], resources do not promote efficiency but mainly technological improvements.

Access to imported materials significantly boosts firm production. We discovered that increasing the use of imported materials by 1 percent could increase productivity by about 0.01 to 0.218 percent. However, the findings suggest that firms importing materials face higher levels of inefficiency. The conclusion is consistent with the technical efficiency effects observed in foreign-owned and large firms in Indonesia [36], implying that imported materials in Indonesia are associated with higher quality goods rather than more efficient production. Transfers of technology have also been studied in the context of Vietnam, implying that firms may gain access to higher technologies through foreign purchasing [4]. Importing technological advancements is a more viable option for firms lacking R&D resources.

4.5. Discussion at the Technology Group

We look at specific groups to analyze our findings. First, we focus on the HT group of firms, consisting of, for example, computers and electronics and pharmaceutical subsectors. Regarding firms within the HT sectors, productivity gains are mainly derived from absorptive capacity, firm size, foreign input use, and foreign investors' ownership (FDI). However, the productivity of HT firms does not improve through the channels of technology adoption nor the competition effects. This finding supports the argument of Suyanto and Salim [29], who noted that domestic firms in the pharmaceutical industry (high-tech) learn little from foreign firms. The demonstration effect and competition significantly affect local firms' efficiency but do not foster productivity growth. For instance, FDI mainly helps HT firms to improve their efficiency performance. Policies to support increasing absorption capability, labor mobility, and the scale of operation may help firms within the HT sector to absorb more extensive knowledge and technology needed to increase productivity.

Regarding MHT and MLT, productivity gains arise from horizontal spillover and absorptive capacity. However, MNCs harm productivity through technology adoption and competition. Furthermore, foreign investment can encourage gains in efficiency in MHT and MLT firms. Policy makers can expect a larger impact from MNC presence through efficiency gains than through productivity. Additionally, MLT and MHT sectors include chemical, metals, electrical equipment, machinery, motors, and trailers, among others, where MNC firms may seek to produce at high volumes (efficiently). As for LT sectors, the presence of MNCs can help increase production through absorptive capacity, labor mobility, and competition (possibly indicating the need to scale up).

4.6. Discussion: The Relationship between FDI and Open Innovation

FDI is hypothetically expected to generate both productivity gains and managerial expertise that may result in technical efficiency improvement. The linkages MNCs create with domestic firms through the different channels of labor mobility, competition, and absorptive capacity [31] are all related to the concept of open innovation. Governments worldwide provide incentives for MNCs to invest in host countries on the premise that the presence of foreign firms will contribute to the sharing of knowledge, practices, technologies, and knowledge, resulting in gains in efficiency and productivity [7,63]. The spillovers from FDI can occur directly and indirectly, or voluntary and involuntarily. In any case, knowledge and technologies are expected to be transferred to domestic firms to some degree. Although governments actively offered incentives for MNCs, policy makers are less active in designing a more open innovation system in which the transmission of knowledge and technology from MNCs to local firms can have a larger impact. So far, we found that the benefits depend on firms' absorptive capacity, suggesting that potential benefits from MNC presence remain untapped.

Generally, all four groups benefit from horizontal spillover via either productivity or technical efficiency channels. Nevertheless, we found that among the four groups of firms, none of them gain both the benefits of horizontal spillover via productivity and technical efficiency mechanisms. This finding indicates that a firm may boost its production level by demonstration, technology adoption, or competition, but it may not necessarily improve its managerial expertise (technical efficiency). However, firms may improve in efficiency but experience low productivity levels. We argue that accounting for heterogeneity in a firm's capabilities to absorb, learn, and implement new knowledge and technologies is important [54]. Helping firms build capabilities to engage in the flow of open knowledge and technologies may be crucial to increasing MNCs' impact.

In the results, the impact of FDI on firms' productivity is noticeably generally positive through an absorptive capacity (proxied by average labor cost per worker) and firm size, suggesting that skilled workers and large firms grasp the most benefits from FDI. Government and firms may support the development of labor skills, capabilities, absorptive capacity [31], and competencies that firms need to face competition challenges and technological change. Adopting an open innovation system may be crucial for firms (domestic and

MNCs) to increase performance (efficiency and productivity) and remain competitive in the market. Open innovation suggests that innovative practices can be enhanced by acquiring knowledge from outside sources (e.g., MNCs' presence in the country) and engaging with external partners to commercialize knowledge resources developed within the firm.

Our findings suggest that the manufacturing sector must improve firms' absorption capacity to benefit more from FDI. A potential way of increasing absorption capacity is by improving labor mobility. Calì et al. [25] noted that Indonesia faces one of the highest labor mobility costs in Asia, more evident for low-skilled workers, finding that controlling housing prices and improving infrastructure can help reduce mobility costs. Meanwhile, Bryan and Morten [24] also noted that removing barriers to mobility in Indonesia can boost productivity by 22 percent, although noting that targeted policies may be more effective as impacts are localized (i.e., some communities and sectors benefit more than others). We support the need for localized policies, as the impacts of FDI differ across sectors.

Interestingly, according to Calì et al. [25], job-seeking advertisements do not appear to promote more efficient labor mobility, implying that a labor–job mismatch exists in the manufacturing sector, particularly for medium-low skilled workers. According to the World Bank Enterprise Survey (2015), nearly 55 percent of Indonesian firms report difficulty hiring production workers (skilled) with the necessary skills, and 55 percent of companies report higher wage expectations from applicants. Mismatching is lower for jobs pertaining to unskilled workers, whereas mismatching for jobs requiring higher-skilled workers appears to be lower, as noted in earlier studies in Indonesia [25,26,64].

The promotion of an open innovation framework for manufacturing is expected to increase interaction between foreign and domestic firms, fostering mutual support, a larger exchange of knowledge, technological transfers, and the sharing of practices that can benefit both MNCs and domestic firms [47]. Previously successful public policies to promote open innovation systems at the regional and local level have been documented [65]. Public policy can promote collaboration for technological improvement and innovation among firms (domestic and foreign), entrepreneurs, research units, and the public sector, facilitating collaborative innovation [66]. MNCs can benefit from more efficient domestic suppliers, more skilled and innovative labor force, a large customer base in host countries, and a growing understanding of domestic practices and innovations that can help them compete in foreign markets [66–68]. We argue that open innovation efforts should take into account the channels through which spillovers occur, such as the technology adoption capacity of firms and workers [54,55,69], demonstration effects fueled by workers mobility, and market competition.

4.7. Limitations and Future Research

Our research is not free of limitations. First, although we tried disentangling the horizontal spillover effects at homogenous groups of firms (based on technology intensity), such aggregation is still likely to produce some bias in the results. Resources and capabilities across sectors and firms are diverse, suggesting that further disaggregation is needed. Employing more specific firm data would help explore heterogeneity in firms and sectors to a greater extent.

Second, our measurement of horizontal spillovers primarily captures the effects of demonstration and competition while failing to provide more in-depth effects from technological spillovers. Using more disaggregated data and alternative methodologies may allow for more specific effects of technological spillovers to be captured. Moreover, considering the relevance of competition effects in our results and the possibility of market stealing phenomena, future research may explore the mechanism by which foreign firms affect domestic firms' survival and market structure changes. Additionally, demonstration effects seem to require a higher degree of analysis, limited now by a lack of data (e.g., worker mobility, skills, and wage data across firms are inexistent in Indonesia).

Third, future research may consider the vertical spillover effects through the backward and forward linkages in homogeneous groups of firms. The benefits from MNCs in a host country may likely differ across sectors. For example, manufacturing firms in developing countries may benefit from the presence of MNCs from the service sector that can serve advanced needs that local service firms cannot provide competitively. Similarly, identifying sectors in which MNCs have larger horizontal spillover effects and vertical spillovers (through the backward and forward linkages) can help devise targeted policies.

Fourth, firm heterogeneity is a promising area for future research, given that the origins of MNCs firms, entry strategies, ownership structures, technological capabilities, and technological strategy, among other factors, are likely to magnify the impact of spillovers. Similarly, the heterogeneity of domestic firms in terms of internationalization process, technological capabilities, skill intensity, orientation, and technological strategies, among others, is likely to play a moderating role in spillover transmission. Unfortunately, data constraints are a significant barrier to overcome in future research.

5. Conclusions and Implications

For four technological sectors in Indonesia, we have demonstrated the potential FDI spillovers from various channels, namely, demonstration, technology adoption, and competition. We employed stochastic frontier analysis to examine the manufacturing sector in Indonesia from 2011 to 2015. We investigated whether FDI spillovers (via technology adoption, demonstration, and market competition), firm size, and access to imports influence Indonesian firms' production capacity and technical efficiency.

The findings show that all types of firms—HT, MHT, MLT, and LT intensity—benefit from the presence of foreign investment in Indonesia, whether in terms of productivity or technical efficiency. None of these groups profit from both channels (production and efficiency together). The findings indicate that if a firm gains benefits and raises its production level from demonstration, technology adoption, or competition, its technical efficiency is not necessarily improved. Productivity gains may come at the expense of lower efficiency, or vice versa.

The HT firms benefit from FDI spillovers in productivity and efficiency, depending on firms' absorptive capacity. However, no evidence indicates that HT firms benefit from technology adoption or demonstration effects. On the contrary, we identify that the demonstration effect is positive for MHT and MLT firms in boosting domestic firms' production. Nonetheless, the demonstration effect promotes technical efficiency in LT firms while decreasing output in local firms. Prior research in Indonesia has argued that less advanced technology groups may adopt new technology from foreign companies to boost production even though it does not improve their technical efficiency because they rely heavily on unskilled labor. In this sense, FDI supports the use of foreign techniques in new markets but does not appear to foster technological capability in LT firms. The results suggest that the impact of MNCs within manufacturing highly depends on the absorptive capabilities of workers and firms to benefit from open innovation in the form of knowledge, practices, technologies, and knowledge that MNCs bring to host countries.

Earlier studies in Indonesia found evidence of positive horizontal spillover effects in the manufacturing sector. However, we contribute to the existing literature by providing evidence on the need to estimate spillovers at disaggregated groups of firms. Companies have different absorptive capacities and different innovation strategies; hence, generalizations of the impacts of horizontal spillovers in the sector may be unprecise. Drawing on the concept of absorptive capacity, we determine that differences in workers' skills, technological intensities, and differences in access to resources play important roles in the capability of firms to benefit from external knowledge and technologies. The benefits of open knowledge are likely to be moderated by the existing mechanisms in the market, the degree of openness in technologies, and the capability of firms to employ knowledge and technology in business practices and innovation activities.

We add to the existing literature by demonstrating that the effects of incoming FDI differ across groups of firms, implying that clustering firms into homogeneous groups aids in reducing estimation bias. Although MT firms experience efficiency gains, they also experience productivity losses. Meanwhile, LT firms increase productivity but lose efficiency. For example, FDI provides significant benefits to firms. However, it may have indirect effects, such as crowding out effects in the labor and capital markets, increased production costs, and lower profitability of less efficient firms. In some cases, FDI influxes may create the possibility of market stealing in the presence of market imperfections. Differences are most likely due to different access to knowledge, different capabilities to absorb technology, and different firm strategies. Gaps can be filled by establishing a more open innovation system that improves transmission mechanisms and encourages knowledge sharing.

Allowing FDI inflows remains critical, although government policies may need to assist domestic firms in building the capacity to benefit from foreign players' technological and managerial knowledge. The government of the host country should ensure that FDI recipient sectors have the technical capacity to benefit from foreign presence. Earlier studies in other geographies [56] embarked on a detailed assessment of workers' skills, capabilities, and competences that can help assess the necessary additional resources and capabilities for firms to increase absorption capacity and drive change. Furthermore, expanding regional research, collaboration, and innovation programs [66,67] can assist firms in increasing their capabilities to absorb knowledge, improve innovation competencies, and implement new technologies. Investment promotion policies in Indonesia (and likely in other developing countries) must be accompanied by capacity-building programs.

Moreover, supporting the creation of an open innovation system in the manufacturing sector can assist firms in capitalizing on the innovative capabilities of more competitive players (i.e., MNCs, large firms, or high-tech intensity firms). Linkages that domestic and foreign firms hold (horizontally or vertically) can increase firms' and workers' innovation capabilities, resulting in higher firm performance as firms innovate in practices, products, and services, leading to higher efficiency and productivity. Human capital development must be accelerated for this to occur. Lastly, higher training quality may help local firms catch up and, as a result, absorb the benefits of foreign companies more quickly.

Author Contributions: Conceptualization, M.Z.Y. and M.A.E.; methodology, M.Z.Y. and R.P.; validation, L.S., D.P. and R.P.; formal analysis, M.Z.Y.; investigation, M.A.E.; resources, L.S.; data curation, M.Z.Y.; writing—original draft preparation, M.A.E.; writing—review and editing, D.P. and L.S.; supervision, R.P.; funding acquisition, L.S. All authors have read and agreed to the published version of the manuscript.

Funding: The APC was funded by Universitas Airlangga.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The raw data was obtained from the national survey for the large and medium manufacturing sector by the Indonesian Central Bureau of Statistics (BPS) from 2011 to 2015. https://www.bps.go.id/subject/9/industri-besar-dan-sedang.html#subjekViewTab1 (accessed on 28 April 2022).

Acknowledgments: The project presented in this article was supported by the Direktorat Riset dan Pengabdian Masyarakat, Direktorat Jenderal Penguatan Riset dan Pengembangan Kementerian Riset, Teknologi, dan Pendidikan Tinggi Republik Indonesia.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Estimation of production function and inefficiency effects for all technology groups.

Production Frontier		High Technology Coeff	SE	Medium-High Technology Coeff	SE	Medium-Low Technology Coeff	SE	Low Technology Coeff	SE
Constant	β_0	−0.889	0.525	−3.803 ***	0.644	−2.266 ***	0.140	−0.703 ***	0.111
k	β_1	0.025 *	0.013	0.058 ***	0.007	0.036 ***	0.003	0.041 ***	0.001
l	β_2	0.108 ***	0.013	0.097 ***	0.007	0.087 ***	0.003	0.086 ***	0.001
e	β_3	0.407 ***	0.030	0.390 ***	0.016	0.239 ***	0.008	0.239 ***	0.004
r	β_4	0.515 ***	0.016	0.565 ***	0.008	0.661 ***	0.004	0.638 ***	0.002
k^2	β_5	0.003	0.005	0.005 ***	0.002	0.009 ***	0.001	0.004 ***	0.001
l^2	β_6	−0.028	0.032	0.092 ***	0.017	0.071 ***	0.009	0.039 ***	0.004
e^2	β_7	0.033 ***	0.008	0.042 ***	0.004	0.047 ***	0.002	0.040 ***	0.001
r^2	β_8	0.099 ***	0.010	0.116 ***	0.005	0.118 ***	0.002	0.149 ***	0.001
$k \times l$	β_9	0.028 ***	0.011	0.024 ***	0.005	0.038 ***	0.003	0.028 ***	0.002
$k \times e$	β_{10}	−0.012 ***	0.005	0.010 ***	0.003	−0.004 ***	0.001	0.007 ***	0.001
$k \times r$	β_{11}	−0.020 ***	0.006	−0.030 ***	0.003	−0.020 ***	0.001	−0.037 ***	0.001
$l \times e$	β_{12}	0.008	0.010	−0.005	0.005	0.014 ***	0.003	0.017 ***	0.002
$l \times r$	β_{13}	−0.106 ***	0.013	−0.140 ***	0.006	−0.106 ***	0.003	−0.119 ***	0.002
$e \times r$	β_{14}	−0.048 ***	0.007	−0.049 ***	0.004	−0.042 ***	0.002	−0.053 ***	0.001
t	β_{15}	0.085 ***	0.018	0.007	0.009	0.029 ***	0.005	0.020 ***	0.002
t^2	β_{16}	−0.056 ***	0.024	−0.001	0.011	0.015 ***	0.006	−0.015 ***	0.003
$k \times t$	β_{17}			−0.006 ***	0.003			−0.001	0.001
$l \times t$	β_{18}			0.025 ***	0.008			0.013 ***	0.002
$e \times t$	β_{19}			0.000	0.003			0.003 ***	0.001
$r \times t$	β_{20}			−0.003	0.004			−0.008 ***	0.001
HSpill	β_{21}	0.547	0.918	4.201 ***	1.263	4.009 ***	0.471	−2.150 ***	0.374
Absp	β_{22}	0.088 ***	0.030	0.247 ***	0.038	0.124 ***	0.008	0.043 ***	0.007
HSpill × *Absp*	β_{23}	−0.028	0.055	−0.235 ***	0.073	−0.175 ***	0.028	0.117 ***	0.023
HHI	β_{24}	−2.498	1.797	0.631	0.548	0.442 ***	0.139	0.016	0.053
HSpill × *HHI*	β_{25}	1.222	2.089	−1.983 ***	0.776	−5.242 ***	0.644	8.116 ***	0.515
Import	β_{26}	0.200 ***	0.049	0.115 ***	0.036	0.148 ***	0.024	0.099 ***	0.018
FOR	β_{27}	0.291 ***	0.054	0.237 ***	0.029	0.245 ***	0.021	0.168 ***	0.015
Firm Size	β_{28}	40.410 ***	2.546	74.306 ***	5.410	15.311 ***	1.270	290.890 ***	4.364
Inefficiency Effects									
Constant	δ_0	−4.057	3.611	−29.190 ***	6.642	−19.741 ***	1.391	1.266 ***	0.243
HSpill	δ_1	2.954	2.878	53.768 ***	12.073	31.422 ***	2.060	−12.899 ***	1.051
Absp	δ_2	−0.737 ***	0.166	1.490 ***	0.368	0.214 ***	0.091	−0.102 ***	0.015
HSpill × *Absp*	δ_3	0.291 *	0.153	−2.964 ***	0.657	−0.430 ***	0.132	0.645 ***	0.063
HHI	δ_4	−24.916 ***	7.374	6.209 **	2.738	16.882 ***	0.865	−0.140	0.134
HSpill × *HHI*	δ_5	−34.698 ***	11.815	−23.362 ***	4.506	−127.991 ***	2.212	22.849 ***	1.665
Import	δ_6	2.181 ***	0.791	0.207	0.192	2.074 ***	0.087	0.399 ***	0.054
FOR	δ_7	4.202 ***	0.789	0.985 ***	0.125	3.989 ***	0.106	0.311 ***	0.041
Firm Size	δ_8	81.364 ***	13.279	74.577 ***	5.124	43.973 ***	1.524	286.411 ***	4.349
σ^2		6.355 ***	1.015	1.286 ***	0.077	2.823 ***	0.032	0.440 ***	0.008
γ		0.970 ***	0.006	0.806 ***	0.010	0.939 ***	0.001	0.693 ***	0.004

Note: ***, **, and * are significant at 1, 5, and 10 percent. SE, standard deviation. Coefficients for the production function (upper panel) and inefficiency function (lower panel).

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