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The Impacts of Foreign Direct Investment and Export Expansion on the Performance of the High-Tech Manufacturing Industry

(Impak Pelaburan Asing Langsung dan Pengembangan Eksport terhadap Prestasi Industri Berteknologi Tinggi)

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ABSTRACT

This study investigates the impact of foreign direct investment and export expansion on firm performance. Using firm-level data from the Indonesian high-tech manufacturing industry, we employ stochastic frontier analysis to determine firm efficiency. Our study provides evidence of negative backward and positive forward FDI spillovers on firms' efficiency level. The results further show that foreign firms in the high-tech manufacturing industry are more efficient than local firms. Furthermore, a greater degree of fragmented trade integration is related to better performance among firm in the high-tech manufacturing industry. This indicates the significance of the production of component goods relative to the finished goods. In terms of the policy, the authority might need to consider whether the existence of FDI benefits local producers beyond promoting trading of component goods of the high-tech manufacturing industry.

Keywords: Foreign direct investment; export expansion; high-tech manufacturing industry; stochastic frontier analysis
JEL: F14, F64, L63

ABSTRAK

Kajian ini bertujuan untuk meneliti kesan pelaburan asing langsung dan eksport ke atas prestasi firma. Menggunakan data di peringkat firma bagi industri teknologi tinggi Indonesia, kaedah analisis sempadan stokastik digunakan dalam menentukan tahap kecekapan firma. Keputusan menunjukkan bahawa terdapat bukti negatif ke arah belakang dan positif ke arah depan dari limpahan FDI ke atas kecekapan firma. Hasilnya juga membuktikan bahawa firma asing berteknologi tinggi lebih cekap daripada firma tempatan. Selanjutnya, semakin besar darjah integrasi perdagangan produk yang belum jadi maka semakin baik prestasi firma dalam industri berteknologi tinggi. Ini menunjukkan kepentingan pengeluaran barangan komponen relatif barangan siap. Dari segi dasar, pihak berkuasa mungkin perlu mempertimbangkan sama ada kewujudan FDI membawa faedah kepada pengeluar tempatan di samping mempromosikan perdagangan barangan komponen industri berteknologi tinggi.

Kata kunci: Pelaburan asing langsung; perluasan eksport; industri teknologi tinggi; Analisis Sempadan Stokastik

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INTRODUCTION

Global trade is a crucial determinant of economic growth and an essential feature of production acquisition. In this situation, trade usually refers to exchange for final goods. This measure is calculated by the exported goods divided by the total goods produced, which is recognized as export intensity and is reflected as key indicator of competitiveness. On the other hand, the phenomenon of global trade, shaped by manufacturers' usage of inputs which are imported by manufacturers to produce output which then exported, has not yet been entirely acknowledged. These phenomena mostly arise for foreign firms owned by multinational corporations (MNCs) that can unbundle their production process or sub-contract into other countries that have low-cost inputs.

This means that exporters from domestic plants export final goods using local inputs, while exporters from foreign plants owned by MNCs are allowed to unbundle their production process or outsource into other countries, for which usage inputs are cheap. Recently, several empirical studies have focused on the role of fragmented goods trade. A cross-border component goods trading, as a consequence of the fragmented production processes, has turned into a major feature in global transaction, especially for components of high-tech products. International trade of manufacturing high-tech components in East Asia has commonly grown faster than the total world trade (Athukorala 2011; Khalifah & Jaffar 2017; Natsuda & Thoburn, 2020; Torsekar & VerWey 2019).

Companies face some incentive to diversify their production plants into other countries. A push factor for foreign investors is labor costs. When they start looking around, Indonesia remains attractive for foreign assemblers owned by MNCs to relocate their plants. Some studies have found the cost of wages in Indonesia are the lowest in Asia. Indonesian monthly wages are around \$113 on average, which is less than the level of wages in Malaysia, Thailand, and China (Asian Development Bank 2015; Jomo 2019). Consequently, Indonesia has a comparative advantage and is a major host of MNCs and exporter of high-technology component products.

However, because high-quality components were not being produced locally, foreign firms imported the majority of their components and only assembled them domestically. The emergence of fragmented trade integration, which is usually conducted by MNCs, has raised the question of whether to take account of the high-export intensity of firms on high-tech product is a feasible policy choice under these conditions. Indeed, the impacts of FDI spillover and fragmented trade integration on firms' efficiency in the Indonesian high-tech industries are an outstanding case of study using firm-level data.

According to the Ministry of Industry of Republic Indonesia (2016), high technology industries, which include chemical and pharmaceutical, metal, machinery and electronic, and motor vehicles and other transport equipment industry were the top three industries receiving foreign direct investment during the years from 2012 to 2015, with the exception of 2014. Supporting evidence shows that the chemical and pharmaceutical industry attracted the highest inflow of annual FDI from 1975 to 2006 (Suyanto & Salim 2011). This evidence makes the study of production gains from FDI spillover effects appealing for investigation.

Furthermore, previous studies conducted by Abor (2010), Alegre et al. (2012), Estrin et al. (2008), Pla-Barber and Alegre (2007), and Wang and Ma (2018) measured export expansion using export intensity such as export over output. Since the majority of input components of high-tech manufacturing industries are imported and afterwards their output is exported, this measurement can be misleading. Therefore, this study contributes to the literature, and a more desirable measure of export expansion such as fragmented trade integration is implemented in the models.

Because high-tech manufacturing industries are a significant recipient of FDI and a subject of concern in measuring export expansion, hence this study proposes to investigate spillover effects from FDI and export expansion in determining firm performance among other explanatory variables in the high-tech manufacturing industry in Indonesia. Additionally, other environmental factors that could affect firm performance, namely foreign share, market competition, and scale of production, are also included in the models.

The paper discusses the literature reviews of the impact of FDI spillovers, export expansion, and other environmental factors on firm performance. Next, it is followed by the data and methodology of this study. In methodology, the measurement of overall variables and descriptive statistics are presented. The subsequent section consists of a discussion of the empirical results, with the conclusion provided in the last section.

LITERATURE REVIEW

This study investigates the impacts of FDI spillovers, export expansion, and environmental factors on firm performance. In this study, firm performance is measured using the firm's efficiency level. Spillovers from FDI can be classified into three categories: horizontal spillovers, backward spillovers, and forward spillovers. According to Huynh et al. (2019), Sari (2019), Sari et al. (2016), Takii (2005), and Vu and Le (2017), all of these kinds of spillovers can influence a firm's efficiency. Moreover, previous international trade studies identified that most manufacturers exported finish goods which had comparative advantages (Aw et al. 2000; Clerides et al. 1998; De Loecker 2007; Van Biesebroeck 2005; Wagner 2007). However, in recent years, the phenomenon of global trading has been changing. Firms attempt to unbundle their production process into other countries whose inputs are cheap. This phenomenon is also expected to have an impact on a firm's efficiency level. Additionally, a firm's efficiency could be affected by environmental factors. These factors can come from the external or internal environment of the plants. Firms can have a relationship with a neighboring environment, such as the degree of business competition and foreign companies' presence.

Furthermore, the inside environment of the firm itself also has the potential to impact its efficiency (Ahn 2002; Gu 2016; Teece 2011).

THE IMPACTS OF FOREIGN DIRECT INVESTMENT SPILLOVERS ON FIRM PERFORMANCE

Inviting FDI to host countries can bring enormous gains. Both direct and indirect advantages can arise from having a foreign corporation. The direct benefits of the existing foreign companies can be in the form of new investments, increased production capacity, demand for local workers and raw materials, and facilitated foreign market, which encourages export, offers different opportunities, and increases tax revenues (Alka 2020; Doan 2020; Takii 2005). By means of gaining access to the international market and improving transfer technology, the host country could integrate into the global economy and foster economic growth (Ajayi 2006). In addition to having foreign affiliates, host countries get indirect benefits created through non-market mechanisms. Local firms face competitive pressure from the presence of foreign corporations. This case provides local firms motivation to improve their efficiency. The literature often refers to these indirect benefits as FDI spillovers (Blomström et al. 2000; Görg et al. 2008; Hanousek et al. 2019; Lipsey & Sjöholm 2005; Nuruzzaman et al. 2019).

FDI spillovers are defined as externalities that can generate production gains for domestic firms. Gains can arise in the form of advanced managerial knowledge, advanced product, technical efficiency, as well as cost efficiency. Advanced managerial knowledge, which is disseminated by foreign corporations, offers skills to local companies to reduce their technical inefficiencies. Domestic firms learn production techniques from foreign affiliates on how to maximize outputs with a given number of inputs or how to minimize the combination of inputs to produce a certain quantity of output. These production techniques cause domestic firms to reach their production in the frontier, leading to technical efficiency (Kravtsova & Zelenyuk 2007). The existence of advance products leads to technological change in domestic firms. They then move upward into the technological frontier of domestic firms (Caves 1971; Liang 2017; Sari et al. 2016; Suyanto et al. 2014). Cost efficiency is a crucial determinant for efficiency of scale. The domestic firms absorb the behavior of multinational affiliates in terms of how to reach an optimum scale of efficiency with certain available resources. Some companies might be running their production under the variable return to scale; by studying the performance of multinational affiliates, indigenous companies can raise their scale efficiency (Brican 2019; Girma & Görg 2007; Walheer & He 2020).

The attendance of MNCs generates production advantages to local firms within the industry, dealing with horizontal spillovers through demonstration effects, labor mobility, and competition effects. Proprietary technology has been spread out by MNCs to their affiliates in the host country. This causes their affiliates to be more competitive than domestic competitors and creates distortions in the market equilibrium. This circumstance has pushed the domestic firms to maintain their market share and profit through learning and imitating the behavior of foreign affiliates. Local firms might get a better experience to upsurge their level of efficiency and production, thus establishing the demonstration effect (Belderbos et al. 2020; Das 1987; He et al. 2019; Takii 2011).

An alternative channel of FDI spillovers is associated with labor movement in the same industries. The domestic companies usually play a less active role than foreign companies in providing training to their employees. This makes their employees more aware of foreign advance technology and production techniques. There are opportunities for local manufacturers to employ workers who formerly worked at foreign companies. They know of the better production technology and are ready to apply it in the domestic manufacturers or build their own business, thus resulting in production spillovers (de Mello 1997; Fosfuri et al. 2001; Glass & Saggi 2002; Liang 2017).

The existence of MNCs can create greater competition pressure for the local manufacturers, and it is possible that it is a significant factor for spillovers. When multinational companies help recipient countries and their products substitute each another, then their presence in the local markets will motivate local producers to manage their available resources efficiently and even encourage domestic firms to adopt new technologies. This situation will push domestic manufacturers to sustain their market power by increasing their managerial skills. This not only smoothes the technology transfer, but also the presence of powerful MNC promotes domestic firms to work more closely to the production frontier (Hanousek et al. 2011). This is because the presence of MNCs causes local firms to compete with their rivals, and the local manufacturers will be forced to become more efficient and productive.

Nevertheless, the competition can have negative impacts on the domestic manufacturers. Market sales of local firms could be limited by the presence of MNCs, forcing them to run their businesses under an efficient scale and result in an increase in average costs. Furthermore, the existence of multinational affiliates might reduce domestic market share, leading some domestic firms to depart from the markets and restore the sales of the rest of firms to its normal profit level. Since the effects of efficiency are less than the effects of profit, the competition pressure might consequently bring undesirable spillovers toward local manufacturers (Alka 2020; Aitken & Harrison 1999; Markusen & Venables 1999; Sari, 2019).

THE IMPACTS OF EXPORT EXPANSION ON FIRM PERFORMANCE

Some studies offer explanations of the effect of export expansion on firm performance. The non-exporting manufacturers are predicted to be less efficient than exporting manufacturers. Through global trading activity, the exporting manufacturers might have practices with their importing partners. Their experiences may generate better managerial knowledge and production scale awareness, which enlarges their efficiency level (Keller 2009; Lemi & Wright 2020; Rath 2018).

Only more efficient and productive firms are chosen by themselves into the global markets. Most exporter firms can penetrate the international market. They have better skills and knowledge to deal with sunk cost and world market complexities. These sunk costs are usually associated with export expansion achievement, such as the expenses of marketing, distribution, and transportation; costs of modifying current products for foreign consumption; and costs of maintaining or expanding their networks. In order to compensate these costs, exporting manufacturers are likely to be more efficient and productive. On the other hand, non-exporting firms can be protected by their government and more profitable, but they are not as productive as the exporting firms. As a result, firms with lower production might only choose the domestic market and not enter the global market. Therefore, manufacturers that are more efficient and productive are preferred for participation in the global market (Bernard et al. 2003; Corsetti 2019; Efrat et al. 2018; Gruber & MacMillan, 2017; Krammer et al. 2018; Melitz 2003; Pham 2015; Yasar & Paul 2007; Yoon et al. 2018).

Another reason the exporting manufacturers are more productive is because they demonstrate greater core competence. Exporting firms try to optimize the scope of their product by specializing based on their comparative advantages. Indeed, competitive pressure in the global market could induce exporting firms to become more concentrated on what they do best. The reallocation of their activity within firms but not across firms is reflected in their concentration and specialization after they export their product, leading to efficiency enhancement and production growth (Carsten & Neary 2010; Freund & Moran 2017; Nocke & Yeaple 2008; Rossato et al. 2018).

The exporter could have a higher production than the non-exporter due to the learning-by-exporting experiences. Many studies prove that exporter firms are on average more efficient and productive than non-exporter firms (Aw et al. 2000; Clerides et al. 1998; de Loecker 2007; Esaku, 2020; Fernandes & Isgut 2015; López 2005; Van Biesebroeck 2005; Wagner 2007). Exporting manufacturers increase their efficiency and production by participating in the world market. The exporters receive a benefit because they can get in touch with foreign customers. In general, foreign customers require products with higher quality standard than domestic customers. Simultaneously, they can also deliver information on how to fulfill higher quality products. Therefore, exporting firms can learn from foreign customers who need specific products and standard process and get ideas from them, whereby they provide information about others. Through learning in the exporting process, their experience can enlarge their production, and manufacturers can still compete and continue to export their product in the global markets.

In the fragmentation trade integration framework, international product fragmentation might also increase the plant level of efficiency and production. This framework appears since there is a multistage production process. During a multi-stage production process, each part of a good is produced in various phases from the basic upstream production to the final completion of the finished good in the downstream production. This allows companies to engage in multi-stage production so that each phase of production can be placed in other countries for which labor or other inputs are cheap. The relative prices and nature of factor intensity are jointly determined by the selected countries to produce each component of a good. Companies that outsourced their intermediates inputs can reach higher profits than those that do not. Additionally, relocating their stages of production can be pointed out as a technique of attaining cost reductions and accessing technical expertise which cannot be obtained in a home country (Calia & Pacei 2017; Dean et al. 2017; Görg & Hanley 2005; Kar & Dutta 2018).

According to Arvanitis et al. (2017), Görg et al. (2008), and Valiyattoor and Bhandari (2020), a multi-stage production process can create impacts on firms' efficiency and production. The firm involving global outsourcing has access to international trading, which may be obtainable to get better quality inputs than those offered locally. Increasing the usage of internationally traded inputs can bring about the direct enhancement in a firm's efficiency, moving its production into the production frontier. This could be important for manufacturers that are producing far away from their international technological frontier. If a plant engages with several production stages in its home country, it can have the advantage to rearrange those goods for which it is more inefficient or less productive to move abroad to where it can be carried out at lower cost. Domestic production could then focus on production, which is more efficient or productive, and import the some part of goods which produced overseas. Hence, it could rearrange resources to a more efficient production phase, expand output, and push its production function outward, thus generating higher firm production.

THE IMPACTS OF ENVIRONMENTAL FACTORS ON FIRM PERFORMANCE

In addition to FDI and global trade variables, there are several environmental factors that can affect a firm's efficiency under the control of the manufacturer, but they are neither inputs nor outputs. A firm can have a relationship with an external factor, which can be related to the surrounding environment of the firm such as the degree of business competition and the presence of foreign companies. In addition, it is also possible for the internal condition of the firm to have an influence on its production capabilities. This can be shown from the production scale of the firm.

The degree of business competition can be measured through the Herfindahl–Hirschman Index (HHI). Higher values of HHI express higher market concentration in the same industry, which indicates the existence of dominant players or monopoly power resulting in a less competitive market (Krivka 2016; Nawrocki & Cater 2010; Wright & Zhu 2018; Guinea & Erixon 2019; Davis & Orhangazi 2021). In contrast, a lower score of HHI indicates less market concentration in the same industry, less dominant players, more economic activity, and greater competition in the market (Alhassan et al. 2015; Gu 2016). There are two alternative arguments that have clarified a relationship between firm's efficiency and competition. A competitive environment stimulates the industrial progress and motivates firms to be efficient and incentivize to be more innovative (Evenett 2005). This statement is supported by Ahn (2002) argues that efficiency enhancement can be encouraged through more competitive environment or less market concentration. Competitive pressure, which is compensated by giving more incentives to managers and their employees, can influence the level of effort managers and workers put forth. This competitiveness would drive firms into efficient operation.

On the other hand, Teece (2011) and Lyubyashenko (2019) state that higher market concentration or less competitiveness can create efficiency improvement. Well-organized firms can utilize existing resources efficiently. Furthermore, the most efficient firms have better technological innovation or devote greater effort to conduct research and development (R&D). The most efficient companies have greater profit and dominate the market share, thus leading to the market concentration upsurge. Hence, bigger concentration seems to have quick technological adjustment which deals with greater efficiency. Another argument is that a high concentration market might be created by efficient firms (Demsetz 1973). Efficient firms produce at lower cost, leading to higher profits and larger market share. As a result, efficient firms grow rapidly in comparison to inefficient firms.

Foreign ownership in a company has control over strategic aspects of the company's operations, making it possible to exploit the company's particular assets from foreign associates. This straight impact not only influences capital transfers but also generates technological progress, innovative managerial expertise, and scale-production awareness. It is feasible that foreign companies have extensive intangible assets compared to national companies and thus, greater foreign share ownership plays a role in improving company efficiency (Chen et al. 2017; Hintošová & Kubíková 2016; Ting et al. 2016).

Furthermore, a firm with greater production scale can benefit from research and development, have better access to foreign technology, and have the ability to bear higher risks compared to a smaller-scale firm. To become a bigger firm, a firm must be productive by establishing a low-cost structure, which allows it to shrink prices and enlarge its scale of production.

DATA AND METHODOLOGY

DATA

The industrial data come from a yearly survey of medium and large manufacturers. This survey is designed for all manufacturers with at least 20 employees. All data are taken from Central Board of Statistics (BPS) of Indonesia. Unfortunately, the most recent publication of industry data provided by BPS is the year 2014. Therefore, the data of medium-large manufacturers are used in this study only covering period from 2010 to 2014. The additional data used in this study are wholesale price index and the input-output (I-O) table of year 2010. The wholesale price index data are used to deflate the value output and all inputs into real values at a constant price for 2010, except labor.

UNIDO (2019) classifies high-tech manufacturing industries based on the intensity of technology into three categories. Those are industries with high and medium-high technology, medium technology, and low technology. This study applies unbalanced panel data with high and medium-high technology manufacturing industries. Henceforth, these industries under investigation are called high-tech manufacturing industries. According to the International Standard Industrial Classification (ISIC), there are 7 groups of high-tech manufacturing industries with 2-digit ISIC level and 107 groups with 5-digit ISIC level. All high-tech manufacturing industries in this study are categorized based on the 5-digit ISIC level. The high-tech manufacturing industries classification can be observed in Table 1.

In the standard production function, a production frontier refers to the maximum output that can be produced using combinations of given inputs. This means that the firms produce their output exactly on their production frontier. In this case, all firms are assumed to produce their output with a given quantity of

TABLE 1. The high-tech manufacturing industries classification

2-digit ISIC Code	Classified Industry 2-digit ISIC	Number of Industry 5-digit ISIC	2010	2011	2012	2013	2014
20	Chemicals and chemical products	33	866	875	910	974	1.002
21	Pharmacy	4	244	240	246	245	240
26	Computers, electronic and optical products	16	309	295	308	335	342
27	Electrical equipment	16	301	290	306	320	337
28	Machinery and equipment	27	325	304	342	356	377
29	Motorized vehicles, trailers and semi-trailers	3	291	297	307	369	380
30	Other transportation equipment except ships	8	267	270	276	317	331
Number of firms each year			2,603	2,571	2,695	2,916	3,009
Total Observation = 13,794 firms							
Number of Industries based 2-digit ISIC = 7 industries							
Number of Industries based 5-digit ISIC = 107 industries							

inputs at full efficiency level. However, in reality, firms can produce their output below their production frontier, and these firms are expected to be inefficient. Therefore, this study employs a stochastic production function. All of the coefficients of inputs in the stochastic production function and the coefficients of foreign direct investment (FDI) spillovers, export expansion, and environmental factors in the inefficiency function are estimated using stochastic frontier analysis (SFA).

The estimation of the stochastic production function not only predicts the coefficients of production function but also predicts the coefficients of inefficiency function simultaneously by separating the errors into two components (Battese & Coelli 1995; Sari 2019). The general form of stochastic production function with inefficiency effect for panel data can be represented as follows:

$$Y_{it} = f(\boldsymbol{X}_{it};\alpha,\boldsymbol{\beta}).\exp(v_{it} - u_{it}) \quad (1a)$$

$$u_{it} = \boldsymbol{Z}_{it}\boldsymbol{\delta} + \omega_{it} \quad (1b)$$

where Y and $\boldsymbol{X}$ stand for output and input, and α and $\boldsymbol{\beta}$ are the estimated coefficients in the stochastic production function. Subscript it in equations (1a) and (1b) represent the usage of panel data, for which i is individual firms and subscript t is years. v is the random error component and u is the inefficiency component. $\boldsymbol{Z}$ expresses explanatory variables which have an impact on a firm's inefficiency. $\boldsymbol{\delta}$ denotes the coefficients of the inefficiency function. ω is a residual of the inefficiency function.

Equation (1a) represents the stochastic production function, while equation (1b) denotes the inefficiency function. Equation (2a) is related to the equation (1a), which is known as a translog stochastic production function, while equation (2b) is related to the equation (1b), which is the inefficiency function with explanatory variables. Henceforth, equations (2a) and (2b) are formulated as follows:

$$y_{it} = \alpha_0 + \sum_{k=1}^{K}{}_k x_{kit} + \frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{L}{}_{kl} x_{kit}x_{lit} + \sum\nolimits_{k=1}^{K}{}_{kt} x_{kit}t + {}_t t + \frac{1}{2}{}_{tt} t^2 + v_{it} - u_{it} \quad (2a)$$

$$u_{it} = {}_0 + \sum_{m=1}^{M}{}_m \boldsymbol{Z}_{mit} + \omega_{it} \quad (2b)$$

where y and x symbolize the logarithm natural of output and inputs, while t is a time trend.

The maximum-likelihood method is realized for the estimated coefficients of equations (2a) and (2b) simultaneously, such as previous studies conducted by Sari et al. (2016) and Silva et al. (2017). The function of maximum likelihood is specified as variance parameters, such as $\sigma_s^2 \equiv \sigma_v^2 + \sigma^2$ and $\gamma \equiv \sigma^2 / \sigma_s^2$, where $0 < \gamma < 1$. When $\gamma = 0$, the conventional production function is realized. This means that the $\boldsymbol{Z}$ variables can be directly inserted into the production function. This points out that the usage of standard panel data regression to predict production function is appropriate with the data used. Conversely, when γ is closer to 1, the SFA model is satisfied to estimate equations (2a) and (2b).

The parametric model of SFA is difficult to estimate because of the numerical and statistical instability of the infinite samples. In this case, a precise parametric functional form is requested. Henceforth, to choose a correct stochastic production function, the generalized log-likelihood test was applied. The several types of production functions, such as Hicks-neutral technological progress, no technology progress, Cobb-Douglas, and no inefficiency effect production functions were tested against the translog production function (Sari 2019).

The interacting coefficients of inputs with time is equivalent to zero $(\beta_{it} = 0)$. This is recognized as a Hicks-neutral technological progress production function. The coefficients of time equal to zero $(\beta_t = \beta_{tt} = \beta_{kt} = 0)$ are known as a no-technology progress production function. The input coefficients equal to zero $(\beta_{lt} = \beta_{kt} = \beta_t = \beta_{tt} = 0)$ are identified as a Cobb-Douglass production function. Furthermore, the coefficients of inefficiency functions are equal to zero ($\gamma = \delta_0 = \delta_m = 0$). It is acknowledged to be a no-inefficiency effect function, where γ is the variance of inefficiency function. Since $\gamma = 0$, the exogenous variables were directly placed into the conventional production function.

In addition, the suitable production function is chosen using a statistic test of generalized likelihood ratio, which can be specified by:

$$\lambda = -2\left[l(H_0) - l(H_1) \right] \quad (3)$$

where $l(H_o)$ and $l(H_1)$ are the log-likelihood statistic values of the sub-types of production functions and a statistic value of translog production function. The null hypothesis (H_0) is not rejected, since the statistic value is near its distribution of χ^2, with *df* equal to the number of coefficients restricted in the sub-various production functions. The statistic test of no inefficiency effect production function is executed using a distribution of mixed $\div^2$.

MEASURING VARIABLES

The variables in production functions involve output and inputs. The output is the value of total gross output, while the inputs usage in production process are composed by capital, labor, material input, and energy. Stock of capital consists of land and building, machinery, and other equipment as well as vehicles. All values of these fixed assets are called capital (*k*). Labor (*l*) is measured by the number of workers. Material input (*m*) is the total expenditure for material inputs purchased locally or abroad. Measurement of energy (*e*) sums up all costs of electricity, diesel fuel, gasoline, gas lubricants, and kerosene. The output and input, except labor, are valued in monetary terms in thousand rupiah. Consequently, they are deflated into real values using a wholesale price index at a constant price of year 2010. Furthermore, the natural logarithm forms will be performed for output and input variables.

The exogenous variables in the inefficiency function contain foreign direct investment variables and environmental variables. The FDI variables are horizontal spillovers, backward spillovers, forward spillovers, and a dummy of the variable of foreign firms. The export variables are divided by fragmented trade and export intensity. While the environmental variables are market competition *(HHI)* and production scale.

To calculate the horizontal and vertical spillovers, this study follows Blalock and Gertler (2008) as well as Javorcik (2008). A slight adjustment takes place, particularly for measuring across-industry relationships such as backward and forward linkages. Previous studies only involved a direct linkage, but this study covers direct and indirect linkages, which are recognized as total linkages.

The FDI spillover in the similar industry is admitted as the horizontal spillover *(Hs)*, which can be defined as follows:

$$Hs_{jt} = \frac{\sum_{i \in j} ForShare_{it} * Y_{it}}{\sum_{i \in j} Y_{it}} \quad (4)$$

$ForShare$ is the proportion of total equity, which is owned by overseas manufacturers. Subscript j defines the j-th industry, and $i \in j$ points out a firm i in the industry j.

Using an input-output framework such as Leontief inverse matrix, backward and forward spillover variables can be constructed to measure both direct and indirect (total) linkages. Input-output framework is a system of related tables that is created to represent the flow of intermediate goods between various economic sectors. The Leontief inverse matrix is an economic multiplier that deals with the successive effects on the economy as a result of the production process from the start of production to final goods. An increase in production initially involves a demand for intermediate goods for further processing; intermediate goods are then produced by other branches using new intermediate goods, and so on. This is what is known as the spillover effect, which arises between different branches of economic activity (Sonis & Guo 2000; Zeng 2001).

The FDI spillover in the different industries is known as a vertical spillover. The backward spillovers (*Bs*) from FDI occurs, when overseas manufacturers are linked to the upstream market. Conversely, the forward spillovers (*Fs*) from FDI arises when foreign manufacturers are linked to downstream markets. From the Input-Output Table, it can set up a Leontief inverse matrix and develop across-industry linkages as follows:

$$Y = AY + D + EX,\ A = [a_{mn}] \text{ and } a_{mn} = \frac{Y_{mn}}{Y_n} \quad (5a)$$

Solving for Y, it gives:

$$Y = [I - A]^{-1}[Y + EX],\ [I - A]^{-1} = [b_{mn}] \quad (5b)$$

where Y implies a domestic gross output matrix, A denotes a domestic input output coefficient matrix, a_{mn} stands for a direct linkage matrix, D symbolizes a final demand vector, EX describes an export matrix, $[I - A]^{-1}$ reveals Leontief inverse matrix, and b_{mn} is element of matrix $[I - A]^{-1}$ which implies a total linkages matrix.

The Bs variable, which depicts spillovers from FDI presence, is formulated as follows:

$$Bs_{jt} = \sum_{m} b_{mn} * Hs_{jt} \quad (6)$$

where b_{nm} is from equation (5b), which releases as across-industry linkages. It represents the extent of output produced by industry m, which is required by industry n and utilized as inputs for producing an extra unit of output.

The technique to calculate the variable of Fs is similar to the technique to calculate a variable of backward spillover. However, the output for export is excluded $(Y_{it} - EX_{it})$. Hence, the forward spillover is constructed as:

$$Fs_{jt} = \sum_{n} b_{mn} * \frac{\sum_{i \in j} ForShare_{it} * (Y_{it} - EX_{it})}{\sum_{i \in j} (Y_{it} - EX_{it})} \quad (7)$$

Variable of FOR shows the equity share from foreign ownership. Measuring foreign share follows OECD (2009) definitions. All foreign equity share with 10 percent or more are counted as foreign ownership. FOR is measured with a binary variable. The score is one if the share of foreign ownerships is greater than or corresponds to 10 percent, otherwise the score is zero.

The export expansion variables used as determinants on the firms' efficiency level contain export intensity and fragmented trade integration. The export intensity (XI_{it}) is measured by ratio export to gross output of firm i at time t. The fragmented trade integration (FTq_{it}) at the firm level is calculated by a ratio of the overlap of exports and imported inputs to output. This measurement follows a study conducted by Khalifah and Jafaar (2017). The international fragmentation trade integration of firm i at time t is defined as follows:

$$FTq_{it} = \frac{2\min(EX_{it}, IM_{it})}{Y_{it}} \quad (8)$$

where EX_{it} and IM_{it} refer to exports and imports of material inputs of firm i at time t, and Y_i describes the gross output of the firm i at time t. The value of FTQ_{it} is restricted at interval [0, 2], with the lower limit showing no overlap between exports and imported input and the upper limit indicating a huge overlap of exports and imported inputs relative to output.

The degree of market competition is measured by the Herfindahl–Hirschman Index (HHI). Higher HHI shows greater concentration of output sales in the same industry and it has less competitive markets. Meanwhile, lower HHI refers to less concentration of output sales within the industry, and it has higher competitive markets (Owen et al. 2007; and Gu 2016). The HHI is framed as follows:

$$HHI_{jt} = \sum_{i \in j} sh_{ijt}^2 \quad (9)$$

where sh_{ijt} is the market share measured by the ratio of output of firm i, with a total output of industry j at period t. sh_{ijt}^2 is known as the Herfindahl-Hirschman index (HHI_{jt}) of industry j in year t. Since the number of observations contains of lots of industries and most of the measurement of the variables conduct aggregation data, it is necessary to insert scale of production ($PScale$) in the model. $PScale$ is needed to control the industrial effects. It is calculated from the output of firm i divided by the total output of industry j at period t.

DESCRIPTIVE STATISTICS

Table 2 shows a summary statistic of the data used in this study. There are 13,795 firms on Indonesian high-tech manufacturing industries from 2010-2014. Based

TABLE 2. Summary statistics of the data

Variables	*Units*	*Obs*	*Mean*	*SD*	*Min*	*Max*
Output (y)	*ln (000 rupiah)*	13,794	0.000	2.049	-6.657	7.975
Capital (k)	*ln (000 rupiah)*	13,794	0.000	2.287	-7.457	9.623
Labor (l)	*ln (worker)*	13,794	0.000	1.255	-1.621	4.922
Material (m)	*ln (000 rupiah)*	13,794	0.000	2.173	-7.828	8.528
Energy (e)	*ln (000 rupiah)*	13,794	0.000	2.141	-7.726	9.002
Time (t)	*annual*	13,794	0.111	1.851	-2.500	2.500
Hs (Horizontal spillover)	*ratio*	13,794	0.368	0.263	0.000	1.000
Bs (Backward spillover)	*ratio*	13,794	1.787	2.305	0.000	7.840
Fs (Forward spillover)	*ratio*	13,794	2.425	2.694	0.000	10.416
FOR (foreign share)	*binary*	13,794	0.225	0.418	0.000	1.000
XI (Export Intensity)	*ratio*	13,794	0.117	0.275	0.000	1.000
FTq (Fragmented Trade)	*ratio*	13,794	0.062	0.209	0.000	1.797
HHI (Herfindahl-Hirschman Index)	*ratio*	13,794	0.197	0.181	0.023	1.000
Pscale (Production Scale)	*ratio*	13,794	0.038	0.110	0.000	1.000

Notes: Mean = arithmetical mean; SD = standard deviation; Min = minimum value; and Max = maximum value.

on Coelli et al. (2003), the main variables are estimated using a natural logarithm of their values of main variables minus the natural logarithm of their geometric means, so the mean values of all main variables (output, capital, labor, material, and energy) equal zero.

RESULTS AND DISCUSSIONS

DIAGNOSTIC TESTS

The proper stochastic production function is chosen to estimate the coefficients of production itself and the coefficients of FDI spillover, export expansion, and environmental factors in the inefficiency function, using the general likelihood statistic test. All the results are provided in Table 3, and the translog production function is sufficient with the data used in this study. Hence, the estimated coefficients of translog models are used to interoperate the phenomena of FDI spillovers and export expansion on Indonesian high-tech manufacturing industries.

Table 4 in the inefficiency functions report the estimation results of FDI spillovers, export expansion as well as environmental factors toward firms' efficiency level. We start by focusing on FDI spillovers toward firms' inefficiency level. In all models, the coefficients of horizontal spillover (*Hs*) are not statistically different from zero. This means that the presences of foreign competitors within similar high-tech manufacturing industries do not have competitive impacts on the firms' inefficient level. Even though they have observed and imitated the behavior of high-tech foreign competitors, they still could not shrink their innovation costs. Prior studies conducted by Havranek and Irsova (2011) as well as Wooster and Diebel (2010) also showed results similar to this finding. The horizontal spillovers from FDI were largely nonexistent in many countries.

On the other hand, the backward (*Bs*) coefficients in all models are significantly different from zero. The coefficients of backward spillovers (Bs) in all models show positive signs, so there are negative impacts from MNCs in the upstream high-tech manufacturing industries. This finding is different from previous studies conducted by Barrios et al. (2011), Gorodnichenko et al. (2014), and Javorcik (2004). The backward spillovers from FDI have a consistently positive effect on firm performance. However, in this study, the finding indicates that the foreign affiliates are not used intensively for material inputs from the local traders. Perhaps the quality of input material from local suppliers does not match the input quality desired by foreign companies and they have imported their material inputs from abroad. In addition, there is a possibility that the bargaining power from MNCs on Indonesian government is very strong. The contract agreement that has been made by MNCs, and policy makers can spoil the capability of domestic manufacturers in high-tech manufacturing industries. Therefore, the production of domestic manufacturers falls and can decrease their profits.

In contrast, the coefficients of forward spillovers in all models have different signs from the coefficients of backward spillovers. The forward spillovers (*Fs*) coefficients have negative signs and are statistically different from zero. This points out that there is a linkage between foreign and domestic companies in the downstream industries. Domestic companies do not need to import input materials from abroad, because the presence of foreign companies in Indonesia can offer good quality input materials. As a consequence, foreign affiliates can stimulate domestic companies to increase their level of technical efficiency by reducing input costs and improving the quality of their products. Lin et al. (2010) also confirm that there are strong and consistent positive forward spillovers from foreign invested firms.

The export intensity (*XI*) and fragmented trade integration (*FTq*) are interesting determinants of firm efficiency in Indonesia high-tech manufacturing industries. We compare the relative performance between export intensity and fragmented trade integration. In Model 1, when we include an export intensity variable and exclude a fragmented trade integration variable in the equation, the coefficient of *XI* is not significant, while in Model 2, when we exclude an export intensity variable and include a fragmented trade integration variable in the equation, the coefficient of *FTq* is statistically significant. Furthermore, in Model 3, when we include *XI* and *FTq* in the equation, the results show that the coefficient of *XI* is still not significant, while the coefficient of *FTq* is statistically significant and has a negative sign. Most of the earlier studies focused more on export intensity, which did not differentiate between the exports of finished goods and fragmented goods.

TABLE 3. The General Likelihood Test of sub-various production function

Models	H_0	λ	χ^2 1%	Conclusion
Hicks-neutral	$\beta_{kt} = 0$	56.480	13.277	H_0 rejected
No-technological progress	$\beta_t = \beta_{tt} = \beta_{kt} = 0$	625.524	16.812	H_0 rejected
Cobb-Douglas	$\beta_{ll} = \beta_{kl} = \beta_t = \beta_{tt} = 0$	2344.910	23.209	H_0 rejected
No-inefficiency effects	$\gamma = \delta_0 = \delta_Z = 0$	495.713	20.972	H_0 rejected

Note: Calculation of λ from the generalized likelihood ratio statistic

TABLE 4. The estimation results of the stochastic production and inefficiency functions

Variables	*Coefficients*	*Model 1*		*Model 2*		*Model 3*	
Constant	β_0	0.081	*	0.107	*	0.135	*
		(0.031)		(0.009)		(0.008)	
k	β_k	0.165	*	0.171	*	0.169	*
		(0.007)		(0.006)		(0.006)	
l	β_l	0.094	*	0.097	*	0.093	*
		(0.006)		(0.006)		(0.006)	
m	β_m	0.492	*	0.494	*	0.496	*
		(0.007)		(0.007)		(0.007)	
e	β_e	0.275	*	0.270	*	0.268	*
		(0.007)		(0.007)		(0.007)	
k^2	β_{kk}	-0.022	*	-0.021	*	-0.022	*
		(0.003)		(0.003)		(0.003)	
l^2	β_{ll}	0.039	*	0.037	*	0.037	*
		(0.005)		(0.005)		(0.005)	
m^2	β_{mm}	0.218	*	0.219	*	0.219	*
		(0.007)		(0.007)		(0.007)	
e^2	β_{ee}	0.147	*	0.147	*	0.148	*
		(0.008)		(0.007)		(0.007)	
kl	β_{kl}	0.000		-0.002		-0.001	
		(0.003)		(0.003)		(0.003)	
km	β_{km}	-0.016	*	-0.016	*	-0.016	*
		(0.003)		(0.003)		(0.003)	
ke	β_{ke}	0.042	*	0.041	*	0.041	*
		(0.003)		(0.003)		(0.003)	
lm	β_{lm}	-0.043	*	-0.040	*	-0.038	*
		(0.004)		(0.004		(0.004)	
le	β_{le}	0.013	*	0.012	*	0.010	**
		(0.004)		(0.004)		(0.004)	
me	β_{me}	-0.187	*	-0.188	*	-0.188	*
		(0.007)		(0.006)		(0.006)	
t	β_t	-0.037	*	-0.036	*	-0.041	*
		(0.002)		(0.002)		(0.002)	
t^2	β_{tt}	-0.056	*	-0.059	*	-0.056	*
		(0.003)		(0.003)		(0.003)	
kt	β_{kt}	-0.007	**	-0.009	*	-0.007	**
		(0.003)		(0.003)		(0.003)	
lt	β_{lt}	0.008	**	0.009	*	0.008	*
		(0.003)		(0.003)		(0.003)	
mt	β_{mt}	0.017	*	0.018	*	0.016	*
		(0.003)		(0.003)		(0.003)	
et	β_{et}	-0.016	*	-0.015	*	-0.015	*
		(0.003)		(0.003)		(0.003)	

cont.

cont.

Inefficiency Functions							
Variables	*Coefficients*	*Model 1*		*Model 2*		*Model 3*	
Constant	δ_0	0.049	**	0.060	*	0.105	*
		(0.020)		(0.020)		(0.009)	
Hs	δ_{Hs}	0.006		0.019		0.002	
		(0.024)		(0.023)		(0.014)	
Bs	δ_{Bs}	0.040	*	0.029	*	0.016	*
		(0.009)		(0.008)		(0.002)	
Fs	δ_{Fs}	-0.041	*	-0.030	*	-0.013	*
		(0.008)		(0.008)		(0.002)	
XI	δxi	0.218				0.249	
		(0.023)				(0.011)	
FTq	δ_{FTq}			-0.013	*	-0.118	*
				(0.027)		(0.103)	
FOR	δ_{FOR}	-0.065	*	-0.070	*	-0.041	*
		(0.023)		(0.018)		(0.005)	
HHI	δ_{HHI}	0.031		0.021		0.019	
		(0.030)		(0.031)		(0.004)	
Pscale	δ_{Pscale}	-0.095	***	-0.123	***	-0.080	*
		(0.082)		(0.065)		(0.011)	
Sigma-squared	σ^2	0.104	*	0.102	*	0.102	*
		(0.003)		(0.002)		(0.001)	
Gamma	γ	0.020		0.014		0.002	*
		(0.040)		(0.015)		(0.000)	
Log likelihood function		-3928.34		-3860.55		-3830.05	
LR test of the one-sided error		72.84		208.41		269.42	

Note: * denotes significance at 1%, ** denotes significance at 5%, *** denotes significance at 10%

Furthermore, the results indicated that export intensity has a potential effect to increase firm productivity performance (Baldwin & Gu 2003; Castellani 2002; Greenaway & Yu 2004; Pham 2015). On the other hand, our results show that the fragmented production networks in the high-tech manufacturing industries have increased firms' efficiency level. In high-tech manufacturing industries, the firms involving different stages of the production process from basic upstream production to the finished product in the downstream production have impacts on firms' efficiency level and not export intensity per se.

All coefficients of foreign share (*FOR)* are statistically significant and have negative signs. This indicates that foreign firms have less inefficiency than domestic firms. This evidence is consistent with former studies conducted by Sari (2019), Suyanto and Salim (2013), and Wang (2010). They improve the new knowledge and the technology faster than domestic firms. Therefore, local firms are less efficient than foreign firms.

Other environmental factors that affect firms' efficiency level is market concentration (*HHI*) and production scale (*Pscale*). The coefficients of *HHI* are not statistically significant in all models, which indicates that the degree of market concentration in high-tech manufacturing industries does not have an impact on firms' efficiency level. However, this finding is different with the previous study. Grosfeld (2006) found that firms belonging to the sector of high technology with lower ownership concentration have positive impacts on firm performance. The remaining regressor, the coefficient of *Pscale*, is statistically significant and has negative signs in all models. This confirms that the larger scale of production decreases firms' inefficiency level. This is because the bigger scale of production is expected to have better knowledge and modern technology than a smaller scale of production. This finding is supported by earlier studies done by Opeyemi (2019), Olawale et al. (2017), and Wang et al. (2018).

CONCLUSION

The results show that there is evidence of negative backward and positive forward FDI spillovers on firms' efficiency level, but in the horizontal spillovers, they are not found. The results also prove that foreign firms in high-tech industries are more efficient than local firms. The negative impacts of backward spillover from foreign corporations have a policy implication for promoting FDI. The government must consider whether the existence of FDI brings advantages to local producers. Since the multinational affiliates create potential damages to domestic manufacturers, the Indonesian government as a policy maker must be cautious of the attendance of foreign companies. It must ensure that the losses of arriving FDI do not go beyond its total gains. However, where the gains of incoming FDI offset their losses, policy makers should support the entrance of multinational companies in Indonesia as the host country.

Furthermore, a greater degree of fragmented trade integration is absolutely related to the firms' efficiency level in high-tech industries, indicating the importance of net production compared to gross production. More fragmented trade is positively associated with the production of establishments in the Indonesian high-tech industry, thereby pointing out the importance of net production relative to gross production. The policy implications of these results confirm that the government should consider whether the existence of MNCs in the high-tech industries bring a benefit to local producers.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15