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Clustering and firm productivity spillovers in Indonesian manufacturing

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ABSTRACT

Earlier studies on foreign direct investment (FDI) and firm productivity have mainly focused on the general impacts of FDI on local firms' productivity. This current research extends the existing literature by examining the heterogeneity issue in firm productivity by clustering Indonesian manufacturing firms into nine industrial groups. Two estimation methods are applied: stochastic frontier analysis and panel data analysis, which emerge three key findings. Firstly, the impacts of FDI vary among firm clusters, with six out of nine clusters are able to grasp the positive benefits of FDI, whereas three out of nine clusters experience negative productivity effects. Secondly, the labor-intensive clusters tend to receive negative productivity effects, whereas the capital-intensives clusters receive positive productivity impacts. Thirdly, the sources of FDI-productivity vary across clusters, with scale-efficiency as the most dominant source and technology advancement as the second dominant source. These findings justify the importance of estimating firms in homogenous industrial groups to gain precision findings of productivity benefits.

1. Introduction

Earlier studies on foreign direct investment (FDI) and firm productivity have focused mainly on the general impacts of FDI on firm productivity.[1] The findings are mixed as the firm-level data are estimated altogether, and the heterogeneity issue remains in the data estimation.[2] High capital intensity is estimated together with high labor intensity firms, resulting in a large dispersion in the productivity score among firms and between each firm to the best-practice firm. The recent studies (for example Abdullah and Chowdhury, 2020; Latief et al., 2020; Nguyen et al., 2020) address the mixed findings of the earlier studies by pointing out the firm heterogeneity issue; it is argued that firm heterogeneity might reduce the precision of findings as some firms are not fully extracting the productivity benefits from FDI; hence empirical findings of existing literature remain inconclusive. Firm heterogeneity issue can be minimized by clustering firms into homogenous groups and estimate them separately (Chen et al., 2020; Kowalski, 2020) or adding some specific factors that accounted for the variation in ability to grasp productivity benefits, such as firm age, ownership, and competitiveness (Esquivias and Harianto, 2020; Morrales and Moreno, 2020) or breaking down the FDI-productivity into technology and efficiency (Nguyen et al., 2020). This paper contributes to the empirical debate within the framework of foreign direct investment to Indonesia by clustering firms into nine homogenous groups based on product similarity in the International Standard of Industrial Classification (ISIC). This current research attempts to answer the key questions on which firm groups receive FDI-productivity spillovers by dealing with the heterogeneity issue. Two significant contributions are provided. Firstly, this current research minimizes the heterogeneity issue by clustering firms into homogenous groups and estimates them separately. Secondly, the productivity benefits are separated into three parts, which enables identifying the variation in the source of FDI-spillovers among the group of firms.

The inflows of Foreign Direct Investment (FDI) to Indonesia have been recorded since the 1970s. The remarkable surge of FDI inflows is noticeable since the mid-1980s when various incentives were introduced, including tax breaks, investment subsidies, financial incentives, and permission to repatriate profits. The recent significant infrastructure development and the ease of investment procedures are some efforts done to attract FDI. These efforts resulted in a more than 90-fold increase in FDI from 1986 to 2019, which rises from US$ 0.26 billion to US$ 24.58 billion (World bank-, 2020).

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[1] For example, Suyanto et al. (2012, 2014), Sari et al. (2016).

[2] Bruno and Cipollina (2018), Demena and van Bergeijk (2017), Hampl et al. (2020) provide comprehensive reviews on the mixed evidence of the FDI-related productivity effect.

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The rapid inflow of FDI is widely believed to benefit Indonesia in fresh capital, new employment, source of funds for government spending, and source of funds for savings-investment gaps. Another benefit at the micro-level, which is equally important, is that FDI is, in fact benefiting local firms' productivity through knowledge transfer in the forms of advanced technology, managerial expertise, and knowledge of scale-setting of production (Jin et al., 2020; Khalifah et al., 2015; Malik, 2015). Such benefits increase the productivity of local firms, as local firms can imitate the technology possessed by FDI and adapt managerial knowledge through the recruitment of managers whom multinational corporations have trained (Drahokoupil and Fabo, 2020; Kim, 2016; Newman et al., 2015). These benefits are often underlooked in the study of the impacts of FDI.

The Indonesian manufacturing industry is the major sector receiving FDI inflows since the 1980s. Although the percentage of FDI inflows to this sector decreased to only 37.68% and 46.11% of the total manufacturing FDI in 2014 and 2015, respectively, the manufacturing industry remains at the top position as the major recipient of FDI up till the current year of 2019 (Indonesian Investment Coordinating Board-, 2020). Due to the variation in a characteristic of each sub-sector in the manufacturing industry, ranging from the labor-intensive sub-sectors such as Food and Beverage to the highly capital-intensive sub-sectors such as Chemical and Pharmaceutical, the benefits extracting from FDI could be varied among the sub-sectors. The heterogeneity becomes a remaining issue when estimations are performed on all firms in the manufacturing industry. Clustering firms into sub-sectors and performing the estimation of FDI benefits on each sub-sector would reduce the heterogeneity and provide more precise results. This current research focuses on two combining-ways in dealing with the heterogeneity issue: (1) clustering the firms into nine sub-sectors with homogeneous products; and (2) adding specific firm characteristics, namely age and foreign ownership, in tracking the ability of firms to extract FDI-related benefits.

2. Literature review and hypothesis development

2.1. Foreign direct investment and firms' productivity

FDI in the form of Multinational Corporations (MNCs) can generate productivity benefits to local-owned firms[3] (Fujimori and Sato, 2015; Kwon and Chun, 2015; Li and Tanna, 2019). Productivity benefits occur when the local-owned firms experience an increase in productivity due to the existence of MNC subsidiaries in local markets (Barge-Gil et al., 2019; Kim, 2016; Lenaerts and Merlevede, 2018; Newman et al., 2015; Suyanto et al., 2014; Tamura, 2006). According to the industrial organization theory of FDI, the mechanism of productivity benefits materializes through transferring knowledge from the MNC headquarters to its subsidiaries. However, this knowledge spills to the local-owned firms in the same industry via competition (Chang and Xu, 2008), imitation processes (Glass and Saggi, 2002; Merlevede et al., 2014), hiring trained-managers processes (Drahokoupil and Fabo, 2020; Markusen and Trofimenko, 2009; Wang et al., 2013), and interaction processes as upstream or downstream industries with MNCs (Khalifah et al., 2015; Newman et al., 2015; Ni and Kato, 2020). Within the framework of this FDI theory, MNCs are assumed to have more superior knowledge than their local-counterpart, enabling a transfer of knowledge in the form of higher performance levels of output productivity from MNCs to local-owned firms. To test whether this is the case in the Indonesian manufacturing sector, this current study formulates the following hypothesis:

***H1*.** *There are positive productivity benefits from FDI to local-owned firms.*

[3] Local-owned firms are firms with a 100 percent asset owned by local people.

2.2. Firm clusters and FDI-related benefits

Although it is true that there are productivity benefits from FDI to local firms, but the firm's individual ability to grasp the benefits may be varied. Lipsey and Sjoholm (2005) highlight the variation in productivity benefits depends highly on the nature and the group of the firms or industry. A cluster of firms with high labor-intensity, such as the clothing and textile industry, benefits differently from a cluster of firms with high capital-intensity, such as the chemical and the electronics industry (Suyanto and Salim, 2010) support the argument by showing that a high labor-intensive industry such as food and beverage receives productivity benefits in the form of technical efficiency, while a high labor-intensity industry such as electronics obtains productivity benefits from technological progress. Similar findings were also noted in Khalifah et al. (2015) for the electrical and electronic industries in Malaysia and Baltagi et al. (2015) for the same industry in China. Meanwhile, Gorodnichenko et al. (2014) also show that different industries are experiencing varying productivity outcomes for the economies in transition.

This current research clusters the Indonesian manufacturing firms into nine groups. The clustering is based on the similarity in products, following the International Standard of Industrial Classification (ISIC). The nine groups are Food and Beverage (ISIC 31), Textile and Leather (ISIC 32), Wood and Wood Products (ISIC 33), Paper and Paper Products (ISIC 34), Chemical and Pharmaceutical (ISIC 35), Non-Metal Metals firms (ISIC 36), Basic Metal (ISIC 37), Metal Products (ISIC 38), and Others (ISIC 39). Testing the FDI productivity benefits on these groups of firms separately will indeed reduce the heterogeneity issue that commonly exists in the empirical studies.

Based on the nine firm clusters, this current study extends the testing of productivity spillovers on every cluster of the Indonesian manufacturing firms examining the potential variation in a firm's ability to extract FDI productivity benefits. Thus, the hypothesis related to the clustering of firms can be put forward is as follows:

***H2*.** *There is a variation in ability among firms in different clusters in extracting FDI productivity benefits.*

2.3. FDI and the types of productivity benefits in firm clusters

When the variation in the ability to extract productivity benefits is estimated, as in the second hypothesis, a further step is to identify the types of FDI productivity benefits. The productivity benefits from FDI take the form of two types of benefits, namely efficiency and technology. Efficiency benefits are the increase in the efficiency of local-owned firms due to the presence of MNC subsidiaries (foreign-owned firms) in the local market. In contrast, the technological benefits are the advancement of local-owned firms' technological level because of MNC subsidiary knowledge transfer through non-market mechanism (Suyanto and Salim, 2010). Furthermore, the efficiency benefits can be broken down further into technical efficiency and scale efficiency, with the former is the increase in the technical ability of local-owned firms in combining inputs to produce output, whereas the latter is related to the enhancement in production scale of local-owned firms (Suyanto et al., 2012). In their study of FDI productivity, Suyanto and Salim (2010) focus on technological benefits and scale efficiency benefits where Suyanto et al. (2014) and Sari et al. (2016) extend the study by examining the three types of benefits, namely technological, scale efficiency, and technical efficiency. This current study extends further Suyanto et al. (2014) and investigates whether the three-types of productivity benefits exist in the nine clusters of the Indonesian manufacturing firms, with a notable extension is in the heterogeneity of clusters in receiving benefits. Three hypotheses that can be raised are as follows:

***H3a*.** *There is a variation among the nine clusters of local firms in extracting technological benefits from foreign firms.*

***H3b*.** *There is a variation among the nine clusters of local firms in extracting technical efficiency benefits from foreign firms.*

H3c. There is a variation among the nine clusters of local firms in extracting scale efficiency benefits from foreign firms.

3. Research method

3.1. Method of analysis

Three estimation methods are adopted consecutively to test the three hypotheses:Stochastic Production Frontier (SPF), parametric Malmquist Productivity Index (MPI), and Panel Data. The SPF method is used to assess hypotheses 1 and 2 to examine the productivity benefits that flow from foreign to local firms. The MPI method is used to decompose productivity benefits into three types: technological, technical efficiency, and scale efficiency benefits. The third method is adopted in analyzing the three types of productivity benefits in the nine clusters of manufacturing firms. In the current research, the SPF method adopted is Battese-Coelli's SPF, and the MPI method adopted is Orea's procedure, with the corresponding models are discussed in section 3.2. For readers whose interested in a more detailed discussion on the three related methods, a comprehensive discussion on the SPF method is presented in Coelli et al. (2005) and Kumbhakar and Lovell (2000), with current development in Assaf et al. (2020), whereas a thorough discussion on the parametric MPI is given in Orea (2002). In addition, panel data analysis is concisely discussed in Baltagi (2020).

3.2. Research models

There are three models employed in this current research, which are directly derived from the three corresponding methods in Section 3.1. The first model is Battese-Coelli's model that related to the SPF method. This first model is employed to estimate the FDI productivity benefits for each group of firms in the nine-observed clusters. The second model is Orea's parametric model from the MPI method, which is used to decompose productivity benefits into three types. The third model is the panel data model (both random-effect and fixed-effect) corresponding to the panel data methods used to check the source of productivity benefits extracted by each group of firms in the nine-observed clusters. The three models are presented as follows:

3.2.1. The model of FDI productivity benefits for clustering firms

The model for estimating the FDI productivity benefits is that introduced by Battese and Coelli (1995). In general, the production function for Battese-Coelli's SPF can be written in a linear translog as follows:

$$\ln y_{it} = \beta_0 + \sum_{n=1}^{N}\beta_n \ln x_{nit} + \frac{1}{2}\sum_{n=1}^{N}\sum_{k=1}^{K}\beta_{nk}\ln x_{nit}\ln x_{kit} + \beta_t t + \frac{1}{2}\beta_{tt}t^2 + \sum_{n=1}^{N}\beta_{nt}\ln x_{nit}t + v_{it} - u_{it} \tag{1}$$

where y is output; x represents input variables affecting the output (material, labor, capital, and energy, $N = 4$); i represents firm-i; t is year-t; n is the n-th input variables, and u_{it} is defined as:

$$u_{it} = \boldsymbol{FDI}_{it}\tau + P_{it}\boldsymbol{\delta} + \omega_{it} \tag{2}$$

where **FDI** is *(1xj)* vector of FDI variables in firm-i at time-t, $\boldsymbol{\tau}$ is (jx1) vector of coefficients, P is *(1xp)* vector of other exogenous variables in firm i at time t, and $\boldsymbol{\delta}$ is *(px1)* coefficient of other exogenous variables.

As shown in Eq. (2), FDI is accommodated in the model as exogenous variables affecting efficiency. Thus, the FDI productivity benefits flow through efficiency. Two FDI variables are used in this current research, namely the pure FDI variables that represent foreign-ownership and the FDI spillover variables that represent the productivity benefits. Therefore, these two FDI variables are defined in Section 3.5.

3.2.2. The model of decomposing productivity benefits

In order to identify the types of productivity benefits, it is necessary to decompose the FDI productivity benefits into several parts. In this current study, the decomposition procedure follows Orea (2002), enabling the break-down of FDI productivity benefits into three parts. By assuming that the distance function is as follows:

$$Y_i = f(\mathbf{X}_i; \alpha_0, \beta).exp(v_i - u_i) \tag{3}$$

All three types of FDI productivity benefits can be decomposed into technical efficiency, technological progress, and scale efficiency. So that, the general model can be written as follows:

$$TFPG_{0i}^{t,t+1} = TEC_i^{t,t+1} + TC_i^{t,t+1} + SEC_i^{t,t+1} \tag{4}$$

where TFPG is productivity growth, TEC is technical efficiency change, TC is technological change, and SEC is scale efficiency change.

3.2.3. The model of productivity benefits in three distinctive forms

Based on the panel data method in Eq. (7), the model for estimating FDI productivity benefits into three distinctive types is written as follows:

$$TEC_{it}^{t,t+1} = \propto_0 + \alpha_1 FDI_{it} + \delta_1 L_{it} + \varepsilon_{it} \tag{5}$$

$$TC_{it}^{t,t+1} = \beta_0 + \beta_1 FDI_{it} + \rho_1 L_{it} + \varphi_{it} \tag{6}$$

$$SEC_{it}^{t,t+1} = \theta_0 + \theta_1 FDI_{it} + \sigma_1 L_{it} + \vartheta_{it} \tag{7}$$

where $\alpha,\ \beta,\ \theta, \delta, \rho, \sigma$ are parameters to be estimated, $\varepsilon, \varphi, \vartheta$ are the error terms, and other variables are defined previously.

The three distinctive types of FDI productivity benefits are reflected in Eqs. (5), (6), and (7). These three types of productivity benefits are technical efficiency change (TEC), technological change (TC), and scale efficiency change (SEC). The FDI effect in these models is treated as exogenous variables that affect firms' productivity.

3.3. Data sources

The firm-level data in this current study are taken from the annual survey of large and medium enterprises conducted by the Indonesian Board of Statistics (BPS). It is a rich dataset covering a wide range of variables of production, ownership, and export-import. This survey data is available under license in the form of a database, which is inputted from a questionnaire circulated to each company. In addition, supplementary data are from other BPS publications, such as the Wholesale Price Index (used as a deflator for calculating output and material variables) and the Machinery Price Index (used as a deflator for calculating capital variable). Another supplementary data is taken from the Indonesian Ministry of Energy and Mineral Resources (ESDM) that is the Energy Price Index (used as a deflator in calculating energy variable).

3.4. The procedure to construct the clustered balanced panel data

The data used in this research is balanced panel data which is uniquely formed by following the six-step procedure[4]: (1) selecting firms that exist during the period of analysis; (2) adjusting the Industrial Code; (3) minimizing the inconsistency in variables' definitions; (4) minimizing typographical errors; (5) excluding firms with no information on raw material or labor; and (6) clustering firms into nine groups based on ISIC. By going through this six-step procedure, the total number of observations is 15,197, consisting of 1,169 unique firms throughout 1988-2000 (13 years). From the total observation, 14,339 observations are local-

[4] The detailed discussion on the six-step procedure to obtain the unique balanced panel data is not presented here due to page limitation, but readers can obtain them upon request.

owned firms, whereas 858 observations are foreign-owned firms. When the total observation is divided based on the firm clusters, 6,617 observations are in Food and Beverage (ISIC 31); a total of 1,560 observations are in Textile and Leather (ISIC 32); 936 observations are in Wood and Wood Products (ISIC 33); 715 observations are in Paper and Paper Products (ISIC 34); a total of 2,184 observations are in Chemical and Pharmaceutical (ISIC 35); 1,196 observations are in Non-Metal Mineral (ISIC 36); 195 observations are in Basic Metal (ISIC 37); 1,625 observations are in Metal Products (ISIC 38); and 169 observations are in Others (ISIC 39).

3.5. Variables and definitions

Appropriate measurement of variables is an integral part of an empirical study. This is because the reliability of empirical results is highly dependent on the accuracy of the measurement of variables. Based on the availability of the complete survey data of BPS, combined with up-to-date information from related literature, this study constructs a series of variables as in Eqs. (1), (2), (3), (4), (5), (6), and (7). These variables are grouped into three groups: the production frontier, the inefficiency, and the productivity growth. The symbols and definitions of variables are presented in Table 1.

All variables in Table 1 are calculated based on the raw data from the BPS survey. The mean values and other descriptive statistics for each variable are presented in Table 2.

The values of variables Y, L, K, M, and E in Table 2 are logarithmic. Ln(Y) has a mean value of 13.55 and a standard deviation of 2.09 during the observation period from 1988 to 2000. This shows that the mean value for output is Rp 766.81 billion, with a standard deviation of Rp 8.08 million. The mean value of output Ln(Y) is greater than the mean value of material Ln(M), the mean value of labor Ln(L), the mean value of capital Ln(K), and the mean value of energy Ln(E), indicating that the output value is greater than the value of each production factor. This finding does make sense due to the elasticity of output concerning each production input.

Furthermore, the mean FDI is 0.06, reflecting that only 6 percent of the total observed firms are foreign-owned firms. The remaining 94 percent are local-owned firms. In addition, the mean value of the Spillover variable is 0.17, which reflects that foreign-owned firms produce 17 percent of the output in the Indonesian manufacturing industry. Although only 6 percent of the total firms are foreign-owned firms in the industry, those firms can produce on average 17 percent of the total output. This evidence is intuitively interpreted as foreign-owned firms are at a superior productivity level compared to local-owned firms, so that they can produce a large percentage of output. In relation to firm age (Age variable), the mean value is 19.81 years old, indicating that the observed firms' average age is between 19 and 20 years old. Based on the minimum and the maximum value of Age variable, one can know that the youngest firm is aged less than one year, while the oldest firms are 100 years old.

4. Results and discussion

4.1. The results of testing firm productivity benefits from FDI

Before estimating the impact of FDI productivity benefits, the first step of the estimation is to select the most appropriate representation of production frontier (SPF form) for the dataset. By going through the log-likelihood test as performed in Suyanto et al. (2009), various model specifications are tested against the Cobb-Douglas model. It is found that the Cobb-Douglas model is the best specification representing the data. The Log-likelihood test results are not presented here due to the limitation of pages, but one can obtain the results upon request.

Based on the findings of model selection above, from here onward, the estimates of the FDI productivity benefits are tested using the Cobb-Douglas production frontier. Table 3 presents the estimation results of the FDI-related effects on local-owned firms.

The results of the maximum likelihood estimate for all firms and only local-owned firms are shown in the third and the fourth columns of Table 3, respectively. The discussion of this section follows the results for all firms, as the findings are similar in terms of the significance of the parameters. Starting from the upper part of Table 3, the results of the production frontier show that the overall production factors (labor, capital, raw materials, and energy) have positive coefficients and significant impacts on output at a 99% significance level (or alpha 1%). Meanwhile, each production factor's coefficient is smaller than 1, which is in line with the production theory and similar to the findings in Sari et al. (2016) and Esquivias and Harianto (2020). Although the functional form in this current study is different from those in Sari et al. (2016) and Esquivias and Harianto (2020), the findings are similar.

Going through each production factor, labor (ln L) has an effect of 0.08 percent on output, indicating that a 1 percent increase in labor raises output by 0.08 percent. The capital (In K) has an elasticity of 0.42

Table 1. Variables and the definition.

Variable	Definition
Production Frontier [Eq. (1)]	
Y	Output (in million rupiah), deflated using wholesale price index (WPI) at 4-digit ISIC level with 1993 constant price
L	Labor (people) is the total full-time and part-time labor in production
K	Capital (in million rupiah), deflated using wholesale price index (WPI) at 4-digit ISIC level with 1993 constant price
M	Material (in million rupiah) deflated using wholesale price index (WPI) at 4-digit ISIC level with 1993 constant price
E	Energy (million rupiah) is a sum of electrical expenditure and fuel expenditure, deflated using wholesale price index (WPI) for the electricity and deflated using fuel price index for the fuel at constant price 1993.
T	Time, with value 1 for 1998, value 2 for 1989, and so on.
Inefficiency Function [Eq. (2)]	
FDI	Foreign Direct Investment, measured by dummy variable: 1 if the firm has foreign ownership, 0 if the firm has no foreign ownership.
Spillover	Spillover variable for measuring the spillover effect of FDI on domestic firms. Calculated from the proportion of foreign firms' output on total output of 3-digit ISIC industry
Age	The age of firm, calculated from the year of survey minus the establishment year of the firm.
Productivity Growth Variables [Eq. (4)]	
TFPG	Total Factor Productivity Growth is the percentage of growth of the factors used in production, calculated from the decomposition method of production frontier as in Eq. (10)
TEC	Technical efficiency change of a firm in producing output with the combination of available inputs, calculated from Eq. (11)
TC	Technological change is the percentage of technological progress in production, calculated using Eq. (12)
SEC	Scale efficiency change of a firm in production, calculated from Eq. (13)

Table 2. Descriptive statistics of variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
Ln(Y)	15197	13.55	2.09	6.51	20.52
Ln(L)	15197	4.54	1.27	3	10.54
Ln(K)	15197	7.76	2.06	1	15.23
Ln(M)	15197	12.80	2.27	5.32	20.33
Ln(E)	15197	9.69	2.23	0.35	17.78
FDI	15197	0.06	0.23	0	1
Spillover	15197	0.17	0.27	0	1
Age	15197	19.81	16.13	0	100

Source: Calculated from balanced panel dataset, a survey of medium and large enterprises, The Indonesian Board of Statistics, 1988-2000.

Table 3. Estimation results of maximum likelihood stochastic production frontier.

Variable	Parameter	All Firms	Local-owned Firms
Production Frontier			
Constant	β_0	3.5574*** (58.1141)	3.5239*** (206.8822)
Ln(L)	β_1	0.0880*** (4.1784)	0.0168*** (4.1781)
Ln(K)	β_2	0.4194*** (103.6055)	0.4097*** (120.6284)
Ln(M)	β_3	0.4858*** (39.5043)	0.4929*** (221.6479)
Ln(E)	β_4	0.0980*** (30.8097)	0.0973*** (51.6488)
T	β_5	0.0061*** (3.5786)	0.0079*** (11.0212)
Inefficiency Function			
Constant	δ_0	-0.0498*** (8.7479)	-0.5521*** (9.3562)
FDI	δ_1	-0.1546*** (5.4476)	-
Spillover	δ_2	0.0481*** (30.0286)	0.1011*** (33.6827)
Age	δ_3	0.0185*** (8.1964)	0.0050*** (8.4949)
Gamma	γ	0.0500*** (69.0000)	0.8441*** (69.9088)
Log-likelihood		-4,297.28	-3,188.79
Number of Firms		1,169	1,103
Number of Observations		15,197	14,339

Source: Estimated from Eqs. (1) and (2). Note: Numbers in parentheses are t-statistics. *** represents the significance level at alpha 1% and ** represents the significance level at alpha 5%.

percent, which means that a 1 percent increase in the capital can increase output by 0.42 percent. In addition, raw materials (In M) contribute 0.49 percent to output, reflecting that a 1 percent increase in raw materials raises output by 0.49 percent. Furthermore, energy (In E) has a coefficient of 0.098 percent, which reflects that an increase in 1 percent of energy consumption will raise output by 0.098 percent. Time (T) has a coefficient of 0.0061, indicating that output increases from year to year with an average of 0.0061 percent during the observation period.

The return on the scale for the manufacturing firms can be calculated from the sum of each input elasticity. By adding-up labor elasticity with other elasticities (capital, material, and energy), it is found that the return to scale of the production is 1.0912, which is more than 1. This finding indicates that the production frontier of observed firms exhibits an increasing return to scale.

Moving to the estimation results of the inefficiency function in the lower part of the third column of Table 3, the coefficient of the FDI variable is negative and significant. This dummy variable result shows that foreign-owned firms have lower inefficiency compared to local-owned firms. These findings suggest that the theoretical argument (for example, as notified in Anwar and Sun, 2019; Wang et al., 2013) about MNCs that are more efficient than local firms can be empirically verified. This coefficient has a statistically significant effect up to a 99% significance level (alpha 1%). This finding puts a ground for the possibility of FDI-related spillovers on productivity, which is tested in hypothesis 1. The coefficients of the Spillover variable are positive, indicating that FDI increases the technical inefficiency of manufacturing companies. In other words, there is a negative effect of the existence of foreign firms on the efficiency of local firms. A possible explanation of the negative effect of FDI is that foreign firms "steal" the market share of local firms so that local firms get smaller portions of the market (Merlevede et al., 2014). Another explanation of this negative effect is that foreign firms competing with technology and efficiency are far more advanced than local firms, so local firms are displaced from the market (Iršová and Havránek, 2013). This finding answers hypothesis 1 in this study.

The estimation result of Age variable shows a significant positive influence from firm age to inefficiency. In other words, the older the firm's age the more inefficient the firm. This finding makes sense because, generally, long-operated firms become "overweight" and produce less efficiently than new firms (Kapelko and Lansink, 2015; Navaretti et al., 2014). In addition, new firms usually know the scale of production and modern technology to produce on a more efficient scale than the old firms (García-Quevedo et al., 2014; Lu, 2016).

4.2. Results of the firm cluster and FDI-Related benefit

The estimates in this section are on firm clusters. The results are complementary to the estimation results in the previous section. In this section, estimates are made on firms in sub-sectors of two-digit industry based on the International Standard of Industrial Code (ISIC). Firms are clustered into nine industrial groups of two-digit ISIC, i.e., Food and Beverage (ISIC 31), Textile and Leather (ISIC 32), Wood and Wood Products (ISIC 33), Paper and Paper Products (ISIC 34), Chemical and Pharmaceutical (ISIC 35), Non-Metallic Minerals (ISIC 36), Basic Metal (ISIC 37), Metal Product (ISIC 38) and Others (ISIC 39).

Estimates of each sub-sector in the manufacturing industry have advantages in two ways: (1) firms are more homogeneous in terms of technology, thus allowing the best practice's dispersion is low and (2) frontier technology for each sub-sector is set differently, which more reflects the reality. According to Anwar and Sun (2019), estimates on disaggregate industries with homogenous firms help eliminate the effects of heterogeneity in the data, resulting in better and more efficient estimates. The production frontier estimation results for each sub-sector are shown in Table 4.

For estimation of production frontier, the factors of production besides labor (i.e., capital, raw material, and energy) have a significant positive effect on output in all sub-sectors. Meanwhile, labor variables have a significant positive effect on outputs in five sub-sectors, a significant negative impact in two sub-sectors, and an insignificant positive influence in the other two sub-sectors. These findings justify that most production factors have significant impacts on output in each sub-sector.

Findings of the negative effects of labor on output in the Food and Beverage sub-sector (ISIC 31) and Others sub-sector (ISIC 39) need to be interpreted carefully. The findings of negative labor elasticity in the two sub-sectors can be due to the decreased marginal physical product of labor (MPPL) or other factors. Therefore, these findings need to be treated with care. The inefficiency function estimation results (bottom of Table 4) show that the coefficients of FDI variables are negative across all sub-sectors and significantly affect all sub-sectors, except for Others sub-sector (ISIC 39). The interpretation of these findings is that foreign firms have lower inefficiencies than local firms. These findings support the theoretical arguments put forward by Helpman (2014) and Kokko and Kravtsova (2008) that multinational corporations (MNCs) have higher technical efficiency, allowing them to affect indirectly through productivity spillovers on local firms. These findings are also consistent with the findings of the aggregate level in the previous section.

The results of the Spillover estimation show a significant positive effect of FDI on the firm's inefficiency in the Food and Beverage sub-sector (ISIC 31) and the Textile and Leather sub-sector (ISIC 32). The interpretation of these findings is that the presence of foreign firms in the two related sub-sectors negatively impacts the efficiency and productivity of local firms. Meanwhile, in five sub-sectors, namely Wood and Wood Products (ISIC 33), Paper and Paper Products (ISIC 34), Chemicals and Pharmaceuticals (ISIC 35), Non-Metal Minerals (ISIC 36), and Basic Metals (ISIC 37), the presence of foreign firms has a significant negative effect on the inefficiency of local firms. In other words, there is a positive effect of FDI on the efficiency and productivity of local firms in the five related sub-sectors. Two other sub-sectors, namely Metal Products (ISIC 38) and Others (ISIC 39), have insignificant effects, indicating no effect of FDI on firms in the two sub-sectors. The finding of a negative impact of FDI in labor-intensive firms might be due to a wide gap in knowledge advancement between MNCs subsidiaries and local-owned firms, which makes the local firms unable to imitate the advanced knowledge and the result is the presence of MNCs tend to steal the market share of the local-owned firms. On the other hand, a knowledge gap might not be wide in the capital-intensive sectors so that the local firms are able to absorb the knowledge spillovers, resulting in an increase in productivity.

From the findings of the Spillover Effect variables for the nine sub-sectors, it can be concluded that each sub-sector receives different spillover effects of FDI. For labor-intensive industries such as food and beverage (ISIC 31) and textile and leather (ISIC 32), the presence of FDI negatively impacts local firms. In other words, the presence of foreign firms in both industries reduces the market share of local firms, and there is no knowledge transfer takes place. In contrast, local firms in capital-intensive industries, such as wood and wood products (ISIC 33), paper and paper products (34), chemical and pharmaceutical (35), and non-metal mineral (36), enjoy the presence of FDI. This finding answers hypothesis 3 and justifies the argument puts forward by (Anwar and Sun, 2019; Lipsey and Sjoholm, 2005) that there are variations in the spillover effects that firms derive in each industry cluster. Thus, the treatment of FDI in each sub-sector of industry needs to be different depending on the ability of firms to absorb positive effects. For industries where local firms are able to absorb the positive effects of foreign firms, incentives and policies that support FDI are required. In contrast, in industries where local firms are not able to absorb the spillover effects or otherwise have a negative effect on the presence of FDI, incentives and policies that pro-FDI need to be reconsidered.

Estimated results for the Age variables show that five sub-sectors, namely Food and Beverages (ISIC 31), Textile and Leather (32), Chemical and Pharmaceutical (35), Basic Metal (37), and Metal Products (38), have significant positive coefficients, indicating that firm age increases inefficiency. Two other sub-sectors, Paper and Paper Products (ISIC 34) and Others (39), exhibit significant negative coefficients, which can be interpreted that age decreases inefficiency. Meanwhile, the remaining two sub-sectors have an insignificant negative life coefficient which shows no influence of age in firms' inefficiency. From these findings, it can generally be concluded that firms with long-standing operations in most manufacturing sub-sectors are more inefficient than new firms. A possible argument related to these findings is that new firms have more advanced technology and knowledge than older ones. Organizational structure is increasing "fat" in the old firms, making old firms less efficient than new firms. These findings are in line with findings from (Navaretti et al., 2014) and (Kapelko and Lansink, 2015).

4.3. Results of types of productivity benefits for various firm clusters

To answer hypothesis 3, this section estimates the types of productivity benefits to each cluster of manufacturing firms. The estimation requires two-steps. The first-step is to decompose the Total Factor Productivity Growth (TFPG) based on Eq. (4). The second-step is to estimate the type of benefits from each component of productivity growth (TEC, TC, SEC, TFPG), with Eqs. (5), (6), and (7). As the main interest in this paper is to analyze the types of productivity spillovers for each cluster, only the second-step results are presented in Table 5. The first-step results (the decomposition scores for each firm of the three components of TFPG) are available upon request.

From the results of TFPG decomposition in the first-step, one can estimate the effects of FDI-spillover on the three components of productivity growth. The estimation provides information on the types of productivity benefits, which take the forms of technical efficiency benefit (TEC), technological benefit (TC), and scale efficiency benefit (SEC). Estimation results for each cluster of the firms are shown in Table 5. Of the nine sub-sectors estimated, eight sub-sectors (ISIC 31, 32, 33, 35, 36, 37, 38, and 39) show a positive effect of FDI on the total production growth (TFPG) of local firms, while one sub-sector (ISIC 34) shows a negative effect. From these findings, it can be concluded that in general, almost all two-digit industry of the manufacturing sector is able to absorb the positive effects of FDI in the form of increased total productivity growth for local firms. The paper and paper products industry (ISIC 34) is an exception. These findings support pro-FDI policies, which suggest that the uniqueness of each industry needs to be considered in providing incentives for FDI, as pointed out by (Lipsey and Sjoholm, 2005). Sectors that are able to absorb positive-impact effects need to be prioritized for incentives in attracting FDI, while sectors that obtain negative impacts need to be protected from "market stealing" of FDI.

To dig more detail on which components of the TFPG generate FDI-related spillovers, estimates are made on technical efficiency (TEC) growth, technological progress (TP), and scale efficiency growth (SEC). From estimates of the TEC, it is found that five industries (ISIC 32, 33, 37, 38, and 39) have a significant positive effect on FDI, while the other four industries (ISIC 31, 34, 35, and 36) obtain a significant negative impact. Interestingly, when the findings of the TEC estimates are compared with the findings of the TFPG estimates, it is found that the food and beverage (ISIC 31), the chemical and pharmaceutical (ISIC 35), and the non-metal minerals (ISIC 36) receive a negative effect of FDI on the technical efficiency growth, while the total growth (TFPG) of these three industries has a positive effect on FDI. These findings imply that firms in these three

Table 4. Estimation results of stochastic production frontier for firms in two-digit ISIC.

	Food and Beverages (ISIC 31)	Textile and Leather (ISIC 32)	Wood and Wood Products (ISIC 33)	Paper and Paper Products (ISIC 34)	Chemical and Pharmaceutical (ISIC 35)	Non-Metal Minerals (ISIC 36)	Basic Metal (ISIC 37)	Metal Products (ISIC 38)	Others (ISIC 39)
Production Frontier									
Constant	3.8293*** (131.8026)	2.9293*** (67.0466)	2.5476*** (33.7883)	3.0539*** (34.4017)	3.3818*** (68.9016)	4.1096*** (19.0233)	2.7909*** (17.9866)	3.1699*** (70.3598)	3.2390*** (33.5028)
Ln(L)	-0.0276*** (-4.4847)	0.0366*** (3.6815)	0.0417*** (4.0885)	0.0711*** (2.8297)	0.0494*** (5.2149)	0.1437 (0.1823)	0.0847*** (2.8253)	0.0161 (1.4077)	-0.0999*** (-2.7676)
Ln(K)	0.4428*** (84.2555)	0.3733*** (50.5333)	0.3050*** (31.0475)	0.3602*** (24.4186)	0.4259*** (47.8999)	0.4266 (0.8096)	0.2502*** (14.9499)	0.3971*** (50.4882)	0.4788*** (20.0592)
Ln(M)	0.4530*** (133.4281)	0.5661*** (96.2175)	0.6372*** (74.5431)	0.5566*** (46.5697)	0.5074*** (79.1284)	0.3776*** (52.0499)	0.6119*** (36.2726)	0.5426*** (95.6183)	0.5459*** (50.1269)
Ln(E)	0.1242*** (36.6170)	0.0511*** (12.3632)	0.0359*** (5.8039)	0.0486*** (5.4665)	0.0501*** (9.8474)	0.1097*** (2.8340)	0.0925*** (6.1117)	0.0576*** (10.0103)	0.0159** (2.1411)
T	0.0047*** (3.8097)	0.0105*** (6.9111)	0.0052*** (2.6233)	0.0076** (2.2427)	-0.0017 (-0.9340)	0.0040 (0.0626)	0.0221*** (5.4083)	0.0069*** (3.2189)	-0.0056** (-2.0034)
Inefficiency Function									
Constant	-0.0422*** (11.1653)	-5.6064*** (-11.9636)	0.0501* (1.7283)	0.0602 (0.4110)	0.1321*** (7.2929)	0.0546 (0.2507)	-0.2902*** (-3.7844)	-0.6819*** (-15.8009)	0.1386 (1.4088)
FDI	-0.3011*** (-12.1419)	-0.3525* (-1.6583)	-0.2277* (-1.8283)	-0.2236 * (-1.8676)	-0.2070** (-2.3806)	-0.0627** (-2.0239)	-0.1718*** (-3.1888)	-0.2103* (-1.7329)	-0.0001 (0.0023)
Spillover	0.2639*** (14.6467)	0.2063*** (5.9379)	-0.1145** (-1.9794)	-0.5505*** (-7.3155)	-0.2579*** (-3.6134)	-0.1646** (-1.9972)	-0.1396*** (-3.2651)	-0.0467 (-4.1568)	0.0001 (0.0048)
Age	0.0011*** (8.9013)	0.0498*** (13.8099)	-0.0018 (-1.3603)	-0.0102* (-1.6740)	0.0017** (2.4181)	-0.0006 (-0.0309)	0.0715*** (4.3917)	0.0594*** (18.8335)	-0.0145** (-2.2062)
Gamma	0.0001*** (2.2829)	0.9452*** (191.0910)	0.0148*** (4.5916)	0.1603* (1.6530)	0.0029* (1.7344)	0.0026 (0.0379)	0.8147*** (33.5386)	0.9403*** (248.6909)	0.7550*** (6.5292)
Log-likelihood	-2380.79	-291.8362	-186.7091	-82.7110	-240.1995	-26.3074	-37.9347	-75.6773	-120.0336
Number of Firms	509	120	72	55	168	92	15	125	13
Number of Observations	6,617	1,560	936	715	2,184	1,196	195	1,625	169

Source: Estimations on Eqs. (1) and (2) for each sub-sector of 2-digit ISIC. Note: the numbers in parentheses are t-statistics. *** represents significance at alpha 1% level, ** represents significance at alpha 5% level, and * represents significance at alpha 10% level.

Table 5. Spillover effects of FDI and sources of productivity growth for each sub-sector of 2-digit industries.

	Food and Beverages (ISIC 31)				Textile and Leather (ISIC 32)			
	TEC	TP	SEC	TFPG	TEC	TP	SEC	TFPG
Spillover	-0.1616***	0.2931***	1.9067**	2.3942***	0.1100***	1.1539**	6.2844	1.2506***
R2	0.0002	0.0004	0.0345	0.0005	0.0001	0.0166	0.1087	0.0024
Hausman Test	Prob > chi^2 = 0.2478 → RE	Prob > chi^2 = 0.000 → FE	Prob > chi^2 = 0.000 → FE	Prob > chi^2 = 0.000 → FE	Prob > chi^2 = 0.9958 → RE	Prob > chi^2 = 0.000 → FE	Prob > chi^2 = 0.000 → FE	Prob > chi^2 = 0.7201 → RE
Observation	6108	6108	6108	6108	1440	1440	1440	1440
	Wood and Wood Products (ISIC 33)				**Paper and Paper Products (ISIC 34)**			
Spillover	0.0104***	1.0855***	8.8271**	11.3367***	-0.2728***	-0.1241**	-0.9679**	-0.3660***
R2	0.0000	0.0012	0.0248	0.0019	0.0001	0.0382	0.0257	0.0039
Hausman Test	Prob > chi^2 = 0.8818 → RE	Prob > chi^2 = 0.000 → FE	Prob > chi^2 = 0.000 → FE	Prob > chi^2 = 0.009 → FE	Prob > chi^2 = 0.5846 → RE	Prob > chi^2 = 0.8701 → RE	Prob > chi^2 = 0.0210 → FE	Prob > chi^2 = 0.7476 → RE
Observation	864	864	864	864	660	660	660	660
	Chemical and Pharmaceutical (ISIC 35)				**Non-Metal Minerals (ISIC 36)**			
Spillover	-0.3335***	0.1812**	1.7378**	1.5837**	-0.4923***	0.2401**	1.8369**	3.5748***
R2	0.0025	0.0159	0.0404	0.0133	0.0003	0.0137	0.0190	0.0024
Hausman Test	Prob > chi^2 = 0.0840 → FE	Prob > chi^2 = 0.0000 → FE	Prob > chi^2 = 0.0000 → FE	Prob > chi^2 = 0.0361 → FE	Prob > chi^2 = 0.1140 → RE	Prob > chi^2 = 0.0025 → FE	Prob > chi^2 = 0.0074 → FE	Prob > chi^2 = 0.0119 → FE
Observation	2016	2016	2016	2016	1104	1104	1104	1104
	Basic Metal (ISIC 37)				**Metal Products (ISIC 38)**			
Spillover	0.6371**	0.3107**	3.9836***	0.0863***	0.6049***	0.3540*	2.8415***	1.7457***
R2	0.0065	0.0382	0.0009	0.0079	0.0040	0.0588	0.0031	0.0064
Hausman Test	Prob > chi^2 = 0.4348 → RE	Prob > chi^2 = 0.1170 → RE	Prob > chi^2 = 0.0237 → FE	Prob > chi^2 = 0.2357 → RE	Prob > chi^2 = 0.2387 → RE	Prob > chi^2 = 0.0111 → FE	Prob > chi^2 = 0.0000 → FE	Prob > chi^2 = 0.0093 → FE
Observation	180	180	180	180	1500	1500	1500	1500
	Others (ISIC 39)							
Spillover	0.0002***	0.0001	0.0011*	0.0008**				
R2	0.0011	0.1082	0.0766	0.0134				
Hausman Test	Prob > chi^2 = 0.4220 → RE	Prob > chi^2 = 0.5412 → RE	Prob > chi^2 = 0.0001 → FE	Prob > chi^2 = 0.0839 → FE				
Observation	156	156	156	156				

Source: Estimation results based on Eqs. (5), (6), and (7).
Note: The numbers in parentheses are t-statistics for the Random Effect model and Z-statistics for the Fixed Effect model. *** represents the significance at 1% level, ** represents the significance at 5% level, and * represents the significance at 10% level.

industries are experiencing declining growth in combining input factors to produce output when foreign firms enter the local market. These findings are important because it shows that although the total productivity of local firms in all three industries receives a positive impact, the technical efficiency of these local firms experiences a negative impact. The estimation results on technological advances show that seven sub-sectors (ISIC 31, 32, 33, 35, 36, 37, and 38) receive a positive effect of FDI. Meanwhile, one sub-sector, Paper and Paper Products (ISIC 34), receives a negative technological impact. Another sub-sector, Others (ISIC 39), does not significantly gain the FDI-related technology. Thus, it can be concluded that firms in most of the manufacturing industries experience technology benefits from the FDI. The presence of foreign firms in the seven sub-sectors leads to technology transfer to local firms.

In terms of scale efficiency, the presence of FDI also generates a positive impact on local firms. The estimation results show seven sub-sectors (ISIC 31, 33, 35, 36, 37, 38, and 39) whose local firms have a positive effect on a production scale. Only one sub-sector (ISIC 34) has a negative impact on local firms and only one sub-sector (ISIC 32) whose local firms do not significantly receive scale benefits. In general, it can be argued that the presence of FDI in the cluster of manufacturing industries increases the scale of efficiency of local firms in almost all clusters. Findings from the effects of FDI on the productivity growth in each manufacturing sub-sector provide additional justification that the presence of FDI provides technology transfer and increases technical efficiency and scale efficiency for local firms. Thus, the theoretical arguments put forward by Markusen and Trofimenko (2009) are empirically proven, namely that the transfer of knowledge from foreign firms can be technology and efficiency.

5. Conclusion and policy implications

This study analyzes the productivity impacts of FDI on the Indonesian manufacturing firms. The total number of observations is 15,197 balanced panels, with 1,169 companies for 13 years from 1988 to 2000. The companies under study are clustered into nine sub-sectors of 2-digit ISIC and cover 400 sub-sectors of 5-digit ISIC. Two analytical methods are used to assess the spillover effects of FDI on local firm productivity, namely Stochastic Production Frontier (SPF) and Malmquist Productivity Index (MPI).

The FDI-related productivity is analyzed at the level of technical efficiency and the growth of three pivotal components of TFPG. The analysis at the level of technical efficiency pictures the impact of FDI on local firms' efficiency and productivity in each industry cluster. In contrast, the growth analysis reflects the FDI affects all firms' TFPG components in the industry's nine sub-sectors. The SPF is applied to estimate the analysis at the level of technical efficiency and the MPI is employed for estimating the growth effect of FDI on three components of TFPG.

The results in technical efficiency estimation answer the first and the second hypotheses of this research, whereas the analysis on the growth answers the third hypothesis. Thus, three crucial findings prevail. The first vital finding is that there is indeed a positive FDI-productivity benefit on local-owned firms in the Indonesian manufacturing sector, and this positive benefit is maintained in many clusters of firms with similar products. The second essential finding provides a light on the existing empirical debate on the heterogeneity in absorbing FDI-related productivity among firm groups. The current research adds a new finding that labor-intensive sectors, such as food and beverage (ISIC 31) and textile (ISIC 32), are unable to absorb the FDI-productivity benefits and even receive negative impact from FDI, while capital-intensive industries, such as wood and wood products (ISIC 33), paper and paper product (ISIC 34), chemical (ISIC 35), and non-metal minerals (ISIC 36) are able to grasp the FDI-productivity benefits. This second finding implies a wide gap in knowledge advancement between MNCs' subsidiaries and local-owned firms in labor-intensive sectors, making the local firms unable to imitate the advanced knowledge and the result is MNCs' presence tend to steal local-owned firms' market share. On the other hand, a knowledge gap might not be wide in the capital-intensive sectors so that the local firms are able to absorb the knowledge spillovers, resulting in an increase in productivity. The third key finding adds new evidence that three sources of FDI-productivity benefit Indonesian manufacturing firms. The source of benefits is steamed from technical efficiency change, technological change, and scale efficiency change, with the most evidence source, varies among the nine-clusters of firms.

There are three major implications of the findings of this study. Firstly, policies to attract FDI by providing incentives and facilities are on the right track as FDI generates positive impacts on local firms' productivity. This finding supports the continuation of policies to attract FDI. Secondly, the FDI-related policies need to be more selective on sub-sectors that able to squeeze positive benefits. Thirdly, the type of FDI should be carefully taken into account when providing supportive policies, with a preference on FDI that provides technological progress and efficiency improvement. In other words, FDI with advanced technology and high efficiency needs to be prioritized over FDI that is looking for a market.

Declarations

Author contribution statement

Suyanto Suyanto: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Yenny Sugiarti: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data.

Idfi Setyaningrum: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

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The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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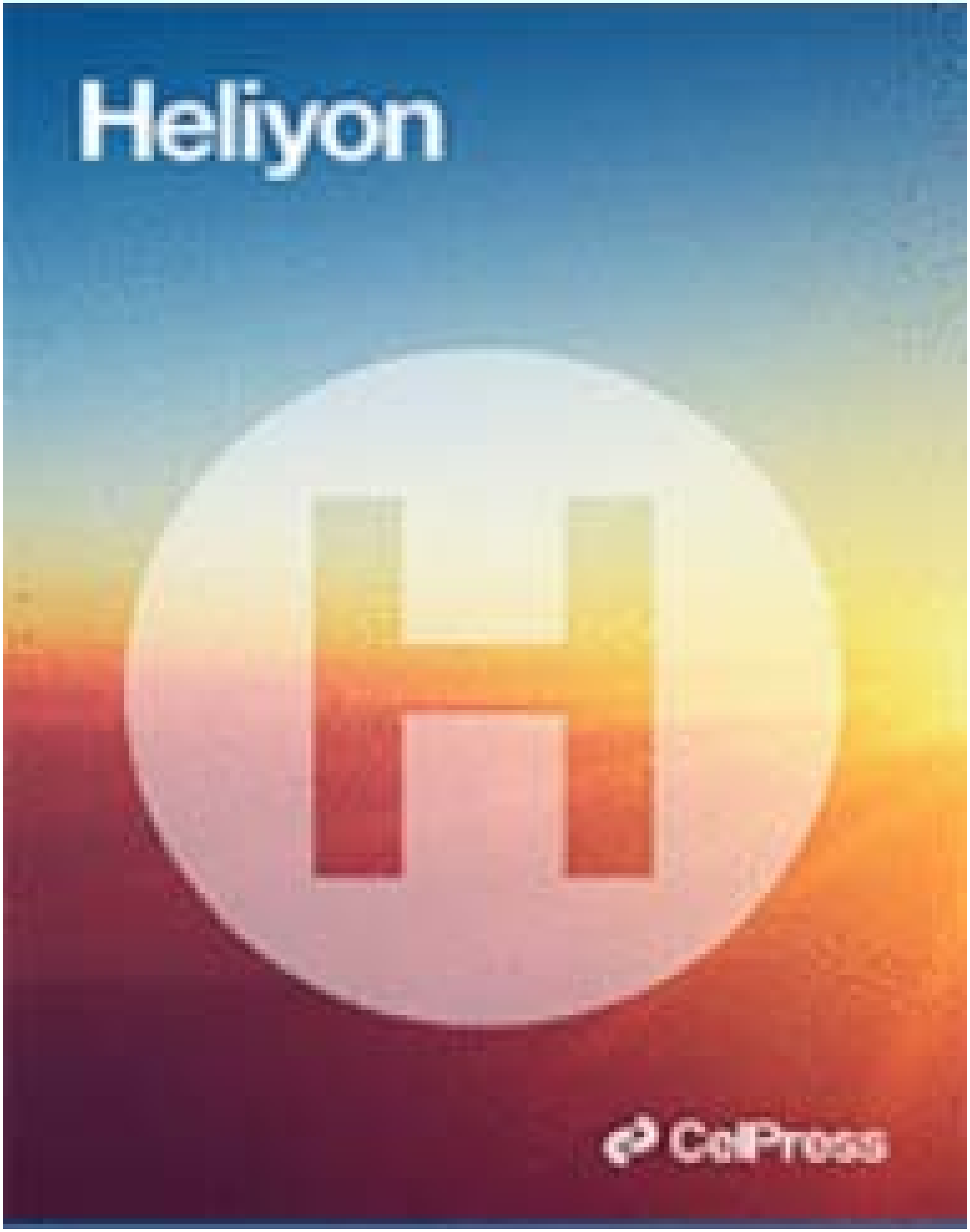
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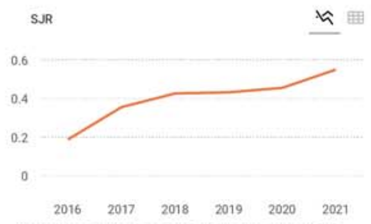

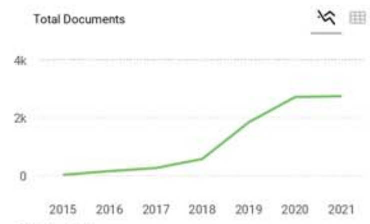

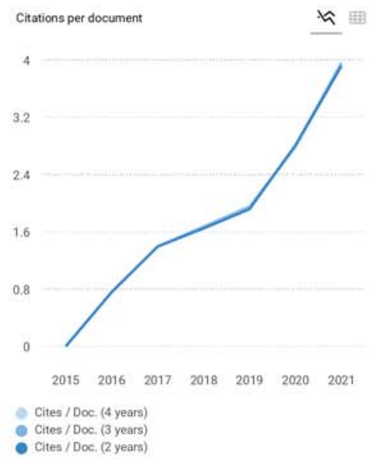

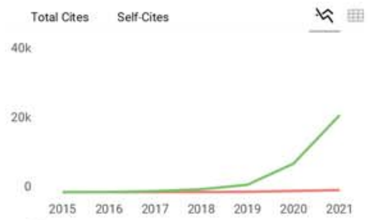

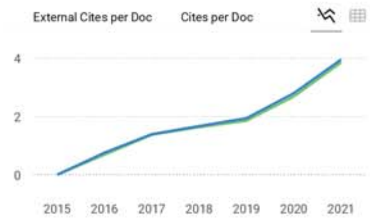

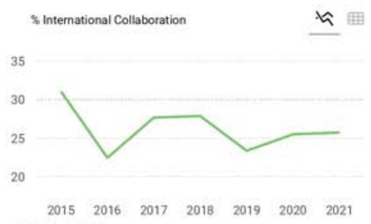

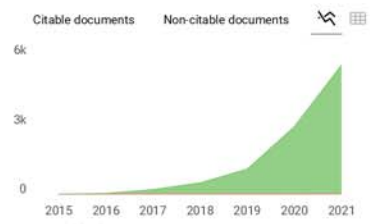

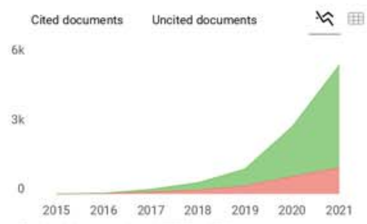

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