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The Role of Agglomeration Economies on Technical Ineficiency of Manufactruing Industies in East Java

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Abstract. This study aims to determine the effect of agglomeration economies on technical inefficiency at the firm level of the manufacturing industry in East Java. The data establish from an annual survey of medium and large manufacturing conducted by Statistical Indonesia covering 2010-204. The Stochastic Frontier Analysis method is used to determine the economic agglomeration of technical inefficiency. The results show that specialization has positive influence on technical inefficiency, while Diversion and Firm Size have a negative influence on technical inefficiency of manufacturing industry firms in East Java Province. Although competition does not influence technical inefficiency. Therefore, the government should consider the externalities of agglomeration including specialization, diversity, and competition, that provide significant advantages to manufacturing companies in East Java. Nevertheless, while these agglomeration benefits contribute to economic growth, they often do not correspond to the actual environmental conditions.

Keywords:
agglomeration economies; technical inefficiency; Stochastic Frontier analysis

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Introduction

The industrial sector plays a crucial role as it serves as the primary catalyst for national economic advancement. Similar to other emerging nations, Indonesia first depended on basic commodities such as agriculture, forestry, fisheries, and mining, while the manufacturing industry played a secondary role (Salendu, 2021; Sarjono et al., 2026). As growth advanced, Indonesia's economic structure underwent transformation. From the mid-1990s forward, the manufacturing industry surpassed the agriculture sector as the primary contributor to the Gross Domestic Product (GDP) (Kapilya, 2025). Finally, there will be a fundamental shift in the economy's structure, with the agricultural sector giving way to the industrial and service sectors, leading to economic development (Liu & Wang, 2022).

The industrial sector has emerged as a prominent sector and has made a significant contribution to the Gross Regional Domestic Product (GRDP) in East Java. According to data released by BPS in 2025, the Manufacturing Sector has consistently been the sector with the largest contribution to the Indonesian economy, with a share of around 20% of the total GRDP during the 2020-2024 period. Its contribution also shows an upward trend from year to year, particularly from 19.91% in 2020 to 20.11% in 2024. Those that prioritize the industrial sector as their primary economic driver rapidly on economic growth compared to those that prioritize other sectors (Wijaya et al., 2021).

Agglomeration, defined by Tao et al. (2025), is the concentration of economic activities that boosts growth but may increase regional disparities. Areas with more manufacturing benefit from capital accumulation, productivity gains, and urban advantages like skilled labor and technology (Malecki, 1991). Duarte et al. (2025) classify agglomeration economies into MAR externalities from specialization, Jacobs externalities from diversion, and Porter Michael (1990) externalities from rivalry, highlighting knowledge spillovers, inter-industry diversion, and competition-driven innovation, respectively.

Khoirunurrofik (2018) finds that specialization promotes manufacturing growth in Indonesia, particularly in the medium term. In contrast, Agovino and Rapposelli (2015)show that excessive specialization increasing ineficiency in Italy, while Cheng et al. (2023) report that specialization externalities do not significantly improve green total factor productivity in China due to limited knowledge diffusion. Widodo et al. (2015) find that greater diversion increases technical inefficiency in Indonesia, consistent with Kuncoro (2009), and Ercole and O'neill (2017) confirm its significant effect on regional productivity. However, diversion can also promote growth through knowledge spillovers, as shown by Cieślik et al. (2018). Moreover, Widodo et al. (2015) note that specialization, divertion, and competition support technical inefficiency whereas Vidyatmoko et al. (2011) argue that economic agglomeration reduces technical inefficiency.

Based on previous explanation, there are empirical inconsistencies about the impact of economic aglomeration on technical inneficiency. However, economic agglomeration, arising from the spatial proximity of firms, may demode technical inefficiency. This study examines the relationship between economic agglomeration and production efficiency in the manufacturing industry of East Java Province. It employs production inputs and outputs, along with inefficiency measures including the Specialization Index (MAR externality), Diversion Index (Jacobs externality), Competition Index (Porter externality), and firm size, using the Stochastic Frontier Analysis method. The paper is organized into data and methodology, empirical results and robustness analysis, and concluding remarks.

Methods

The data were collected from annual survey of medium and large manufacturing firms conducted by Statistical Indonesia (BPS). Medium and large firms are defined as those employing at least 20 workers annually. This study focused on East Java industries manufacturing. This study period was from 2010 to 2014. This period was chosen because after this period there was no detailed information both of industry and location.

Production function consist of output and input variables. The output variablel is measure by the total value output. The inputs are capital, labor, material, and energy. While factors that impact inefficiency functions are specialization, diversion, competition, and firm size. In detail, explanation of variables used in this study in Table 1.

Table 1. Variables Description

Variables	Descriptions
Capital	Capital variables are determined by quantifying the worth of immovable assets, such as land and buildings, as well as firm machinery and vehicles, using units of millions of rupiah.
Labor	The labor variable is measured by calculating the amount of labor used in the production process.
Material	The material variables are determined by computing the aggregate cost of domestic and foreign raw materials utilized in the production process, expressed in millions of rupiah.
Energy	The energy variable is quantified by the company's aggregate spending on fuel oil, gas, and electricity for the purpose of facilitating the production process, measured in millions of rupiah.
Output	This production variable is calculated based on the total output value produced by the company in a certain year with units of millions of rupiah.
Specialization Index or MAR externality (LQ)	Specialization index or MAR externality can be measured by location quotient (LQ) of labor approach.
Diversion Index or Jacobs externality (DIV)	The variety index or Jacobs externality is quantified by the reciprocal of the Hirchman-Herfindahl Index (HHI).
Competition Index or Porter externality (COM)	The ratio between the LQ index of labor and the LQ index of the number of firms.
Firm Size (FSize)	The ratio of output produced by a firm to total output in the same industry. The value of FSize that is close to zero indicates a small company size ratio and vice versa.

Source: Author's elaboration

The unbalanced panel data used in this study covering five years. Due to industries shifting or business closing, the number of observations varies each year. The lowest number of establsihments was 6005 (In 2010), while the highest was 6473 (In 2014). The descriptive variable used in this study following Table 2.

Table 2. Descriptive Statistics

Variables	Units	Obs	Mean	Std.Dev.	Min	Max
Y (output)	million	31,358	82,745.38	928.587.04	2.11	84,020,000.00
k (kapital)	million	31,358	8,750.82	713.576.74	0.05	125,413,132.50
l (labour)	worker	31,358	174.21	819.42	20.00	41,374.00
m (material)	million	31,358	47,969.05	662.090.59	1.21	76,027,368.07
e (energy)	million	31,358	3,112.45	33.729,81	0.03	2,550,043.67
t (time)	year	31,358	0.03	1.84	-2.50	2.50
Mar (Specialization)	ratio	31,358	2.81	2.29	0.01	13.71
Div (Diversion)	ratio	31,358	32.10	41.32	1.00	244.06
Com (Competition)	ratio	31,358	2.02	1.32	0.02	24.15
Fsize (Firm Size)	ratio	31,358	0.00	0.03	0.00	1.00

Note: Obs is observation; Std.Dev is standard deviation; Min is minimum; and Max is maximum.

The study employs the Stochastic Frontier Analysis (SFA) approach, specifically the one-step system described by Battese and Coelli (1995). The FRONTIER 4.1 computer software is utilized to estimate the SFA method, utilizing the probability method. Stochastic Frontier Analysis (SFA) is employed as a data analysis approach to determine the optimal production function model. The efficiency value is quantified on a scale ranging from 0 to 1. A company's efficiency increases as it approaches a value of 1. Conversely, when the value approaches 0, the company's efficiency decreases. Equation (1) represents the generic form of the production function.

$$Y_{\{it\}} = f\left(X_{\{it\}};\ \alpha, \beta\right),\backslash exp\left(v_{\{it\}} - u_{\{it\}}\right) \quad (1)$$

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

Where Y and X stand for output and input, α and β are coefficients estimated in the stochastic production function. it in equation (1) indicates using panel data, where i is the company and t is the year. v is the random error component and u is the inefficiency component. Meanwhile, z in equation (2) states the explanatory variables that affect the inefficiency of the company. δ represents the coefficient of the inefficiency function and ω is the residual of the inefficiency function. Technical efficiency is defined as the ratio between the observed output (Yi) and the maximum possible output (Y*) of firm i, i.e., the maximum possible output (Y*):

$$TE_i = \frac{y_i}{y_i^*} = \frac{\exp(x_i\beta + v_i - u_i)}{\exp(x_i\beta + v_i)} = \exp\left(-u_i\right) \quad (3)$$

The technical efficiency value is between one and zero (0<TE<1). The greater the technical efficiency value close to one, the more efficient the industry is. The best production function model must be chosen to use SFA. Thus, the translog model a flexible functional version of a production function will be evaluated in comparisson to the sub-translog. Equation (1) is the source of inspiration for the translog production function model, which is express as follows:

$$In\ y_{it} = \alpha_0 + \beta_1 lnK_{it} + \beta_2 lnL_{it} + \beta_3 lnM_{it} + \beta_4 lnE_{it} + \frac{1}{2}\beta_5(lnK_{it})^2 + \frac{1}{2}\beta_6(lnL_{it})^2 + \frac{1}{2}\beta_7(lnM_{it})^2 + \frac{1}{2}\beta_8(lnE_{it})^2 + \beta_9 lnK_{it} * lnL_{it} + \beta_{10} lnK_{it} * lnM_{it} + \beta_{11} lnK_{it} * InE_{it} + \beta_{12} lnL_{it} * lnM_{it} + \beta_{13} lnL_{it} * lnE_{it} + \beta_{14} lnM_{it} * lnE_{it} + v_{it} - u_{it} \quad (4)$$

Where y is the total output of the firm, while K (capital), L (labor), M (material), and E (energy) are used in the production input process. vit represents random error, while uit technical inefficiency. Subscripts i and t denote the i-th firm and t-th year, respectively. Meanwhile, β implies the coefficient estimation. In this study, input and output variables are transformed into natural logarithms. The determinants of technical inefficiency are shown in the following equation:

$$U_{\{it\}} = \delta_0 + \delta_1 LQ_{\{it\}} + \delta_2 DIV_{\{it\}} + \delta_3 COM_{\{it\}} + \delta_4 FSize_{\{it\}} + u_{\{it\}} \quad (5)$$

Where, u_{it} represents technical inefficiency, δ represents coefficient, LQ represents specialization index, DIV represents diversion index, COM represents competition index, and FSize represents firm size index.

Results and Discussion

The results and discussion consist of three subsections, are exploration of economic agglomeration, statistical testing, and examines the ompect of economic agglomeration on technical inefficiency.

A. Agglomeration Exploration

The distribution of specialization in East Java (in Figure 1) is the highest with a value range of 1 to 4. If the LQij value > 1, it indicates that sector i has a high level of specialization in region j. It can be concluded that the manufacturing industry in East Java, on average, already has a high level of specialization.

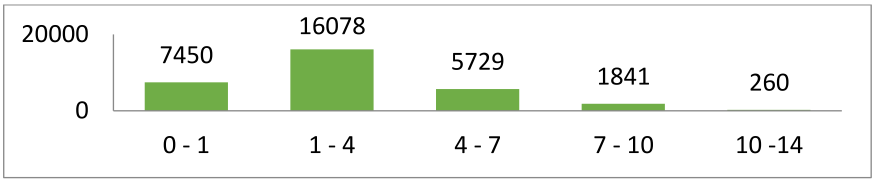

Figure 1. East Java Industry Manufacturing Specialization Distribution

Based on Figure 2, it shows that the distribution of diversion in East Java is the most with a range of values 1 to 50. The manufacturing industry sector that has a lower ratio value indicates a market that is very diverse and vice versa. It can be concluded that the diversion in the manufacturing industry sector has high diversion.

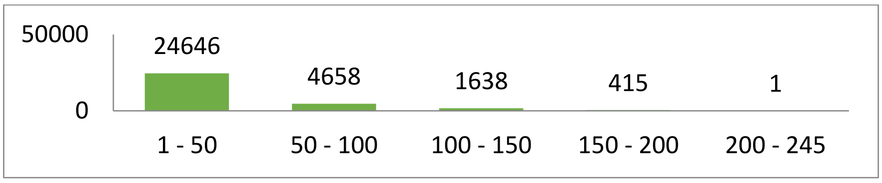

Figure 2. East Java Industry Manufacturing Diversion Distribution

Based on Figure 3, it shows that the distribution of competition in East Java is the most with a range of values 0 to 5. If a company has a ratio of more than one, then the region has a monopoly or oligopoly environment. When a firm has a ratio of less than one, then the region has a competition environment. It can be concluded that firms in East Java have a high competition.

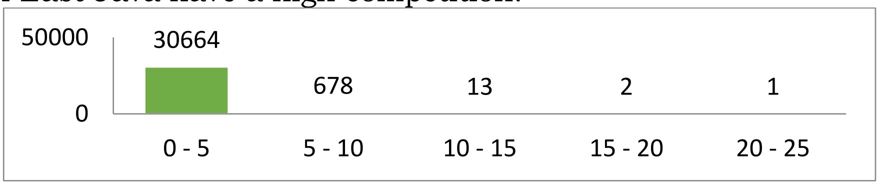

Figure 3. East Java Industry Manufacturing Competition Distribution

B. The Statistical Testing

The analysis starts with selecting the most suitable production function. This study utilizes the translog production function, hence it is crucial for testing to determine whether translog is the most optimal approach. The examination is carried out by utilizing a Log-Likelihood Ratio. The findings are shown in Table 3, indicating that the translog function with $\lambda > X^2$ is more appropriate than the technological progress or Cobb-Douglas model.

Table 3. Stochastic Frontier Production Function Selection Test Results

Model	H_0	λ	x^2 1%	Conclusion	Decision
Hicks-neutral	$\beta_{nt} = 0$	370,873	13,277	H_0 Rejected	Translog
No-technological progress	$\beta_t=\beta_{tt}=\beta_{nt}=0$	1828,441	16,812	H_0 Rejected	Translog
Cobb-Douglas	$\beta_{nm}=\beta_{nt}=\beta_{tt}=0$	7146,459	32,000	H_0 Rejected	Translog
No-inefficiency	$\gamma = \delta_0 = \delta_z$	519,327	12,483	H_0 Rejected	Translog

Note: The critical limit values are based on the Chi-squared distribution *(X^2)*. For the null hypothesis of a no-inefficiency effect function, the critical limit value is based on the mixed-chi squared distribution provided by Kodde and Palm (1986).

Table 4 presents the results of the estimation using SFA from four different production function. The estimation utilizing the translog production function is reliable in this context. The variable of raw material has the highest coefficient magnitude, which aligns with previous research on the Indonesian manufacturing industry (Esquivias & Harianto, 2020; Sari et al., 2021; Suyanto et al., 2012; Yasin, 2022).

Table 4. Production Function Stochastic Frontier Analysis

Variable	Coefficient	Model 1	Model 2	Model 3	Model 4
Production Function					
Constant	β_0	-0.571*	-0.540*	-0.680*	0,081*
		(0.030)	(0.030)	(0.032)	(0,013)
k	β_k	0.225*	0.184*	0.135*	0,098*
		(0.008)	(0.007)	(0.007)	(0,001)
l	β_l	0.274*	0.280*	0.305*	0,160*
		(0.012)	(0.012)	(0.013)	(0,002)
m	β_m	0.005	0.032*	0.039*	0,519*
		(0.011)	(0.011)	(0.001)	(0,003)
e	β_e	0.602*	0.602*	0.626*	0,266*
		(0.012)	(0.012)	(0.013)	(0,003)
k^2	β_{kk}	-0.008*	-0.020*	-0.028*	
		(0.002)	(0.001)	(0.001)	
l^2	β_{ll}	0.025*	0.025*	0.027*	
		(0.003)	(0.003)	(0.003)	
m^2	β_{mm}	0.203*	0.192*	0.202*	
		(0.003)	(0.003)	(0.003)	
e^2	β_{ee}	0.103*	0.115*	0.122*	
		(0.005)	(0.004)	(0.005)	
kl	β_{kl}	0.003	0.004**	0.009*	
		(0.002)	(0.002)	(0.002)	
km	β_{km}	-0.033*	-0.015*	-0.014*	
		(0.002)	(0.002)	(0.002)	
ke	β_{ke}	0.042*	0.033*	0.036*	
		(0.002)	(0.002)	(0.002)	
lm	β_{lm}	-0.036*	-0.039*	-0.045*	
		(0.002)	(0.002)	(0.003)	
le	β_{le}	0.007*	0.010*	0.008**	
		(0.003)	(0.003)	(0.003)	
me	β_{me}	-0.147*	-0.150*	-0.157*	
		(0.003)	(0.003)	(0.003)	
t	β_t	-0.077*	-0.029*		
		(0.006)	(0.001)		
t^2	β_{tt}	-0.049*	-0.058*		
		(0.002)	(0.002)		
kt	β_{kt}	-0.015*			
		(0.001)			
lt	β_{lt}	-0.001			
		(0.001)			
mt	β_{mt}	0.025*			
		(0.001)			
et	β_{et}	-0.013*			
		(0.001)			
Log-likehood function		-6158,46	-6343.90	-7072.68	-9731.69
LR test of the one sided error		519,33	556.38	390.96	271.55

Note: * is significant at the 1% level, ** is significant at the 5% level, and *** is significant at the 10% level

The coefficient derived from the translog specification lacks a direct interpretation. Therefore, it is necessary to do a post-estimation regularity check of the coefficient. This study employs the elasticity technique to investigate the impact of increasing easch inputs leads to response of output (Yasin, 2022). The results is reported in Table 5, showing that the total elasticiy's magnitude with unity, indicating a constant return to sacre of technical inefficiency on industry in East Java. The primary factor contributing to the variability of production throughout all years is predominantly the fluctuation in raw materials, as opposed to other inputs.

Table 5. Output Elasticity

Year	***εk***	***εl***	***εm***	***εe***	***ε total***
2010	0.216	0.271	0.040	0.572	1.099
2011	0.198	0.273	0.074	0.550	1.096
2012	0.180	0.266	0.115	0.528	1.089
2013	0.170	0.270	0.112	0.535	1.086
2014	0.137	0.270	0.060	0.622	1.090
Average	0.179	0.270	0.081	0.562	1.092

Note: ε_k denotes elasticity of capital, ε_l denotes elasticity of labour, ε_e denotes elasticity of energy, ε_r denotes elasticity of raw material, and ε_{total} denotes total elasticity.

C. *The Economic Agglomeration Influence Technical Inefficiency*

The model 1 used to interpret economic agglomeration to technical inefficiency. Based on Table 1, coefficient of MAR has positive sign and significant at level one percent. This indicates that increasing specialization, make the firms less efficient. The fims in highly specialization region tend to have lower level of technical inefficiency. Khoirunurrofik (2018) finds that specialization promotes manufacturing growth in Indonesia, whereas Agovino and Rapposelli (2015) show that excessive specialization reduces efficiency in Italy, and Cheng et al. (2023) report no significant effect on green total factor productivity in China due to limited knowledge diffusion.

Table 6. The Impact of Economics Agglomeration on Techical Inefficiency

Variables	Coefficient	Model 1	Model 2	Model 3	Model 4
Inefficiency function					
Constant	δ_0	-0.051*	-0.003	-0.012	-0.031*
		(0.010)	(0.008)	(0.019)	(0.011)
MAR	δ_{MAR}	0.021*	0.014*	0.021*	0.019*
		(0.001)	(0.001)	(0.003)	(0.002)
DIV	δ_{DIV}	-0.001*	0.001*	0.000*	0.001*
		(0.000)	(0.000)	(0.000)	(0.000)
COM	δ_{COM}	0.003	0.008*	-0.009*	0.001
		(0.003)	(0.002)	(0.004)	(0.003)
Fsize	δ_{FSize}	-0.376*	-0.286*	-0.385*	-0.683*
		(0.067)	(0.002)	(0.075)	(0.127)
Sigma-squared	δ_0	0.088*	0.088*	0.093*	0.113*
		(0.000)	(0.001)	(0.001)	(0.001)
Gamma	Γ	0.021**	0.006*	0.006	0.055*
		(0.009)	(0.000)	(0.006)	(0.020)

Note: * is significant at the 1% level, ** is significant at the 5% level, and *** is significant at the 10% level

The coefficient of DIV is negative and significant at the one percent level, indicating that greater diversion is associated with lower technical inefficiency consistent with Ercole & O'neill (2017), Gosen and Susanti (2019), and

Khoirunurrofik (2018), who find that diversion enhances effecient through inter-industry knowledge spillovers, although Yuan et al. (2017) report limited effects in the textile industry. Widodo et al. (2015) and Li et al. (2023) find that greater diversion increases inefficiency.

The coefficient of COM is not significant, suggesting that competition does not directly affect technical inefficiency, despite its role in promoting innovation and productivity growth (Gosen & Susanti, 2019). Meanwhile, firm size has a negative and significant coefficient at the one percent level, indicating that larger firms tend to be more efficient (Luo et al., 2023; Wijaya et al., 2021).

Figure 4 presents an analysis that examines the technical efficiency score of firms in the manufacturing business in East Java. The average technical efficiency (TE) score of the manufacturing industry in the years 2010-2014 varied between 0.915 and 0.966. The poor technical efficiency score may be attributed to the limited number of skilled workers and the marginal progress in research and development pertaining to critical areas, such as process and product technologies.

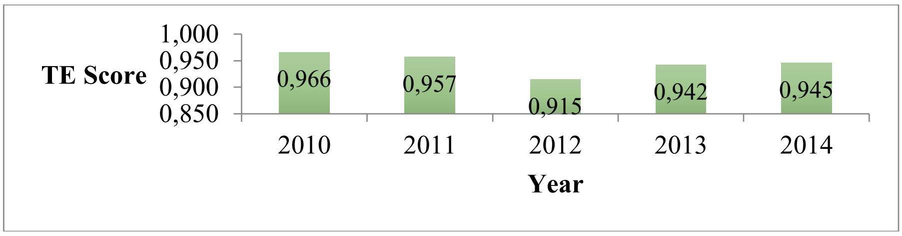

Figure 4. Technical Efficiency Score in East Manufacturing Industry Overtime

Conclusion and Recommendations

The calculation of economics agglomeration, average score already has a high level of specialization and diversion. While the competition has lower score, its mean that firms in East Java more competitive. Furthermore, the coeeficient of specialization has positif sign on technical inefficiency. while the coefficient of diversion and firm size have negative effect on technical inefficiency. Altought, the coefficient of competition is not impact on technical inefficiency. These results show that diversion the main factor in economic agglomeration that impact on decreasing technical inefficiency in East Java. This indicates that diversion will encourage manufacturing firms to be more productive.

Based on the results, discussion, and conclusions. The government should consider the externalities of economic agglomeration such as specialization, diversion, and competition, which can benefit manufacturing companies in East Java. While agglomeration externalities can drive economic growth, they may not necessarily reflect the prevailing environmental conditions. Therefore, the government must ensure that the presence of economic agglomeration is beneficial or detrimental. One way the government can intervene is through the Business Competition Supervisory Commission (KPPU), which monitors and evaluates business activities that lead to unfair competition. Firm size influences technical inefficiency in East Java's manufacturing industry. Therefore, the recommendation is to increase production capacity by increasing capital. Furthermore, companies should conduct regular monitoring and evaluation to achieve efficiency.

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