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Does competition and foreign investment spur industrial efficiency?: firm-level evidence from Indonesia

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ABSTRACT

This study examines the effects of market competition and foreign direct investment on the technical efficiency of firms within the Indonesian manufacturing sector using a Stochastic Frontier Analysis. We employ a firm-level panel dataset for the period of 2010–2014, covering 400 subsectors, and employing two measures of industrial concentration as proxies for market competition. The results suggest that firms operating in less competitive sectors in Indonesia experience higher technical efficiency. Additionally, foreign ownership, international activity (export-import), and firm size are positively related to technical efficiency. Such findings suggest that the efficient structure hypothesis (ESH) applies in Indonesia, as more efficient firms gain in market share as a result from dynamic competition. Foreign direct investment (FDI) via horizontal spillovers has contributed to an increase in intra industry firms' efficiency. Nevertheless, as industrial concentration increases, the positive effects in firm efficiency from FDI and from international trade (imports and export) tend to decrease.

1. Introduction

This study estimates the technical efficiency of manufacturing firms in Indonesia, employing a Stochastic Frontier Analysis (SFA), and considering four main inputs of production: labor, capital, raw materials, and energy. The data includes 400 sub-sectors, and a total of 29,232 items of data. The impacts of FDI, exports, imports, and market competition are empirically investigated as sources of efficiency in Indonesia from 2010 to 2014. In this study, competition then refers to the concentration levels within the different industries, such that there is a low level of competition when there are few firms in the market, each holding large shares of the market. We measure concentration by two indicators: the Herfindahl-Hirschman Index (HHI) and the market share of the four largest firms (CR4) as they complement one another (Setiawan and Lansink, 2018). The HHI measure is often employed to capture the competitive landscapes of an industry, based on the hypothesis that higher industrial concentration lowers competition by promoting collusive behavior among market players (Rumler and Waschiczek, 2016). Although existing studies have addressed the effect of competition on firm efficiency separately (using HHI or CR4), there is a lack of empirical evidence on efficiency and competition in Indonesia that encompasses both indicators.

The oil price shock of the early 1980s triggered a transformation in trade and industrial policy in Indonesia as the government sought to develop non-oil sources of growth, to increase productivity in local firms and to diversify production and export activities. Besides wanting improved productivity, the government also aimed for economic changes in terms of trade openness, business environment, rules of competition, and foreign investment (Pangestu et al., 2015), which have resulted in a new competition playground for firms. Consequently, the Indonesian Investment Coordinating Board (BKPM, 2017) reported that net Foreign Direct Investment (FDI) inflows between 2007 and 2017 increased from Rp. 93.5 trillion to Rp 392.7 trillion, rising more than three times in a decade. The new investment regulations in Indonesia had successfully attracted larger inflows of FDI and stimulated global trade, with manufacturing industries as the major destinations of foreign investment (45% of total FDI in 2007–2017).

Higher exposure of firms to international trade and the opening of markets to foreign investment is generally believed to change the market structure. The presence of new foreign firms could spur competition in

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the market as entrants may bring knowledge, technology, and management that could benefit domestic players. Nevertheless, new foreign investment also put pressure on domestic players, inducing them to perform at a higher level of technical efficiency to protect their market share and to prevent closing down. Greater openness to foreign technologies and wider deregulation could then lead to increase in market power by firms employing superior technology. This study therefore aims to explore the effects of foreign investment and competition on technical efficiency within the manufacturing sector in Indonesia.

In such global interconnectedness, the role of exports, imports, and foreign direct investment on firm's efficiency has attracted much attention of scholars (Lemi and Wright, 2020; Padilla et al., 2019). Market liberalization is generally believed to facilitate improvement in technical efficiency through export and import activity (Ben Yahmed and Dougherty, 2017; Mok et al., 2010; Saputra, 2014) and through technology adoption via high-quality resources (Mazorodze, 2020; Piermartini and Rubínová, 2014; Suatmi et al., 2017). On the other hand, FDI is expected to be advantageous for host countries as it provides new capital, generates employment, supports building production capacity, and brings superior technology (Arnold and Javorcik, 2009; Sari et al., 2016). Besides, FDI has indirect benefits for the host country, known as externalities (spillover), mainly transmitted through a non-market mechanism in the form of superior technology, knowledge, managerial expertise, and scale effects among others (Lu et al., 2017). Spillover effects from foreign firms could impact domestic firms, driving them to higher efficiency levels.

The literature on efficiency and FDI spillovers generally differentiates between vertical spillover effects (across sectors) and those that spread horizontally (within the same sector). Vertical spillovers capture the effects through linkages created by foreign-owned firms with domestic firms in the upstream sectors (backward) or downstream (forward) (Orlic et al., 2018). Horizontal spillovers, by contrast, capture effects derived from within the same sector of investment, in the form of demonstration effects, labor mobility, and competition (Sari, 2019). Some studies investigating the relation between FDI and efficiency in Indonesia suggest that FDI supports efficiency through horizontal spillovers (Sari, 2019; Sari et al., 2016; Suyanto et al., 2014). Still, there is a notion of foreign firms taking market share from domestic players via competition channels (e.g., the pharmaceutical sector in Suyanto and Salim, 2011; e.g., electronics in Suyanto et al., 2012; the food sector in Setiawan and Lansink, 2018). The possibility of foreign players in Indonesia 'stealing' the market eventuates from foreign-owned firms gaining rapid market shares (Arnold and Javorcik, 2009; Suyanto et al., 2012), and from increasing shares of industrial concentration.

Theoretically, higher industrial concentration could lead to two scenarios. First, high market concentration could lead to low technical efficiency improvements in firms as there is less pressure from rivals, with static competition protecting inefficient firms, as Hicks (1935) proposed under the quiet life hypothesis (QLH). Alternatively, in a highly concentrated industry, efficient firms can produce at a lower cost per output, improving firm performance and driving out less efficient competitors, as proposed in the 'efficient structure hypothesis' (ESH) (Demsetz, 1973; Peltzman, 1977).

The empirical evidence looking into the connection between industrial concentration and technical efficiency in the manufacturing sector in Indonesia is mixed (Javorcik et al., 2012; Suyanto et al., 2012). Some scholars suggest that increasing market concentration levels drives lower technical efficiency in firms (Sari et al., 2016; Sari, 2019; Setiawan et al., 2012), which supports the QLH to some extent. As an example, larger firms and often foreign-owned firms, are less efficient than average players in the market (Sari et al., 2016), possibly as foreign-owned firms allocate more resources (wastefully) to gain additional market participation, driving the less productive players out of competition (Javorcik et al., 2012). Foreign-owned and large firms may be less efficient than smaller ones, but may have a greater advantage in productivity via technological progress and scale effects. As more prominent firms gain market share and as pressure from rivals declines, the incentives for them to increase efficiency drop.

A possible explanation for the mixed results in the relation between efficiency and industrial concentration in Indonesia is that although previous studies often include the HHI as a proxy for overall industrial concentration, the market share held by the largest players (CR4) is seldom considered as noted in Setiawan and Effendi (2016) and Setiawan and Lansink (2018). While there would be many firms within a market, there are sectors in which few players held a substantial share of the market, and many firms held the rest. Additionally, the current more extensive liberalization of markets in Indonesia suggests that foreign competition through imports has increased and that local companies may also compete in foreign markets through exports, as noted in Javorcik et al. (2012).

This study estimates the effects of competition and foreign investment on technical efficiency, employing a stochastic frontier (SFA) method. The SFA allows simultaneous estimation of the production function and the inefficiency function, permitting for the introduction of exogenous variables into the model. We address the empirical gaps that are revealed in four ways. First, we measure competition at home by employing two indicators, the HHI and the concentration ratio of the largest four enterprises (CR4) and investigate whether a causal relationship with technical inefficiency exist. Second, we estimate horizontal spillover effects from foreign investment and we interact the measure with the HHI and the CR4 to capture the competition effect derived from horizontal spillovers (often missed in the literature). Third, we complement the measure of industrial concentration (HHI) with proxies of firms' exposure to competition from foreign inputs (imports) and export activities to look at foreign competition (non-domestic based firms). Fourth, firms are differentiated based on size and ownership to test whether firm size and ownership (domestic or foreign) matters. Previous studies suggest that domestic players may be unable to defend their market share due to higher foreign competition (Arnold and Javorcik, 2009; Liu, 2008).

The following section begins with a review of the theory and empirical literature related to this study and presents our contribution to the literature in the field. The third section presents the methodology. The fourth section presents the empirical results and analysis. Finally, the last section provides the conclusion and policy implications.

2. The effect of competition and foreign presence

The relationship between industrial concentration and efficiency can be figured out using two competing approaches, i.e., the quiet-life hypothesis (QLH) and the efficient-structure hypothesis (ESH). Hicks (1935) first proposed QLH, noting that higher concentration will lower competition among firms, reducing incentives for firms to improve efficiency. Large firms operating in concentrated markets may lack cost minimization behavior due to the allocation of resources in wasteful ways aiming at retaining monopoly power, leading to inefficiency (Berger and Hannan, 1998). Some studies find evidence of higher levels of concentration leading to technical inefficiency, supporting the QLH hypothesis (Al-Muharrami and Matthews, 2009; Sari et al., 2016; Sari, 2019; Setiawan et al., 2012; Setiawan and Lansink, 2018; Swaminathan et al., 2015). In the context of Indonesia, Setiawan and Effendi (2016) argue that high market concentration in manufacturing firms may lead to market power rather than higher efficiency.

On the other hand, the ESH approach (Demsetz, 1973; Peltzman, 1977) proposes that in a highly concentrated industry, efficient firms can produce at a lower cost per output, improving firm performance. From the ESH perspective, competition enforcement spurs local firms to improve efficiency. Competition may lead domestic firms to engage in innovation, aiming at achieving higher efficiency in production through differentiation, creativity, quality improvement, and technology advancement. Fierce competition may urge managers to avoid production process slack (X-inefficiency) and to use resources more efficiently. Nickell et al. (1997) noted that competition could act as a disciplining device to put pressure on managers, and could lead to lower X-inefficiency. However, a highly competitive environment could create expectations of lower lifespan of new innovations leading to lower the incentives to innovate as it reduce projected future profits ('creative destruction') (Schiffbauer and Ospina, 2010). Empirical research in Indonesia (Suyanto et al., 2009) pointed out a significant relationship between concentration and efficiency in the chemical and pharmaceutical sectors (mainly non-labor intensive), suggesting that higher levels of market concentration are related to higher efficiency.

Furthermore, from the viewpoint of FDI, foreign presence may prompt efficiency gains for local firms via spillover effects or externalities. Externalities can take place in domestic firms via horizontal spillovers (effects within the same sector) or vertical spillovers (effects across sectors) (Orlic et al., 2018; Takii, 2011). Externalities through horizontal channels are transmitted to domestic players through three paths: demonstration effects (imitation, reverse engineering, and R&D), labor mobility (skills, training, experience, or education) and competition. As argued by Liu (2008), the benefit of competition within firms brought about by foreign players through FDI, is likely to occur when the domestic firms possess the capability to absorb technology and higher skills (Sugiharti et al., 2019).

Previous studies in Indonesia found mixed results related to horizontal spillovers. Suyanto and Salim (2011) suggested negative horizontal spillover effects in manufacturing firms, arguing that competition effects are larger (negative) than the demonstration effects (positive). Javorcik et al. (2012) found sizeable positive labor mobility effects in Indonesia, although suspecting low demonstration effects. Other studies do not differentiate between the transmission channels within horizontal externalities, generally concluding that FDI leads to lower inefficiency in firms via horizontal spillover effects (Sari, 2019; Sari et al., 2016). Our paper posits that a highly competitive environment may help to increase efficiency within the sector. However, as more efficient firms gain market share from less efficient ones, the effects of competition may decline. Similarly, horizontal spillovers via demonstration and labor mobility are likely to be positive, following the insights of Javorcik et al. (2012), and Suyanto and Salim (2011).

The entrance of foreign firms into the domestic market could lead to the market-stealing phenomenon, as production costs increase as a consequence of firms competing for workers and resources (Spencer and Spencer, 2008), leading to higher cost (lower profits), and possibly the crowding out of domestic players (Aitken and Harrison, 1999). Stronger competition may also compel domestic players to defend their market share by adopting new technology and management methods to increase efficiency (Görg and Greenaway, 2004; Sari, 2019). Besides, foreign and domestic goods become substitutes for one another, leading to more competition across firms. Javorcik et al. (2012) claim that Indonesia experienced a substantial increase in import competition in the 1990–2009 period, with a decrease in the number of firms in several sectors and a decrease in the number of firms exporting.

The impact of competition on efficiency will ultimately rely upon the characteristics of the local firms. As noted by Wang and Blomström (1992), firms can behave as active-learning or passive-watching firms. The active-learning firms will dedicate resources to learning investments, enjoy benefits from competition, and capture knowledge transfer from FDI. On the other side, the passive-watching firms will be left behind due to their lack of competency. In the long-run, inefficient firms may be driven out of the market, while firms with more competitive production costs, higher productivity levels, and more substantial profits will survive. It is broadly believed that competition will ensure that inefficient firms will exit the market and be replaced by more productive firms (market sorting effect between-firms). Javorcik et al. (2012) found evidence of higher levels of competition (lower HHI indexes) supporting higher productivity growth among firms in Indonesia, with more productive firms (increasing number among foreign-owned and large firms) driving out less productive ones from the market.

This study contributes to the existing empirical literature in several ways. First, the paper considers the effect of domestic and foreign competition (FDI, Export, and import) on firm-level technical efficiency. Second, the study looks at the links between firm efficiency and competition by estimating two complementary indicators of competition (HHI and CR4), building on the insights of Setiawan and Effendi (2016) related to industrial concentration in Indonesia. Third, the model employs interaction terms that help capture the effect of competition within horizontal spillovers and computes the effects of international openness (exports and imports) on total efficiency.

3. Data and methodology

This study uses firm-level data obtained from the annual Survey of Medium and Large Manufacturing establishments conducted by the Bureau of Statistics of Indonesia (Badan Pusat Statistik, BPS). The survey provides information at the firm level in terms of location, ownership structure, number of workers, data on the output, added value, inputs of production including raw materials, number of workers, fixed capital, and energy. Firms are categorized as medium-size when employing 20 to 99 workers and large-size when employing more than 100 workers.

We compile an unbalanced panel data set of 29,232 manufacturing firms from 2010 to 2014. This study covers 400 subsectors, while the firms within them are categorized according to the five-digit international standard industrial classification (ISIC). The highest number of firms is reported for 2014 (24,259 firms), and the lowest for 2010 (23,345 firms). Establishments reporting missing or zero values, and those with typographical mistakes in either of the inputs or output values are excluded. A ratio of material over output is employed, removing observations when the rate of material input is below 10 percent or higher than 90 percent, as suggested by previous studies employing industrial data from Indonesia (Sari, 2019; Sari et al., 2016).

When it comes to measuring technical efficiency by employing firm-level data, several approaches are available; for instance, data envelop analysis (DEA), production cost functions, dynamic technical efficiency, or the stochastic frontier production approach. The debate over which methodology is more appropriate is still an open discussion (Coelli et al., 2005; Parman and Featherstone, 2019; Simar and Wilson, 2013). The DEA offers several advantages in comparison to the SFA. The DEA does not require the specification of a function, is not technically restrictive, and it does not make a priori distinction between the relative importance of outputs and inputs (Alvarez and Crespi, 2003). DEA is often applied to measure efficiency across a homogeneous set of decision-making units, allowing multiple inputs and multiple outputs simultaneously (Gattoufi et al., 2014). By contrast, the SFA approach based on maximum likelihood requires the specification of a functional form and entails the distributional assumptions to be fulfilled to conform with economic theory (Parmeter and Kumbhakar, 2014).

As noted in Olesen and Petersen (2016), initially, the DEA approach does not make a specification of noise (i.e., measurement errors, sample noise, and specification errors), required for the inefficiency effects stochastic approaches. Although extensions of DEA (e.g., stochastic DEA) can be modeled as stochastic variables, allowing the estimation of stochastic inefficiency by including specifications of random noise and estimating the frontier as stochastic (Olesen and Petersen, 2016).

Considering the existence of advantages and disadvantages for the use of SFA and DEA, Parman and Featherstone (2019) evaluate the ability of four approaches to estimating "true" cost frontier and associated economic measure. The DEA appears as a fairly robust approach, generally overperforming SFA and other approaches in a number of the estimations. Still, the SFA was robust when the estimations observe the correct distribution assumption of the error term. Previous studies in Indonesia employing the survey data that we are employing had obtained robust results using SFA under the assumption of normal distribution and testing different specifications of the production function (e.g., Sari, 2019; Suyanto et al., 2014). While SFA may not necessarily be superior to DEA, it appears to be appropriate.

Previous studies in Indonesia incorporate both parametric SFA and non-parametric DEA approaches (Suyanto and Salim, 2011), finding consistent results in both approaches (direction of effects), with a small difference in the importance (magnitude) of some coefficients. However, the DEA found significant results on some variables not significant under the SFA approach, apparently as fewer restrictions are imposed under DEA. Other studies in Indonesia employed the DEA (Setiawan et al., 2012) to estimate the impact of technical efficiency on industrial concentration in the food industry, finding consistent results (direction) compared to studies employing SFA. In our study, the SFA method is preferred as the production function and the inefficiency function can be estimated simultaneously, permitting the introduction of exogenous variables into the model (e.g., the effect of competition, FDI, size, among other).

This study aims to unveil competition effects through firms' technical efficiency levels by adopting the stochastic frontier analysis (SFA) proposed by Battese and Coelli (1995). The production function is estimated by employing a combination of inputs aimed at achieving maximum output. The SFA approach assumes that firms operating on the frontier are fully technically efficient firms, while it measures inefficiency by computing the distance of firms from the frontier. The SFA allows simultaneous estimation of the production function and the inefficiency function. The model is expressed in linear form as follows:

$$y_{it} = f(x_{it}; \alpha, \beta).exp\{v_{it} - u_{it}\} \quad (1)$$

y_{it} stands for output of firm i at time t; x_{it} is a corresponding $(1 \times k)$ vector of inputs used in the production process by firm i at time t; $\alpha$and β are $(k \times 1)$ unknown parameters to be estimated; while v_{it} and u_{it} are components of the error term, independent of each other. The v_{it} denotes the time-specific and stochastic component, with *iid* $N(0, \sigma_v^2)$. u_{it} denotes the technical inefficiency, which follows a normal distribution but is truncated at zero with mean $z_{it}\delta$ and variance σ_u^2. Technical inefficiency is specified as:

$$u_{it} = Z_{it}\delta + \varepsilon_{it} \quad (2)$$

u_{it} (technical inefficiency effects) is assumed as a function of a Z that denotes a vector $(1 \times m)$of observable non-stochastic explanatory variables. δ denotes a set of unknown parameters to be estimated, and ε_{it} represents an unobservable random variable of inefficiency, defined by the truncation of the normal distribution with zero mean and variance (σ_u^2), truncated below zero $(-Z_{it}\delta)$.

Eqs. (1) and (2) represent production and the inefficiency function, respectively. The model is estimated employing a translog production function with inefficiency effects as proposed in prior studies (Suyanto et al., 2009; Svedin and Stage, 2016), written as:

$$y_{it} = \alpha_0 + \sum_{k=1}^{K}\beta_k x_{kit} + \frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{L}\beta_{kl}x_{kit}x_{lit} + \sum_{k=1}^{K}\beta_{kt}x_{kit}t + \beta_t t + \frac{1}{2}\beta_{tt}t^2 + v_{it} - u_{it} \quad (3)$$

where α_0 is the intercept, y and x are outputs and inputs in natural logarithm forms. The translog functional form is determined by input variables that explain output, including capital, labor, material, and energy $(K = 4)$. The subscript i is firm, and t represents time. u_{it} is defined as:

$$u_{it} = \delta_0 + \sum_{j=1}^{J}\delta_j Z_{jit} + \varepsilon_{it} \quad (4)$$

where δ_0 is the intercept in inefficiency function, Z represents a vector of explanatory variables that explain technical inefficiency, and ε_{it} denotes an unobservable random variable. In this study, technical inefficiency is included as a function of different firm characteristics. The Herfindahl-Hirschman Index (*HHI*) and the market share of the four largest firms (CR4) are proxies to measure market competition. Other variables included in the inefficiency function are export performance (*EP*) and import penetration (*IP*) as proxies for foreign competition. Additionally, foreign ownership (*FO*) and horizontal spillovers (*Hspill*) are proxies for the effect of foreign presence. 'Horizontal Spillovers' captures the impact of foreign presence in other enterprises within the same sector (Sari, 2019). MS_{jt} denotes the market structure of j-th industry in period t. Firm size (*FSize*) and a year dummy variable (*TIME*) are also added, as suggested in Sugiharti et al. (2017).

We also include the interaction between market structure and foreign competition to portray market concentration and greater foreign rivalry. The interaction between market structure and FDI spillover captures foreign spillover within the same industry. The interaction of market structure and time dummy captures the effect of market concentration through time to the firm's technical efficiency. The estimation model is as follows:

$$u_{it} = \delta_0 + \delta_1 MS_{jt} + \delta_2 IP_{jt} + \delta_3 EP_{jt} + \delta_4 Hspill_{jt} + \delta_5 FO_{ijt} + \delta_6 FSize_{ijt} + \delta_7 TIME + \delta_8 MS_{jt} \times IP_{jt} + \delta_9 MS_{jt} \times EP_{jt} + \delta_{10} MC_{jt} \times Hspill_{jt} + \delta_{11} MS_{jt} \times TIME + \varepsilon_{it} \quad (5)$$

Battese and Coelli (1995) suggest using the method of maximum-likelihood for simultaneously estimating the parameters of the stochastic frontier and inefficiency model in Eqs. (3) and (4), under the so-known one-stage estimation procedure. We follow the one-stage versus the two-stage estimation procedure, the latter having been found more likely to provide inconsistent results as technical efficiency might be correlated with production inputs (Kumbhakar and Lovell, 2000). Within the two-stage, the obtained technical efficiency index is regressed against a set of exogenous variables employing the standard OLS method, assuming that exogenous variables can indirectly alter output on technical inefficiency. To avoid possible inconsistencies in the estimation, this study employs the one-stage approach, as proposed in Kumbhakar and Lovell (2000).

The maximum-likelihood function can be expressed in terms of variance parameters $\sigma_s^2 \equiv \sigma_v^2 + \sigma_u^2$ and $\gamma \equiv \sigma^2/\sigma_s^2$, where γ takes a value between 0 and 1. If γ equals 0, it indicates the suitability of applying the conventional production function, comprising z variables, into the production function. However, SFA will be employed if the γ is closer to 1. The value equaling zero also implies that the production function is biased by uncontrolled factors or noises. A lower value of γ reflects a lower impact from the technical inefficiency component.

SFA requires a specific and flexible functional form to reduce the risk of error in the model. Hence, the translog production function is considered as a base and will be tested against four sub-models, such as Hicks-Neutral technological progress (TP), no-technology progress, Cobb-Douglass, and no-inefficiency production functions as in Sari (2019). The production function under the Hicks-Neutral TP takes place when the interacting coefficient for inputs and times equals zero ($\beta_{kt} = 0$). The production function under no-TP considers time (proxy for tech progress) as zero ($\beta_t = \beta_{tt} = \beta_{kt} = 0$). The Cobb-Douglas production function occurs when the coefficients for inputs of production equal zero ($\beta_{kl} = \beta_{kt} = \beta_t = \beta_{tt} = 0$). The no-inefficiency production function occurs when the coefficient capturing inefficiency (γ) equals zero ($\gamma = \delta_0 = \delta_m = 0$). These four sub-models are examined under several null hypotheses, as proposed in Suyanto et al. (2009).

To implement the appropriate stochastic production function, a generalized log-likelihood ratio test is employed, formulated as follows:

$$\lambda = -2[l(H_0) - l(H_1)] \quad (6)$$

where $l(H_0)$ denotes the log-likelihood value of the sub-various production functions, and $l(H_1)$ stands for the log-likelihood value of the translog model expressed in Eq. (3). If the LR test is bigger than the χ^2 distribution, the null hypothesis is rejected. If the test statistic has approximately a χ^2 with a degree of freedom equal to the number of parameters in the restrictions, the null hypothesis is accepted. Meanwhile, under the no inefficiency effects model, the test statistic has approximately a mixed *chi*-square (χ^2) distribution, and the critical value for this test is derived from Kodde and Palm (1986).

Within this study, stochastic production frontier variables are defined as follows: the output variable (y) is proxied by total gross output as a measure of production. Capital stock (k) refers to the estimated value of fixed capital, which covers land, buildings, vehicle, machinery and equipment, and other capital goods. Labour (l) denotes the total number of employees directly or indirectly involved in production activities. Material (m) covers raw and intermediate materials, both domestically produced and imported. Energy (e), is measured as the sum of total expenditure on electricity and kind of fuel and lubricant.

This study uses two approaches to measure industrial concentration. The first approach follows Gu (2016), who used HHI to capture all firms' market share. The second is that of Shepherd and Shepherd (2003), who used the collective share of the four largest firms (CR4) in the industry, offering some alternative measures of oligopoly classifications. Liebenberg and Kamerschen (2008) and Setiawan and Lansink (2018) highlighted that HHI and the concentration ratio are complementary of each other; therefore, this study retains both measures to portray competition and market structure in the industry. *HHI* and *CR*4 are defined as follows:

$$HHI_{jt} = \sum_{i \in j} s^2{}_{ijt} \quad (7)$$

$$CR4_{jt} = \sum_{i=1}^{4} S_{it} \quad (8)$$

where s_{ijt} depicts the output of *i*-th firm in *the j*-th industry in the *t* year. HHI_{jt} stands for the Herfindahl-Hirschman index in *j*-th industry in period *t* and $CR4_{jt}$ indexes concentration of the four largest firms in *j*-th industry in *t* year.

Regarding foreign competition, EP_{jt} and IP_{jt} are selected as proxies. Export performance (EP_{jt}) describes the ratio of total export to total output in *the j*-th industry at *t* period. Import penetration ratio (IP_{jt}) is built as in Lindner et al. (2001), which captures the extent to which raw materials goods come from foreign producers rather than from domestic producers in *j*-th industry at *t* period. Greater import penetration indicates that domestic firms are unable to maintain their market share from foreign competitors. IP_{jt} is expressed as below:

$$IP_{jt} = \frac{M_{jt}}{Y_{jt} + M_{jt} - X_{jt}} \quad (9)$$

where M_{jt} and X_{jt} are the imports and exports of *the j*-th industry at *t* period respectively, and Y_{jt} is the total output of *j*-th industry at *t* period.

The FDI variables in the inefficiency function include *FO* as foreign ownership at a firm-level, measured by a dummy taking the value of 1 for a foreign firm and 0 if otherwise. According to OECD (2008), international firms are those with a reported equity share of ownership of 10% or more. Furthermore, we follow Javorcik (2004) to measure FDI horizontal ($Hspill_{jt}$) at five-digit of sectoral level, and $Hspill_{jt}$ is written as:

$$Hspill_{jt} = \frac{\sum_{i \epsilon j} FShare_{it} * Y_{it}}{\sum_{i \epsilon j} Y_{it}} \quad (10)$$

Eq. (10) shows the ratio of outputs produced by foreign firms to total output in an industry *j* at time *t*. The rise in foreign equity shares ($Fshare_{it}$) will increase the spillover effect in the same five-digit ISIC industry.

This study also observes other potential variables that might influence technical efficiency at firm-level. We hypothesize that firm size is necessary to control the industrial effect. Larger firms have lower operating costs than medium-size ones (SMEs), hence leading bigger firms to achieve superior technical efficiency compared to SMEs. The $FSize_{ijt}$ is derived from firm *i*'s output of the *j* industry in year *t*. Furthermore, the time trend variable (*TIME*) is included to check if inefficiency is affected by time trends.

Table 1 provides information regarding the statistical summary of related variables. The output and input variables are expressed in deviations from their geometric sample means, as proposed by Coelli (2003). The relatively large average of CR4 (0.4311) suggest that some sub-sectors may have market structures that display high market power from a few players. Previous studies have identified several sub-sectors in the Indonesian manufacturing industry following a tight oligopoly structure (Setiawan and Effendi, 2016). This is in line with the criteria for market structure proposed in Shepherd and Shepherd (2003).

4. Empirical results

This section first measures the technical efficiency at firm-level by using the stochastic frontier approach employing four alternative sub-models for the production functions (Hicks-Neutral technological progress, no-technology progress, Cobb-Douglass, and no-inefficiency production function). After estimating the SFA, the translog model is tested against the alternative sub-models as in Suyanto et al. (2009). The generalized likelihood test suggests that the translog model is preferred as the feasible stochastic production function and is used for the analysis.

Using Eqs. (3) and (4) above, the production frontier and the inefficiency function are estimated simultaneously. Table 2 depicts the production function, and Table 3 shows the inefficiency function estimates, including the different exogenous variables capturing competition, foreign presence, and firm characteristics. The input coefficients in the translog production function have no direct economic connotation to output; hence an output elasticity is provided with respect to each of the four inputs (Table 4). Output elasticity is obtained by taking the first derivative of each estimation; it captures the responsiveness of output when additional inputs are used in production.

The results of the production function (Table 2) show positive values and a total output elasticity greater than one, portraying increasing returns to scale. Positive output elasticity suggests that additional inputs could be added to expand production. The largest elasticity of output is related to raw materials, followed by energy and labor inputs, in line with previous studies in Indonesia (Sari, 2019; Suyanto and Salim, 2011). Capital accounts for the input with the lowest output elasticity, suggesting that manufacturing firms in Indonesia are mainly material and labor-intensive, as noted in Sugiharti et al. (2017, 2019). The only input facing decreasing returns to scale is capital (*kk*), as the negative coefficient suggests.

Interaction between inputs of production (cross effect coefficients) helps to identify whether inputs are complementary or substitutes. The results suggest that three combinations of inputs show complementary effects: i) capital and raw materials, ii) labor and raw materials, and iii) raw materials and energy. On the other hand, three combinations of inputs are substitute factors of production: i) capital-labor, ii) capital-energy, and iii) labor-energy.

The estimated effect of time (proxy for trend in technical efficiency) is in line with that of previous studies in Indonesia, displaying a diminishing trend in technical efficiency (Sugiharti et al., 2019), similar to the

Table 1. Descriptive statistics of variables.

Variables	Units	Mean	Std. Dev.	Min	Max
Output (y)	*ln (thousand rupiahs)*	0.0000	2.1248	-8.2132	9.3594
Capital (k)	*ln (thousand rupiahs)*	0.0000	2.2494	-9.8500	9.8801
Labor (l)	*ln (workers)*	0.0000	1.2066	-1.2223	6.7175
Material (m)	*ln (thousand rupiahs)*	0.0000	2.4117	-8.4048	13.2720
Energy (e)	*ln (thousand rupiahs)*	0.0000	2.2231	-8.9091	10.3850
Time (time)	*Annual*	0.0000	1.4186	-2.0000	2.0000
Herfindahl-Hirschman Index (HHI)	*Ratio*	0.1157	0.1527	0.0041	1.0000
Concentration (CR4)	*ratio*	0.4311	0.2458	0.0805	1.0000
Import Penetration (IP)	*ratio*	0.1677	0.1647	0.0000	1.0000
Export Performance (EP)	*ratio*	0.2499	0.2346	0.0000	1.0000
Horizontal Spillover (Hspill)	*ratio*	0.1909	0.1981	0.0000	1.0000
Foreign Ownership (FO)	*binary dummy*	0.0949	0.2930	0.0000	1.0000
Firm Size (FSize)	*Ratio*	0.0161	0.0676	0.0000	1.0000
Time Trend (TIME)	*Trend (year)*	3.0228	1.4186	0.0000	5.0000
Number of observations	*118,502*				

Notes: Mean = arithmetical average; SD = standard deviation; Min = minimum; and Max = maximum; Estimates of *y, k, l, m,* and *e* are obtained from the natural logarithm of their value minus the natural logarithm of their geometric mean. The actual value is $2.011 \times 10 - 7$.

Table 2. Maximum likelihood estimates of stochastic production frontier.

Production Function: Dependent variable (*lnY*)

Variables	Parameters	Coefficient (HHI Model)	Coefficient (CR4 Model)
Constant	β_0	0.0942*** (0.0017)	0.1126*** (0.0030)
k	β_k	0.1517*** (0.0010)	0.1534*** (0.0008)
l	β_l	0.1384*** (0.0012)	0.1411*** (0.0013)
m	β_m	0.5489*** (0.0012)	0.5459*** (0.0004)
e	β_e	0.2038*** (0.0011)	0.2047*** (0.0011)
kl	β_{kl}	0.0017* (0.0009)	0.0017* (0.0010)
km	β_{km}	-0.0349*** (0.0010)	-0.0346*** (0.0011)
ke	β_{ke}	0.0391*** (0.0010)	0.0396*** (0.0011)
lm	β_{lm}	-0.0396*** (0.0012)	-0.0402*** (0.0013)
le	β_{le}	0.0065*** (0.0013)	0.0071*** (0.0014)
me	β_{me}	-0.1590*** (0.0016)	-0.1566*** (0.0015)
kk	β_{kk}	-0.0029*** (0.0010)	-0.0047*** (0.0009)
ll	β_{ll}	0.0294*** (0.0016)	0.0273*** (0.0017)
mm	β_{mm}	0.2159*** (0.0015)	0.2135*** (0.0015)
ee	β_{ee}	0.1198*** (0.0021)	0.1166*** (0.0020)
t	β_t	-0.0219*** (0.0011)	0.0291*** (0.0028)
tt	β_{tt}	-0.0588*** (0.0012)	-0.0200*** (0.0031)
kt	β_{kt}	-0.0200*** (0.0008)	-0.0294*** (0.0007)
lt	β_{lt}	0.0008** (0.0009)	-0.0015* (0.0008)
mt	β_{mt}	0.0307*** (0.0009)	0.0308*** (0.0010)
et	β_{et}	-0.0157*** (0.0009)	-0.0162*** (0.0009)

Source: Authors' calculation.
Notes: Robust clustered standard errors in parentheses and express significance levels until α = 10%. *** significant at 1%, ** significant at 5%, * significant at 10%.

time trends in productivity found in Javorcik et al. (2012). In other countries (e.g., Vietnam), Newman et al. (2015) found evidence of diminishing trends in technical efficiency in manufacturing, similar to the findings of Orlic et al. (2018) for transition European countries. Additionally, the time square variable is negative, suggesting no evidence of technological progress in the sector. Among the coefficients of interaction between input variables and time, capital and energy display a significant and negative sign, suggesting non-neutral technological regress. Furthermore, only the interaction between raw materials and time displays a positive and significant coefficient, indicating technological progress in the use of materials, most likely because rapid growth in imports allows access to higher quality materials (Javorcik et al., 2012).

Looking at the elasticities of output with respect to each input, the output elasticity of capital in concentrated industries (0.0933) is slightly higher than in industries with lower concentration levels (0.0905). Less concentrated industries display greater elasticity of raw materials (0.6454) than industries facing higher concentrations (0.6341). The elasticity of labor to output is marginally higher in less concentrated industries (0.1410) than in industries with a high concentration level (0.1400). Moreover, concentrated industries rely on more substantial amounts of energy (0.1622) to expand production than less concentrated ones (0.1534), a finding in line with Sugiharti et al. (2019). For instance,

Table 3. Maximum likelihood estimates: Inefficiency function: Dependent variable (u).

Variables	Parameters	Coefficient HHI Model	Coefficient CR4 Model
Constant	δ_0	0.0755*** (0.0045)	-0.3915*** (0.0196)
HHI	δ_{HHI}	-0.0882*** (0.0105)	
CR4	δ_{CR4}		-0.1153*** (0.014)
IP	δ_{IP}	-0.2585*** (0.0142)	-0.1612*** (0.0365)
EP	δ_{EP}	-0.0098** (0.0049)	-0.1249*** (0.0123)
HSpill	δ_{Hspill}	-0.1903*** (0.0231)	-0.3457*** (0.0090)
FO	δ_{FO}	-0.0520*** (0.0069)	-0.0565*** (0.0058)
Fsize	δ_{Fsize}	-0.2337*** (0.0056)	-0.4749*** (0.0299)
TIME	δ_{TIME}	0.0287*** (0.0011)	0.1738*** (0.0087)
HHI × *IP*	$\delta_{HHI\times IP}$	0.2156*** (0.0183)	
HHI × *EP*	$\delta_{HHI\times EP}$	0.1046*** (0.0199)	
HHI × *Hspill*	$\delta_{HHI\times Hspill}$	0.0886*** (0.0083)	
HHI × *TIME*	$\delta_{HHI\times TIME}$	0.0062** (0.0035)	
CR4 × *IP*	$\delta_{CR4\times IP}$		0.0564 (0.0437)
CR4 × *EP*	$\delta_{CR4\times EP}$		0.3456*** (0.0243)
CR4 × *Hspill*	$\delta_{CR4\times Hspill}$		0.1337*** (0.0349)
CR4 × *TIME*	$\delta_{CR4\times TIME}$		-0.0037*** (0.0010)
Sigma Squared	σ^2	0.0863** (0.0003)	0.0915*** (0.0004)
Gamma	γ	0.0084*** (0.0009)	0.1148*** (0.0146)

Source: Authors' calculation.
Notes: Robust clustered standard errors in parentheses and express significance levels until α = 10%. *** significant at 1%, ** significant at 5%, * significant at 10.

Table 4. The elasticity of output with respect to each input.

Output	Concentration	
	Less concentrated	More concentrated
Capital (ε_k)	0.0905	0.0933
Labor (ε_l)	0.1410	0.1400
Material (ε_m)	0.6454	0.6341
Energy (ε_e)	0.1534	0.1622
Total Elasticity (ε)	1.0303	1.0297

Note: Total Elasticity is $\varepsilon = \varepsilon_k + \varepsilon_l + \varepsilon_m + \varepsilon_e$

sectors characterized by larger market concentration rely more on capital and energy to expand output, and less on labor and raw materials.

Further results of determinants of firm inefficiency are derived from the inefficiency function related to the exogenous variables introduced into the model (Table 3). The coefficient for market competition *HHI* is negative and significant, indicating that firms tend to be less inefficient at higher levels of market concentration. This finding is in line with the argument that higher market concentration comes from dynamic competition, positively impacting the firm's technical efficiency, in line with Suyanto et al. (2009). On the other hand, the negative coefficient of industrial concentration (CR4) suggests that higher shares captured by the top four largest firms act as an enticement to increase efficiency within the sector.

The findings related to competition support the claim that the efficient structure hypothesis (ESH) applies in Indonesian manufacturing firms, mainly displayed in sectors with larger market concentration (i.e., in sectors where the top four players enjoy large market share). A higher market concentration can result in dynamic competition among firms, but with the consequence of the less efficient firms having to exit the market (Sidak and Teece, 2009). Javorcik et al. (2012) found a sharp decline in the numbers of firms operating within manufacturing in Indonesia, mainly in those experiencing lower productivity performance. Still, firms gaining more rapidly in efficiency levels can gain in market share as they may be more profitable, allowing them to increase market share. Similar results are also found in Indonesia's food and beverage sector, where both HHI and CR4 are also employed (Setiawan and Lansink, 2018). This finding corroborates the work of Driffield and Kambhampati (2003) who found that higher concentrations of firms in the Indian textile sector created adequate competition within the sector, driving firms to operate more efficiently (at minimum costs).

The coefficients of trade (*IP* and *EP*) are negative and statistically significant, showing that higher foreign competition through global market connection is related to higher technical efficiency. Chu and Kalirajan (2011) and Ben Yahmed and Dougherty (2017) observed that import penetration induces more competition pressure, encouraging local firms to compete against foreign goods in the domestic market. Moreover, we find that exporting firms have lower technical inefficiency than firms that focus on serving the domestic market and do not import intermediate goods, which is similar to previous findings in Indonesia (Saputra, 2014). Export-oriented firms may enjoy broad markets abroad with incentives to increase the scale of production and raise efficiency. Intense foreign competition also encourages firms to meet international standards and higher customer expectations, thereby increasing their competitiveness through efficiency enhancement (Lemi and Wright, 2020). Our results support previous findings in Indonesia by Javorcik et al. (2012) who suggest that firms with higher access to imported inputs and oriented to exports, experience higher performance.

Moving to the coefficient of horizontal spillovers, as noted in Orlic et al. (2018), the commonly employed measurement of horizontal spillover mainly captures the demonstration and mobility effect. For instance, the competition effect is split by introducing an interaction variable of horizontal spillover and market concentration (HHI and CR4). The results suggest that a larger presence of foreign-owned firms has positive effects on the technical efficiency of firms within the sector through demonstration and labor mobility effects (horizontal spillover) and a negative effect on efficiency via the competition channel (HHI – CR4). The signs of the coefficient for horizontal spillover effects are in line with those of previous studies (Sari, 2019; Sari et al., 2016; Suyanto et al., 2012), although no interaction between competition and horizontal spillovers was previously investigated in such studies.

The FDI variable (*FO*) shows negative and significant effects, which implies that firms that are recipients of foreign investment experience larger efficiency gains than domestic firms. Foreign-owned firms often employ superior technology and enjoy more advanced knowledge than local firms, thereby experiencing lower inefficiency (Sari, 2019). Foreign entrants may induce higher technical efficiency within manufacturing firms via externalities, suggesting that opening to FDI has positive effects on efficiency, a result in line with previous findings in Indonesia (Suyanto et al., 2009; Suyanto and Salim, 2011). Javorcik et al. (2012) found positive effects in openness to FDI and integration with global markets in firm-level productivity within the sector (horizontal spillover). Both technology - knowledge transfers and competition effects on firms may be taking place in Indonesia, accompanied by more efficient resource reallocation, leading to greater efficiency in firms.

The firm size coefficient (*FSize*) is negative and significant, in line with earlier studies (Sugiharti et al., 2019; Tingum and Ofeh, 2017; Vu, 2016) suggesting that larger size firms experience lower inefficiency on production. Larger firms are often equipped with more capital and more modern equipment than smaller ones, thereby enjoying more benefits from technology diffusion. As stated by Chapelle and Plane (2005), large firms have developed managerial expertise that leads to a better organizational framework and higher technological absorption capability, leading to larger profits.

As for the coefficient of the time trend (*TIME*) is positive and significant, implying lower technical efficiency over the period. The positive sign and statistically significance is also found in the interacting variable of $HHI \times TIME$, inferring technical efficiency is diminishing as the market concentration increases over time. Nevertheless, the coefficient of $CR4 \times TIME$ is negative and significant, signaling that the rate of technical efficiency would improve in markets with a higher industrial concentration in the top four largest players (perhaps resembling signs of oligopolistic structures).

All the interacting variables of market concentration (HHI and CR4) and foreign competition are positive and significant, except for $CR4 \times IP$, that shows an insignificant impact. The interaction of competition (HHI and CR4) and horizontal spillover suggest that in industries where market concentration is high, the horizontal spillover effects tend to lower technical efficiency among Indonesian firms. This finding suggests that foreign owned firms in less competitive markets may be able to protect knowledge and technology to freely leak to domestic competitors. In markets with lower competition, foreign firms may also benefit from their superior technology to further increase market power and drive out less efficient domestic players from the market (Orlic et al., 2018). Negative effects captured from horizontal spillover in highly concentrated sectors could signal the ‘market stealing phenomenon’, noted in Sari (2019) and Suyanto et al. (2012). Opening to FDI in sectors with high market concentration should be allowed with caution, as FDI may not result in large benefits for local players.

The coefficient of $CR4 \times EP$, $HHI \times IP$, and $HHI \times EP$ underlines that firms holding more substantial market power and with higher export/import links, tend to experience lower levels of technical efficiency. Firms that are more exposed to open markets may employ different combinations of inputs that account for larger production costs compared to domestic firms. However, export oriented firms may be more profitable in foreign markets (exporting), or they may be producing differentiated and higher quality goods for the domestic market. Besides, globally connected firms may be paying higher wages and employing higher quality of inputs than non-globally integrated players, putting pressure on prices for production factors, leading to lower profits, and possibly crowding out the domestic players (Aitken and Harrison, 1999; Orlic et al., 2018).

The notion of crowding out is in line with previous studies in Indonesia, that have reported that exporters, importers, and foreign-owned firms are more productive and hold larger market shares than domestic players (Arnold and Javorcik, 2009; Javorcik et al., 2012). Foreign-owned and globally oriented firms in Indonesia pay substantially higher wage premiums than domestic and (Javorcik et al., 2012). An alternative notion is that more liberalization of investment and trade (exports – imports) is related to increasing market concentration, suggesting that the effects of liberalizing may benefit most productive companies to a large extent (Li and Miao, 2018; Meinen and Raff, 2018).

5. Concluding remarks

This study aimed to examine the competition effect and the effect of foreign presence on the technical efficiency of Indonesian manufacturing firms over the period 2010 – 2014. Competition was measured by two indices capturing market concentration: the Herfindahl-Hirschman Index (HHI) and the concentration ratio of the four largest firms (CR4). Using a stochastic production frontier, we found that higher industrial concentration and higher foreign competition (export and import activities) are positively related to firms' technical efficiency. The study has found that higher efficiency is achieved by firms characterized by large size, foreign owned firms, those having access to imported raw materials, and export-oriented firms. Such enterprises are likely to gain market share, leading to higher industrial concentration and possibly leading to the exit of less efficient firms from the market.

We provide evidence to support the efficient-structure hypothesis (ESH) in Indonesia, suggesting that higher levels of market concentration arise as firms compete for higher efficiency levels that lead them to gain larger shares in the market. Although higher industrial concentration is associated with lower levels of inefficiency, the time trend suggests that as firms gain in market power, technical efficiency growth decreases. Locally owned firms also experience a decrease in technical efficiency (time trend).

We identify that foreign ownership has positive effects on technical efficiency. Additionally, the presence of foreign firms offers positive externalities in technical efficiency to other firms within the sector of investment, via horizontal spillovers. Access to imported raw materials and access to export markets are also positively associated with technical efficiency.

Policies regarding promoting FDI in the Indonesian manufacturing sector should continue as they appear to be working as intended. Nevertheless, the spillover effects of FDI could be negatively associated with firms' technical efficiency when market concentration is too high (HHI or CR4). Similarly, effects from external competition (export-import) on technical efficiency are negative when market concentration is high. Hence, investment policy should revise the market structure (competition landscape of sectors) when considering further liberalization or facilitation in investment policies. The Indonesian Competition Authority (KPPU) should be aware of high industrial concentration as it could lead to anti-competitive practices (e.g., creation of barriers to entry for new firms), reducing the positive externalities that could arise from a wider opening of markets (FDI and trade). Continuous efforts to help domestic firms to benefit from externalities in the form of knowledge, technology, skills, and management arising from large FDI inflows, are needed.

Declarations

Author contribution statement

S.K. Harianto: Conceived and designed the experiments; Performed the experiments.

M.A. Esquivias: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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