Productivity Changes in The Manufacturing Industry of East Java: An Application of the Malmquist Index Decomposition Analysis

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ABSTRACT

This study examines the productivity performance of East Java's total manufacturing industry using the Malmquist Productivity Index (MPI) approach, which decomposes productivity growth into Technological Change (TECH), Technical Efficiency Change (TECCH), and Scale Efficiency Change (SECH). The results show that the Total Factor Productivity Change (TFPCH) for the overall industry is greater than one, indicating a positive growth in productivity during the study period. The increase in SECH further suggests that industries are operating closer to their optimal scale of production. The findings imply that sustained productivity improvement requires continuous innovation, investment in technology, human capital development, and stronger supply chain integration. Therefore, strengthening local input industries, enhancing industrial clusters, and promoting digital transformation are essential strategies to ensure sustainable and competitive industrial growth in East Java's manufacturing sector.

1. Introduction

This study focuses on the inefficiency of the manufacturing industry in East Java. This focus arises because the industrial sector in East Java plays an important role in promoting economic growth; however, many manufacturing industries in the region remain inefficient (Rostiana et al., 2022). This statement is supported by several previous studies, including those by Amaliyah, (2018). The estimation results concluded that the manufacturing industry in East Java has not yet achieved efficiency and still has the potential to increase its output to reach an efficient condition. In general, the processing industry in East Java experienced only a very small change in efficiency, indicating a decline in efficiency within the sector.

There is another reason why East Java is used as the focus of this study. The manufacturing industry in East Java contributes significantly to Indonesia's GDP formation. However, the contribution of East Java's manufacturing industry to Indonesia's GDP has shown fluctuations and a downward trend (BPS, 2024). The decline in East Java's industrial GDP contribution does not automatically indicate lower national demand. It may also reflect relative price movements, changes in output composition, or structural shifts in the national economy that alter sectoral GDP shares without reducing actual demand for industrial output. According to Setiawan, (2019), the decrease in the manufacturing industry's contribution to GDP is not necessarily associated with a reduction in the production capacity of the manufacturing sector. Such a decline is actually reasonable, as the prices of manufactured products tend to decrease more rapidly than those of non-manufactured products due to the higher productivity levels in the manufacturing sector compared to other economic sectors (Färe et al., 2018).

A different condition is observed in East Java's GRDP performance, as the contribution of the province's industrial sector tends to increase, ranging between 29 and 30 percent (BPS, 2024). This indicates that the demand for industrial sector output in East Java is higher compared to the national level, reflecting a rise in business activities within the region. Therefore, the industrial sector has become a leading sector in East Java's economy. The growth of East Java's manufacturing industry is higher than that of Indonesia's overall manufacturing industry, representing a notable achievement for the province. This achievement cannot be separated from the manufacturing capacity of East Java Province, which hosts 11 industrial estates covering an area of 7,398.25 hectares (Ministry of Industry of the Republic of Indonesia, 2022). Furthermore, during the 2012–2019 period, the lowest growth of East Java's industrial sector occurred in 2016, at 4.4 percent. This decline was attributed to a decrease in investment performance within the manufacturing sector. The problem faced by the manufacturing industry in East Java is related to the high contribution of imported raw materials, which ranges from 79.00 to 81.00 percent. In comparison, the contribution of imported raw materials at the national level ranges from 73.77 to 75.07 percent.

Specifically, the share of imported raw materials in East Java's manufacturing industry is higher than the national average, suggesting that East Java remains dependent on imported inputs. This dependency arises because industrial producers in East Java rely more heavily on imported raw materials than on domestically sourced ones. Furthermore, from the perspective of manufacturing productivity, it refers to the ability of the manufacturing industry to produce goods and services by utilizing available resources efficiently and effectively (Septianingsih et al., 2024). According to Widodo *et al.* (2015), manufacturing productivity means that the production inputs used in the production process yield maximum results with minimal effort.

The productivity of the manufacturing industry is an important factor in the production performance of East Java Province. Increasing the productivity of East Java's manufacturing industry can enhance welfare because higher real income improves people's ability to purchase goods and services, enjoy leisure time, improve housing and education, and contribute to social and environmental programs. Productivity growth also helps businesses become more profitable (Isa et al., 2024).

The productivity of the manufacturing industry can be measured by comparing the output produced with the input used in the production process (Li & Tanna, 2019). According to Zhang et al. (2020), industrial productivity in the short term is not everything, but in the long term, it is almost everything. In the long run, improving industrial productivity is the only way to increase employment absorption and promote sustainable economic growth (Chen et al., 2017). Amaliyah (2018) found that labor productivity in East Java has declined because technology continues to develop rapidly, yet many industries still use outdated technology, and many industrial workers remain unskilled in operating new technologies.

2. Literature Review

The DEA Malmquist index method is one of the non-parametric panel data techniques commonly used to measure productivity changes or Total Factor Productivity Change (TFPC) of a Decision Making Unit (DMU). The value of this index is decomposed into technological change and efficiency change. The Malmquist index has two main advantages: first, it does not require price components in the calculation; and second, it can be decomposed into measures of technical change at the overall activity level (Aparicio & Santín, 2024). However, the main limitation of the Malmquist index is that its calculation depends on sequential estimations, and panel data must be available for comparative analysis. When using the Malmquist index method, if the resulting index value is greater than one, it indicates that the Decision Making Unit (DMU) has experienced an increase in its total productivity (Sulistyaningsih et al., 2019). Conversely, If the productivity index value is greater than 1, it indicates an increase in productivity; if the value is less than 1, productivity has decreased; and if the value equals 1, productivity remains unchanged (Restikasari & Sari, 2022).

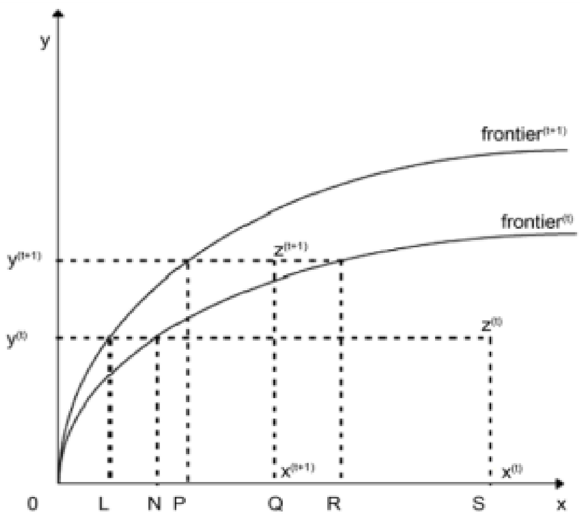

Figure 1. Decomposition of Total Factor Productivity Change or TFP growth
Source: Coeli et al., (1998)

The curve in the figure illustrates the concept of the Malmquist productivity index using the production frontier approach in two different time periods, denoted as t and t+1. The x-axis represents the input level, while the y-axis represents the output level. The two frontiers $frontier^{t}$ and $frontier^{(t+1)}$ depict the production technology available in periods t and t+1, respectively. The frontier curve shows the maximum achievable output for each level of input given the technology at that time. Points $z^{(t)}$ and $z^{(t+1)}$ represent the actual production points of a Decision Making Unit (DMU) in periods t and t+1. The vertical and horizontal dashed lines illustrate the changes in input and output levels over time. The movement from $z^{(t)}$ on $frontier^{t}$ to $z^{(t+1)}$ on $frontier^{(t+1)}$ represents Total Factor Productivity Change (TFPC).

If $frontier^{(t+1)}$ lies above $frontier^{t}$, as shown in the diagram, it means that technological progress has occurred the same level of input can now produce more output. Therefore, the figure effectively visualizes how productivity growth can result either from improved efficiency (catching up to the frontier) or from technological advancement (an upward shift of the frontier). The Malmquist productivity index can be decomposed into two components efficiency change and technological change (Mombini et al., 2020). According to Färe et al., (2018), this decomposition is particularly useful because it allows for more specific and detailed analysis of each component. However, the Malmquist Index also has limitations. One of its main weaknesses is that it requires balanced panel data, which means it cannot be applied effectively to simple time-series data without comparable observations across all periods.

Masri & Asbu, (2018) The pursuit of efficiency and productivity is one of the goals of health systems. In the era of Sustainable Development Goals and particularly the move towards universal health coverage, it is imperative to curb wastage of resources to ensure sustainable access of the population to needed and effective health services without enduring financial hardship. This study aims to assess total factor productivity change of national health systems of 20 countries in the WHO's Eastern Mediterranean Region. Data Envelopment Analysis (DEA)-based Malmquist index is used to assess total factor productivity change and its components – efficiency change and technical change. To assess the robustness of the Malmquist index estimates, bootstrapping was performed. Outputs used are life expectancy at birth for both sexes and infant mortality; while total expenditure on health per capita in international dollars (PPP) is used as a measure of input. Panel data for the period 2003–2014 was extracted from databases of the WHO and the World Bank. In all but five countries covered in the study, a decline in the mean total factor productivity is observed during the period 2003–2014. The decline is driven by technical regress. In all countries, the technical change component of the Malmquist TFP index is less than unity (range: 0.896 to 0.945). All countries exhibited growth in efficiency (efficiency change exceeding one) except two countries (Djibouti and Iraq). The growth in efficiency was mainly due to change in scale efficiency. Overall, total factor productivity in the region declined by 3.8%. This was due to a 9.1% decline in technical change, which overshadowed the 5.8% increase in efficiency. Three countries - Libya, Qatar and Yemen – showed a marginal growth in total factor productivity. There was no change in total factor productivity in Kuwait and Lebanon.

Zrelli et al., (2020) examined productivity changes in Tunisia's manufacturing industry during 2002–2016 using the *Data Envelopment Analysis* (DEA)-based Malmquist approach. Their results indicated that average TFP grew by about 2% per year, mainly driven by technological progress (3.1%), although technical efficiency slightly declined (–1.2%). Similarly, Hajıhassanıasl, (2021) analyzed TFP changes in Iran's agricultural, industrial, and service sectors for the 2012–2017 period using the same method. The findings revealed positive productivity growth in the industrial and service sectors, while the agricultural sector experienced a decline in TFP due to low technical efficiency and slow technological adoption.

Kondo et al., (2008) conducted a study on agricultural cooperatives in Hokkaido, Japan, using the Malmquist index to measure productivity changes from 1982 to 1991. They found that improvements in TFP were primarily driven by gains in technical efficiency (*catch-up effect*) rather than technological progress. (Sugiharti et al., 2017) estimates Technical efficiency (TE) and Total Factor Productivity (TFP) through a stochastic frontier analysis and decomposes growth into technological progress, technical efficiency change, and scale for the Indonesian manufacturing sector. Global economic slowdown characterises the period of study (2007-2013), as well as peak and fall of commodity prices, massive global integration and development of a Master plan for Indonesia (MP3EI). This study looks at patterns of productivity as important sources of growth. Results are aggregated based on technological intensity, firm size, capital/output ratio, labour skills, and location. The findings show that companies perform differently as those factors vary, and while larger companies are more efficient, smaller ones have higher rates of TFP growth, mainly through technological progress and scale. The TFP had moved from initial negative levels to positive ones. Firms with low tech, low capital/output ratio, and more skilful workers have the highest TFP.

Jyoti, (2019) paper is to measure the total factor productivity (TFP) growth of Indian firms listed in BSE- 500 index with reference to efficiency change and technological change. The study uses a balanced panel dataset of 49 companies over the period of 2001 to 2012. DEA based a non parametric Malmquist productivity index was used to compute total factor productivity and its components- technical efficiency change and technological change. The result shows that technological change has contributed more than efficiency change among Indian firms to the total factor productivity growth. It means TFP growth progress was obtained mainly due to innovations.

Agostino et al., (2022) paper analyzes the changes in productivity of small and large firms operating in the automotive industry in France, Italy and Spain, occurred during the pre-crisis (2001-2008) and post-crisis (2009-2014) periods. To this aim, the Malmquist index as a measure of total factor productivity (TFP) variation is computed, by using the non-parametric technique DEA, integrated by a bootstrap technique proposed by Simar and Wilson (1999). The analysis allows distinguishing among different possible sources of TFP changes, i.e. pure technical efficiency change, scale efficiency change and technological change. The latter comes up to be the main channel through which the global crisis negatively impacted on productivity, presumably by hampering the primary engines of technological change, i.e. research, innovation and investment through reduced availability of financial resources for SMEs, worsened perspectives for firm growth and greater concentration in selected geographical areas of investments by parent companies.

Suatmi, (2020) research aims to investigate the pattern of and to decompose the growth of total factor productivity (TFP) the Indonesian chemical industry(ISIC 35) during the period of trade reform (1981-2000). Using data envelopment analysis (DEA) output-oriented Malmquist productivity index, TFP growth can be decomposed into efficiency change and technological change. Results of two-digit level of the chemical industryshow that generally, the growths of TFP were positive during all sampleperiod, with the main driver was efficiency change. Exception was in the sub-period of further reform (1992-1996), where TFP growth was negative. These results similar to the analysis of three-digit level in sub-periods. Exceptions are incombined industries of others chemical industri(ISIC 352) and industrial chemical industries (ISIC 351) and plastic industries (ISIC 356), where TFP growths were negative in the sub-period of further reform). The implication of this study show that tradereform policy may have different effect across sub-sectors and sub-periods in the Indonesian chemical industri.

Asgari et al., (2024) evaluated the efficiency and productivity of the manufacturing industries of Singapore. Singapore is one of the world's most competitive countries and manufacturing giants. All 21 manufacturing industries as classified by Singapore's Department of Statistics were included in the study as decision-making units (DMUs). Using the Malmquist DEA on data spanning 2015–2021, we found that excerpt for the Paper and Paper product industry, all industries recorded positive total factor productivity (TFP). TFP ranged from 0.977 to 1.481. In terms of technical efficiency, 14 out of 21 industries showed positive efficiency change. The highest TFP was recorded in 2020 and the lowest in 2016. By measuring and improving efficiency, industries in Singapore can achieve cost savings, increase output, and enhance their competitiveness in the global marketplace. In addition, efficiency measurement can help policymakers identify potential areas for improvement and develop targeted policies to promote sustainable economic growth. Given these benefits, performance measurement is inevitable for industries and policymakers in Singapore to achieve economic objectives. Manufacturing industries need to find ways to manage the size and scale of operations as we flag this as an area for improvement.

Xue et al., (2008) construction in China. Xue used a DEA-based MPI for the Chinese construction industry (1997–2003). The same method (distance function-based MPI from DEA) facilitates the measurement of TFP changes over time and the decomposition of sources of change. The findings show an overall upward trend in productivity but a temporary decline (2001–2002), highlighting the importance of periodic analysis for volatile sectors. (Han et al., 2019) paper proposes total factor productivity analysis method based on Malmquist model to analyze the production efficiency statically and dynamically. Based on the input and output data of ethylene production plants in China, the total factor production index of ethylene production plants in industrial processes is decomposed into technical efficiency, technical progress, pure technical efficiency and scale efficiency through the Malmquist model based on the data envelopment analysis (DEA). Moreover, the energy efficiency of ethylene production plants can be improved.

Based on the reviewed studies, it is evident that the DEA-Malmquist approach has been widely applied to measure total factor productivity (TFP) across diverse sectors and countries, including healthcare systems in the Eastern Mediterranean (Masri & Asbu, 2018), manufacturing in Tunisia and Iran (Zrelli et al., 2020; Hajıhassaniasl, 2021), agricultural cooperatives in Japan (Kondo et al., 2008), chemical and manufacturing industries in Indonesia (Suatmi, 2020; Sugiharti et al., 2017), IT and listed firms in India (Jyoti, 2019), automotive firms in Europe (Agostino et al., 2022), Singapore's manufacturing sector (Asgari et al., 2024), and construction and chemical plants in China (Xue et al., 2008; Han et al., 2019). However, despite the methodological robustness and broad application of the DEA–Malmquist approach, several critical gaps remain in the literature. First, most existing studies are confined to specific sectors or single-country contexts, limiting cross-sectoral and sub-regional generalization, particularly in developing economies. Second, sustainability considerations, including environmental or energy-related efficiency, are still insufficiently incorporated. Third, firm- or industry-specific determinants such as technological intensity, labor quality, capital-output structure, and scale effects are not systematically linked to TFP dynamics. Fourth, the role of external shocks and policy-related changes across sub-periods remains underexplored.

3. Research Method

In this study, the variables are defined and measured as follows. Output (Y) represents the real value generated through the manufacturing production process in East Java, measured in Rupiah, and is transformed into a natural logarithm to ensure data normality and reduce heteroscedasticity. Labor (L) refers to the number of workers employed in the manufacturing industry, measured in the number of persons, and similarly transformed into a natural logarithm. Capital (K) denotes the financial resources used by the manufacturing industry in production activities, measured in Rupiah, and also expressed in logarithmic form to linearize the relationship among variables. Raw Material (M) represents the value of basic materials used at the beginning of the manufacturing production process, measured in thousand Rupiah and transformed into a natural logarithm to capture proportional changes (Rostiana et al., 2022). Lastly, Energy (E) reflects the value of energy resources used as inputs in production, including expenditures on fuel, lubricants, and electricity consumption, which is also transformed into a natural logarithm. Together, these variables represent the essential inputs and output in estimating productivity changes using the Malmquist index approach.

The data used in this study are firm-level data from the manufacturing industry in Indonesia, categorized by province. These data were obtained from surveys conducted by Statistics Indonesia (BPS). Subsequently, the data were selected and adjusted using the balanced panel data method with the STATA 17 software to ensure that only data meeting the required criteria were processed for analysis. Data collection in this study was carried out through several procedures involving multiple processes, including collecting firm-level data obtained directly from the Central Bureau of Statistics (BPS) of East Java. Gathering secondary data obtained from relevant institutions, such as BPS and other credible sources, to serve as supporting materials for this research.

This study adopts both constant returns to scale (CRS) and variable returns to scale (VRS) assumptions within the DEA–Malmquist productivity framework. The CRS assumption reflects a production technology in which outputs change proportionally with inputs and is appropriate when firms are assumed to operate at an optimal scale without significant market distortions. Under this assumption, productivity changes capture the combined effects of pure technical efficiency and scale efficiency. In contrast, the VRS assumption allows for non-proportional changes between inputs and outputs, thereby accommodating scale inefficiencies arising from market imperfections, regulatory constraints, or heterogeneous firm sizes conditions commonly observed in developing economies. By employing both CRS and VRS specifications, this study is able to distinguish between pure technical efficiency change and scale efficiency change, providing a more nuanced interpretation of productivity dynamics. This dual approach enhances the robustness of the results and aligns with established DEA literature.

In this study using Malmquist index. The stages involved in applying the Malmquist Index method generally follow a structured process to measure changes in productivity over time. The first stage is data preparation, which involves collecting firm-level or sectoral data on inputs and outputs. Inputs may include labor, capital, raw materials, and energy, while the output variable typically represents the total production value. The data must be organized in a balanced panel format, meaning that observations for each Decision Making Unit (DMU) are available for all periods being compared. The second stage is efficiency estimation using the STATA approach. STATA was selected for this study due to several methodological and practical considerations. STATA provides a well-documented and widely validated implementation of the DEA–Malmquist index, ensuring consistency and reproducibility of results. The use of STATA allows for seamless integration between efficiency measurement and subsequent econometric analysis, such as panel regression and sub-period analysis, within a single software environment. This integrated workflow reduces data handling errors and improves analytical coherence.

The third stage involves computing the Malmquist Productivity Index, which measures productivity change between two time periods, typically denoted as t and t+1. This index is calculated based on the distance functions of each DMU relative to the production frontier in both periods. The Malmquist index value greater than one indicates productivity growth, a value equal to one shows no change, and a value less than one indicates a productivity decline.

Next, the fourth stage is the decomposition of the Malmquist Index into two main components: Efficiency Change (EC) and Technological Change (TC). Efficiency change reflects how much a DMU has moved closer to or further from the frontier (catch-up effect), while technological change indicates shifts in the frontier itself due to innovation or technological progress (frontier shift effect). In some analyses, further decomposition is performed into Pure Efficiency Change (PEC) and Scale Efficiency Change (SEC) to provide a more detailed understanding of productivity sources.

Finally, the fifth stage is interpretation and analysis of results, where the obtained index values are analyzed to determine the main drivers of productivity changes whether they stem from improvements in efficiency, scale, or technological innovation. The results are then linked to contextual factors such as policy changes, technological adoption, or structural transformations within the industry or region being studied. Through these systematic steps, the Malmquist Index method provides a comprehensive understanding of total factor productivity dynamics over time.

The general formula for the Malmquist Productivity Index (MPI) between period ttt and t+1 is given by (Suatmi, 2020):

$$M_0^{t,t+1}(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \times \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)} \right]^{1/2} \quad \text{.......................................(1)}$$

Where D_t^0(x,y) distance function measuring the efficiency of producing output y from input x in period t. x is vector of inputs (e.g., labor, capital, materials, energy). And Then y is vector of outputs (e.g., production value). The Total Factor Productivity Change (TFPC) can be expressed as the product of its components, TFPC=EC×TC, And when further decomposed, TECCH=PECH×SECH. Thus, the full model becomes TFPC=(PEC×SEC)×TECH, where PECH = Pure Efficiency Change (under VRS assumption), SECH = Scale Efficiency Change, and TECH = Technological Change

Efficiency Change (EC), also called the catch-up effect, measures how much a Decision-Making Unit (DMU) improves or declines in efficiency relative to the production frontier between two periods. The formula is (Sugiharti et al., 2017):

$$EC = \frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^{t+1}, y^{t+1})} \quad \text{.......................................(2)}$$

Efficiency Change (catch-up effect): the movement of the DMU toward or away from the frontier between periods t and t+1. It reflects how much closer a DMU gets to the best-practice frontier. EC>1 is efficiency improvement (the DMU moves closer to the frontier). EC<1 is efficiency decline (the DMU moves further from the frontier). EC=1 is no efficiency change.

Technological Change (TC), or frontier shift effect, measures how much the production frontier itself has shifted due to innovation or technological progress between periods ttt and t+1. The formula is (Sugiharti et al., 2017):

$$TC = \left[\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)}\right]^{1/2} \quad \text{.......................................(3)}$$

Technological Change (frontier shift effect): the shift of the entire frontier between periods t and t+1, indicating progress or regression in technology. TC>1 is technological progress (frontier shifts outward). TC<1 is technological regression (frontier shifts inward) (Guo & Ye, 2025).

Scale Efficiency Change (SEC) reflects changes in efficiency due to operating at a more optimal production scale. It is derived by comparing constant returns to scale (CRS) and variable returns to scale (VRS) efficiency scores. Interpretation, SEC>1 is improvement in scale efficiency (firms operate closer to the optimal scale). SEC<1 is decline in scale efficiency, and SEC=1 is no change in scale efficiency. Pure Efficiency Change (PEC) represents the change in a firm's efficiency under the assumption of Variable Returns to Scale (VRS). It isolates the part of efficiency change that is due to managerial performance or operational improvements, excluding the effects of scale size. Interpretation, PEC>1 is improvement in pure (managerial) efficiency the firm is getting closer to the VRS frontier. PEC<1 is decline in managerial efficiency the firm is moving away from the frontier, and PEC=1 is no change in pure efficiency.

4. Results and Discussion

This study consists of two types of variables: production variables and inefficiency variables. The production variables include the dependent variable, namely output (Q), and the independent variables, which are capital (K), labor (L), energy (E), and raw materials (M).

Table 1. Descriptive Statistics of the Manufacturing Industry in East Java

Variable	Notation	Unit	Mean	Std. Dev.	Min	Max
Output	Q	Million IDR	116,196.97	1,616,938.71	2.113	540,395
Capital	K	Million IDR	1,800.90	16,133.17	0.063	3,600,000
Labor	L	Persons	10,847.46	104,201.57	17	2,100,000
Energy	E	Million IDR	3,797.86	42,251.62	0.033	76,000,000
Raw Materials	M	Million IDR	71,133.11	1,429,877.91	1.211	5.65

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Table 1 presents the descriptive statistics of key production variables used in the analysis of the manufacturing industry in East Java. The variables include Output (Q), Capital (K), Labor (L), Energy (E), and Raw Materials (M), all measured over the observation period. These indicators represent the core inputs and outputs of industrial production activities and provide a preliminary understanding of the overall productivity structure and production scale across firms. The mean value of output (Q) is 116,196.97 million IDR, indicating that, on average, manufacturing firms in East Java produce an output of over 116 billion rupiah annually. However, the standard deviation of 1,616,938.71 million IDR reveals a very high level of variability among firms. This wide dispersion suggests that the manufacturing sector in East Java is highly heterogeneous, with significant differences between small-scale and large-scale producers. The minimum output value of only 2.113 million IDR compared to a maximum of 540,395 million IDR confirms that some firms operate on a very small scale while others reach large-scale industrial production.

The capital (K) variable also exhibits substantial variation, with an average of 1,800.90 million IDR and a standard deviation of 16,133.17 million IDR. The minimum capital investment is 0.063 million IDR, while the maximum reaches 3,600,000 million IDR, indicating the presence of both micro-industries with minimal investment and large enterprises with significant capital accumulation. The large gap between minimum and maximum values implies unequal access to financial resources and investment capacity among manufacturing firms in the region.

In terms of labor (L), the mean value is 10,847.46 persons, with a remarkably high standard deviation of 104,201.57 persons. This again illustrates large disparities in firm size and employment capacity. While some manufacturing firms employ as few as 17 workers, others employ up to 2,100,000 workers. This variation reflects the coexistence of small labor-intensive industries alongside large, possibly multinational, enterprises within East Java's industrial landscape. It also suggests a wide range of technological adoption, managerial capacity, and production complexity across firms.

The energy (E) variable, which captures the value of fuel, lubricants, and electricity used in production, has an average of 3,797.86 million IDR and a high standard deviation of 42,251.62 million IDR. The energy expenditure ranges from as low as 0.033 million IDR to as high as 76,000,000 million IDR, underscoring the scale differences between firms and their production intensity. Firms with higher energy consumption are likely to be capital- and technology-intensive industries that rely heavily on machinery and large-scale production processes. Lastly, the raw materials (M) variable shows an average value of 71,133.11 million IDR, with a standard deviation of 1,429,877.91 million IDR, indicating substantial variation in material input costs among firms. The minimum value is 1.211 million IDR, while the maximum value is 5.65 million IDR, suggesting that firms differ considerably in their dependence on raw materials. This variation can be attributed to differences in production technology, product types, and the degree of vertical integration across manufacturing sub-sectors.

The bar chart depicts the average values of several productivity and efficiency indicators obtained using the Malmquist Productivity Index (MPI) method for the manufacturing industry in East Java. The five indicators TFPCH, TECH, TECCH, SECH, and TFP represent different dimensions of productivity dynamics, capturing both technological progress and efficiency improvements within firms. The first indicator, Total Factor Productivity Change (TFPCH), records an average value of 1.3814, which is above one. This result indicates that, on average, the manufacturing sector in East Java experienced an increase in total productivity during the study period. Since TFPCH combines the effects of both technological progress and efficiency change, this value suggests that firms in the region were able to improve their overall performance through a combination of innovation, learning, and better utilization of production resources (Aufa et al., 2023). The positive TFPCH value implies that the sector was moving closer to the efficient production frontier or even expanding it (Surjaningsih & Permono, 2014).

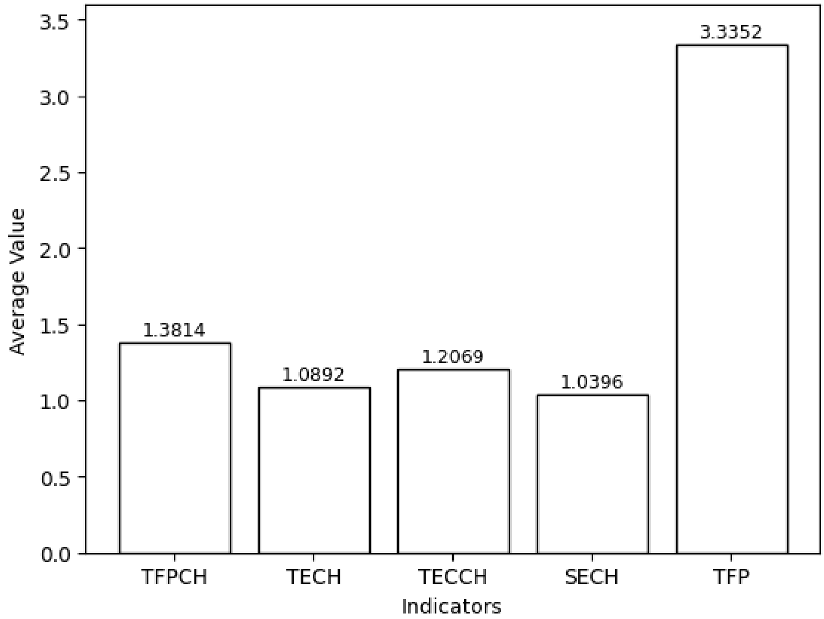

Figure 2. Average of TFPCH, TECH, TECCH, SECH, and TFP For The Manufacturing Industry In East Java

The second component, Technological Change (TECH), shows an average of 1.0892. A TECH value greater than one signifies technological progress, meaning that production technology improved over time, allowing firms to produce more output with the same level of input. This technological advancement may have stemmed from the adoption of modern machinery, better production processes, or innovations in management and supply chain systems. However, the value being only slightly above one also indicates that the pace of technological improvement was moderate, suggesting that technological adoption was not uniform across firms larger industries may have benefited more from technological upgrades compared to smaller ones (Sulistyaningsih et al., 2019).

Meanwhile, Technical Efficiency Change (TECCH) records an average value of 1.2069, implying a notable improvement in efficiency across firms. This component measures how well firms catch up to the best-practice frontier. A TECCH greater than one indicates that firms became better at utilizing existing technologies and optimizing their input mix (Sugiharti et al., 2017). The improvement in technical efficiency may have resulted from enhanced managerial capabilities, learning-by-doing effects, or more effective resource allocation. It also reflects how firms in East Java's manufacturing sector adapted to competitive pressures and policy reforms that encouraged more efficient production practices.

The Scale Efficiency Change (SECH) indicator shows an average of 1.0396, indicating a slight improvement in scale efficiency. This suggests that some firms were able to adjust their production scale to better align with the most productive scale size. In other words, industries became marginally more efficient in terms of operating at an optimal production scale neither too large to suffer from diseconomies of scale nor too small to underutilize resources. The relatively low value compared to other components indicates that scale adjustment contributed less to overall productivity growth than improvements in efficiency or technology. Finally, Total Factor Productivity (TFP) shows a much higher average value of 3.3352, which represents the aggregate productivity growth index that combines all the underlying components. The significantly higher TFP value compared to the subcomponents suggests that productivity gains in the manufacturing sector were substantial when viewed in total, possibly driven by combined effects of innovation, improved efficiency, and better scaling strategies. This result reinforces the conclusion that the East Java manufacturing industry underwent, positioning it as one of the key drivers of regional economic growth.

From a structural perspective, Figure 2 illustrates that productivity improvement in East Java's manufacturing sector is not solely dependent on technological innovation but is also significantly influenced by efficiency gains within existing technological constraints. The synergy between TECH and TECCH components implies that innovation and efficiency are complementary forces technological progress provides potential productivity gains, while efficiency improvements ensure that these gains are realized in practice. This dynamic interaction highlights the importance of both technological diffusion and human capital development. Without skilled labor and adaptive management, the benefits of new technologies may remain underutilized.

Furthermore, the pattern observed in Figure 2 points to heterogeneity across sub-sectors. High variability in firm size, capital intensity, and input structure likely leads to uneven productivity performance. Large firms with better access to finance and technology achieve higher productivity growth, while small and medium enterprises (SMEs) may lag due to constraints in innovation capability and infrastructure. This structural gap underscores the need for differentiated industrial policies that cater to specific sub-sectoral characteristics.

From a policy standpoint, the insights drawn from Figure 2 carry several implications. First, the government and regional stakeholders should intensify technology transfer programs, particularly targeting SMEs that often lack the capacity to invest in modern machinery or digital production systems. Second, training and managerial capacity-building initiatives can sustain the observed efficiency improvements (TECCH), ensuring that productivity gains are not short-lived. Third, industrial policies should encourage firms to optimize their production scale through clustering and cooperative production models, which can enhance economies of scale and competitiveness. Lastly, considering that a significant share of East Java's industries depend on imported raw materials (around 79–81%), efforts to develop domestic input supply chains are critical to reduce vulnerability to global disruptions and stabilize long-term productivity.

In the broader context of economic development, the trends shown in Figure 2 signify that East Java's manufacturing industry has entered a phase of sustainable productivity transformation where growth is no longer driven solely by input accumulation but increasingly by efficiency and technological progress. This transition is crucial for maintaining regional competitiveness, especially in the face of global trade liberalization, energy transition, and industrial digitalization. The findings also reinforce the theoretical proposition of the Malmquist framework: productivity growth can occur either through technological frontier expansion (innovation) or catching up to the frontier (efficiency gains), both of which are evident in East Java's manufacturing landscape.

In conclusion, Figure 2 encapsulates a comprehensive narrative of productivity evolution in East Java's manufacturing sector. The combination of a high TFPCH value, moderate but steady technological progress, significant efficiency gains, and slight improvements in scale efficiency collectively reflect a healthy and improving industrial ecosystem. These results underscore the region's potential to serve as a benchmark for other provinces in Indonesia seeking to enhance industrial productivity through balanced technological and efficiency-driven growth strategies.

The decision to expand the study by distinguishing between agro and non-agro manufacturing industries as well as between local and imported raw material usage is crucial for obtaining a more comprehensive and policy-relevant understanding of industrial productivity dynamics in East Java. This analytical refinement enables the study to capture structural differences, input dependencies, and technological behaviors across sub-sectors, thereby enhancing both the explanatory power and practical implications of the research.

East Java's manufacturing sector is highly diverse, encompassing a broad range of industries from agro-based processing (such as food, beverages, tobacco, and agricultural products) to non-agro industries (such as textiles, machinery, and metal manufacturing). These two groups differ significantly in input structures, production technologies, value chains, and exposure to external shocks. Agro-industries typically depend on local agricultural raw materials, are labor-intensive, and operate in rural or semi-rural regions. Non-agro industries, on the other hand, are often capital and technology-intensive, frequently located in urban industrial clusters, and may rely more on imported inputs or intermediate goods. By separating these two categories, the study can identify which industrial group contributes more to productivity growth, and which faces structural inefficiencies or technological constraints. Such differentiation is vital for designing sector-specific industrial policies that reflect the true heterogeneity of East Java's manufacturing economy.

One of the most critical factors influencing industrial productivity is the origin of raw materials. Industries relying on local inputs contribute directly to regional value-added creation and local supply chain strengthening, while those dependent on imported inputs often benefit from higher-quality or more technologically advanced materials but remain vulnerable to exchange rate fluctuations and global supply disruptions. By analyzing local vs. imported input-based production, the study can capture several key dimensions:

Resource utilization efficiency: Whether firms using local raw materials are able to transform them efficiently into high-value outputs compared to firms relying on imported inputs. Technological adaptability: Firms using imported materials might embody more advanced technologies or production processes, thereby influencing *technological change (TECH)* and *technical efficiency change (TECCH)* in the Malmquist decomposition. Economic resilience: Firms depending on imported inputs may experience volatility during global crises (e.g., exchange rate shocks, trade restrictions), whereas those using local resources could demonstrate greater resilience and sustainability (Asgari et al., 2024). Thus, the inclusion of raw material origin enables the study to explain how supply chain structures affect productivity growth and competitiveness within the East Java manufacturing sector.

Figure 3 for the entire manufacturing sector (Total Industry), the average TFPCH value is 1.38, indicating an overall productivity growth of approximately 38% over the study period. This improvement implies that the industry as a whole became more productive in utilizing its input resources (labor, capital, energy, and materials). The TECH value of 1.09 suggests modest technological progress, meaning that the production frontier shifted outward due to gradual improvements in technology or production techniques. Meanwhile, the TECCH value of 1.21 indicates that firms have become more efficient in converting inputs into outputs, reflecting better managerial performance or learning-by-doing effects. The SECH component, valued at 1.04, shows that improvements in productivity also resulted from more optimal production scale, although the magnitude is relatively small (Färe et al., 2018). Finally, the overall TFP value of 3.33 underscores a high level of cumulative productivity growth, demonstrating that industrial firms in East Java experienced substantial improvement.

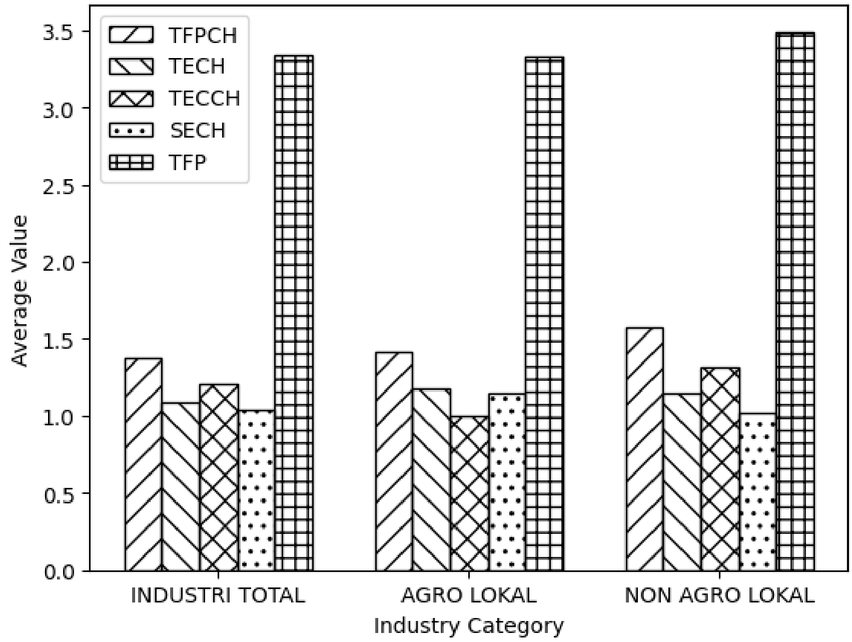

Figure 3. Average of TFPCH, TECH, TECCH, SECH, and TFP For The Agro and Non Agro With Lokal Material Manufacturing Industry In East Java

The Agro Local Industry group exhibits similar but slightly higher performance in some components compared to the total industry. The average TFPCH value of 1.42 indicates that productivity in the agro-based sector increased by 42%, making it one of the strongest performers. Technological progress (TECH = 1.18) appears to be the main driver of productivity gains in this sector, implying that agro-industrial firms have successfully adopted modern processing technologies, machinery, or improved agricultural inputs. The TECCH value of 1.00, however, indicates stagnant efficiency improvement — suggesting that while technology improved, firms did not necessarily become more efficient in managing resources. Interestingly, the SECH value of 1.15 highlights significant gains in scale efficiency, meaning that agro-industrial firms adjusted their production scale closer to optimal levels (either through expansion or consolidation). This improvement in scale efficiency likely contributed to better cost management and competitiveness. The TFP value of 3.33 confirms that agro-industries have maintained steady growth comparable to the overall manufacturing sector. These results demonstrate that the agro-based manufacturing segment has effectively leveraged technological advancement while benefiting from structural efficiency improvements.

he Non-Agro Local Industry displays the highest overall productivity performance among the three categories, with an average TFPCH value of 1.57, meaning productivity grew by 57%. This substantial improvement is primarily driven by Technological Change (TECH = 1.15) and an even stronger Technical Efficiency Change (TECCH = 1.32). The TECCH value suggests that firms in non-agro sectors (such as textiles, machinery, or electronics) have significantly enhanced their internal efficiency, possibly through innovation, process optimization, and better managerial practices. In addition, the TECH component also supports this progress, indicating the adoption of new technologies or modernization of equipment. Although SECH is relatively modest (1.02), it still indicates a slight improvement in the scale of operations. The high TFP value of 3.49 reinforces that non-agro industries are the most productive group, surpassing both total and agro sectors. This suggests that non-agro firms may have better access to capital, technology, and skilled labor, allowing them to adapt more effectively to competitive pressures and technological shifts (Amaliyah, 2018).

When comparing across sectors, it becomes clear that Non-Agro Local Industries lead in terms of overall productivity growth (TFP = 3.49), followed by Total Industry (3.33) and Agro Local Industry (3.33). The results imply that industrial diversification and technological intensity play crucial roles in determining productivity dynamics. Technological Change (TECH) was most pronounced in the Agro Local Industry (1.18), indicating successful modernization efforts in agricultural processing. Technical Efficiency Change (TECCH) peaked in Non-Agro Local Industries (1.32), revealing superior adaptability and operational effectiveness. Scale Efficiency Change (SECH) improvements were strongest in the Agro Local Industry (1.15), suggesting that firms in this sector achieved better alignment between input levels and production capacity.

Table 2. Average of TFPCH, TECH, TECCH, SECH, and TFP For The Agro and Non Agro With Import Material Manufacturing Industry In East Java

Indicator	Total Industry	Agro Industri	Non Agro Industri
TFPCH	1,3814	1,2807	1,3769
TECH	1,0892	1,0711	1,0968
TECCH	1,2069	1,1519	1,2007
SECH	1,0396	1,0346	1,0385
TFP	3,3552	3,2566	3,3347

Source: STATA

Based on Table 2, the average Total Factor Productivity Change (TFPCH) of import-based manufacturing industries in East Java shows a positive performance. Overall, the TFPCH value of 1.3814 indicates an increase in total productivity of about 38.14 percent during the observation period. This improvement is mainly driven by technological progress (TECH = 1.0892) and technical efficiency change (TECCH = 1.2069), suggesting that firms have succeeded in enhancing production capabilities through innovation and better utilization of production inputs. In addition, scale efficiency (SECH = 1.0396) also improved, showing that production capacities were used more optimally. Collectively, the TFP value of 3.3552 reflects a substantial cumulative increase in total productivity across the manufacturing sector.

When observed by sector, the agro-industrial sector experienced a more moderate productivity improvement compared to the non-agro sector. The TFPCH value of 1.2807 represents a 28.07 percent increase in productivity, mainly supported by gains in technical efficiency (TECCH = 1.1519) and technological progress (TECH = 1.0711). However, this growth remains relatively lower than that of the non-agro industries, which recorded a TFPCH of 1.3769 and TECH of 1.0968. This implies that non-agro industries have been more adaptive in adopting new technologies and have achieved higher operational efficiency (TECCH = 1.2007). Meanwhile, both sectors recorded similar improvements in scale efficiency, with SECH values ranging from 1.0346 to 1.0385, indicating a general trend of production optimization across industrial groups.

The positive TFPCH across manufacturing industries in East Java reflects productivity growth that is largely technology-driven, as indicated by the dominant role of technological change relative to efficiency improvement. This outcome is theoretically consistent with productivity dynamics in developing economies, where firms often face scale constraints and market imperfections that limit efficiency gains, making technology adoption and diffusion the primary sources of productivity growth. Similar technology-led productivity patterns have been reported in manufacturing sectors in China, Iran, and Singapore, where technological progress consistently outweighs efficiency change. The stronger productivity performance of non-agro industries and firms utilizing imported or technologically intensive inputs further supports the learning-by-importing and structural transformation hypotheses. These frameworks emphasize that access to advanced inputs and greater exposure to international markets enhance firms' technological capabilities and productivity potential. In contrast, the more moderate productivity growth observed in agro-based industries suggests persistent constraints related to capital intensity, technological absorption, and organizational scale, a pattern also documented in agro-industrial sectors of other emerging economies. Nevertheless, the relatively similar scale efficiency improvements across sectors indicate a broader trend toward production optimization driven by competitive pressures rather than sector-specific technological advantages alone.

The comparison between the two sectors shows that non-agro industries demonstrate slightly stronger competitiveness, particularly in technological adoption and operational efficiency. Nevertheless, the productivity gap between agro and non-agro industries is not substantial, implying that the agro-industrial sector still holds significant growth potential if structural challenges such as limited technology access, raw material fluctuations, and small-scale production can be addressed. Overall, these results indicate that East Java's import-based manufacturing industries are on a positive trajectory of productivity growth. The main drivers of this improvement are technical efficiency enhancement and technological advancement, while increased scale efficiency contributes to long-term competitiveness. Therefore, policies that promote technology transfer, managerial capacity building, and local raw material independence are crucial to sustaining productivity growth in the future (Wang & Tang, 2024).

Table 3. Comparative Analysis: Local vs. Imported Materials

Indicator	Agro Local	Agro Import	Non-Agro Local	Non-Agro Import
TFPCH	1.42	1.28	1.57	1.38
TECH	1.18	1.07	1.15	1.09
TECCH	1.00	1.15	1.32	1.20
SECH	1.15	1.03	1.02	1.04
TFP	3.33	3.26	3.49	3.33

Source: STATA

Table 3 provide a comprehensive comparison of productivity dynamics in East Java's manufacturing industry by distinguishing between agro-industries and non-agro industries, as well as by differentiating their reliance on local versus imported raw materials. The discussion of how the source of raw materials influences productivity, technological advancement, and efficiency improvements across sectors. Overall, both figures reveal that industries using local raw materials tend to achieve higher productivity growth and stronger efficiency performance compared to those relying on imported inputs.

For industries using local raw materials, productivity performance was generally high across all indicators. The total manufacturing sector recorded an average Total Factor Productivity Change (TFPCH) of 1.38, suggesting an overall productivity growth of 38 percent during the observation period. This increase was driven by a moderate technological change (TECH = 1.09) and a more significant technical efficiency improvement (TECCH = 1.21), indicating that firms became more effective in utilizing inputs and adopting new production practices. Meanwhile, the scale efficiency change (SECH = 1.04) showed slight but positive progress, suggesting that firms adjusted their production scales closer to optimal capacity. These improvements collectively produced a total factor productivity (TFP) of 3.33, demonstrating strong cumulative growth. This result implies that industries using local materials were able to better integrate domestic supply chains and reduce dependence on external inputs, which in turn strengthened their overall efficiency and competitiveness.

Within the local-input group, the agro-industrial sector showed a TFPCH of 1.42, representing a 42 percent productivity increase one of the highest among all categories. This growth was primarily driven by technological progress (TECH = 1.18), reflecting successful modernization efforts in agricultural processing and food-based industries. However, the technical efficiency change (TECCH = 1.00) remained stagnant, indicating that while technology improved, firms were not yet fully efficient in utilizing it. On the other hand, the scale efficiency change (SECH = 1.15) was notably high, implying that agro-industrial firms had effectively optimized their production scales through expansion or consolidation. The total TFP value of 3.33 confirmed that productivity gains in the agro-local sector stemmed mainly from improvements in technology and scale rather than operational efficiency. In contrast, non-agro industries using local materials outperformed all other groups, with a TFPCH of 1.57, showing a remarkable 57 percent increase in productivity. These industries such as metals, machinery, and textiles exhibited both technological progress (TECH = 1.15) and strong efficiency gains (TECCH = 1.32), indicating successful integration of innovation and management improvement. Although the SECH of 1.02 was modest, the overall TFP of 3.49 signified that non-agro local industries were the most productive and technologically advanced group in East Java's manufacturing structure.

In contrast, industries that relied on imported raw materials, as shown in Table 3, also experienced productivity growth but at a lower magnitude. The total manufacturing sector recorded a TFPCH of 1.3814, a TECH of 1.0892, a TECCH of 1.2069, and a SECH of 1.0396. While these values are comparable to those of local input industries, they indicate that dependence on imported materials yields slightly lower productivity. This could be due to logistical challenges, price volatility, and limited adaptability of imported inputs to local production conditions. For agro-industries using imported raw materials, the TFPCH was only 1.2807, reflecting a 28 percent productivity increase significantly lower than their local counterparts.

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The technological change (TECH = 1.0711) and efficiency change (TECCH = 1.1519) were both positive but moderate, suggesting that imported materials did not provide a substantial technological or efficiency advantage. Meanwhile, the SECH (1.0346) indicated minimal improvement in production scale, and the total TFP of 3.2566 showed a lower cumulative growth compared to the agro-local group. These results suggest that import dependence can hinder efficiency, especially when firms face fluctuating import prices and supply delays that increase production costs.

Non-agro industries using imported inputs, however, maintained relatively strong performance, with a TFPCH of 1.3769, TECH of 1.0968, TECCH of 1.2007, and SECH of 1.0385. These results demonstrate that non-agro industries are more resilient and adaptable, even when using imported materials. Nevertheless, their productivity was slightly lower than non-agro industries using local inputs, which recorded the highest overall performance. This pattern shows that access to high-quality local inputs, faster logistics, and integrated domestic supply networks contribute significantly to maintaining efficiency and competitiveness. The TFP value of 3.3347 for non-agro import-based industries indicates that they remain technologically strong but are somewhat constrained by their reliance on global supply chains.

Comparing across all groups, several key insights emerge. First, local-input industries consistently outperform those dependent on imported materials across nearly all productivity components. This finding underscores the strategic importance of developing local supply chains and strengthening domestic upstream industries. Second, non-agro industries regardless of input source display the highest levels of productivity and efficiency, highlighting their technological sophistication and superior management capacity. Third, agro-industries show strong technological progress but weaker operational efficiency, suggesting that modernization efforts in agriculture-based sectors are not yet matched by effective managerial practices. Fourth, scale efficiency is most pronounced in agro-industries using local materials, indicating successful production restructuring and optimization.

From a policy perspective, these findings carry several important implications. The higher productivity of local-input industries highlights the need for policies that support local supply chain integration and import substitution, particularly for agro-industries that rely heavily on imported materials. The government should invest in developing domestic raw material industries, improving logistics infrastructure, and encouraging collaboration between farmers, cooperatives, and manufacturers. Moreover, while technology adoption has advanced, many industries especially in the agro sector struggle with operational inefficiency due to limited human capital and managerial capacity. Therefore, policy interventions should focus on technology transfer, vocational training, and managerial capacity building to ensure that technological upgrades translate into real efficiency gains. The significant scale efficiency observed in agro-local industries also indicates that industrial clustering and cooperative models can enhance production capacity while maintaining cost efficiency. Lastly, reducing dependency on imported inputs will strengthen industrial resilience against global supply disruptions and currency fluctuations, making East Java's industrial base more stable and sustainable.

In summary, clearly shows that industries using local raw materials exhibit higher productivity and efficiency than those relying on imported inputs. Among them, non-agro industries emerge as the most dynamic and productive sector, combining technological innovation with operational excellence. Meanwhile, agro-industries particularly those using local inputs demonstrate strong potential for growth through technological modernization and scale optimization. These findings suggest that the future of East Java's industrial competitiveness lies in enhancing local resource utilization, technological innovation, and supply chain independence. Strengthening these aspects will not only sustain productivity growth but also promote inclusive and resilient industrial development across the region.

5. Conclusion

The Malmquist Productivity Index (MPI) results indicate a positive trend in productivity growth in East Java's manufacturing sector, as reflected by an average Total Factor Productivity Change (TFPCH) greater than one. This improvement is mainly driven by technological progress, complemented by gains in technical and scale efficiency, suggesting that some industries are operating closer to their optimal production scale. Nevertheless, productivity performance remains uneven across subsectors, implying persistent challenges related to technological adaptation, capital intensity, and scale optimization. The relatively stronger productivity performance of industries utilizing local raw materials highlights the strategic role of domestic input integration in supporting productivity growth and supply chain resilience.

Based on these findings, policy efforts should prioritize technological upgrading and innovation diffusion, particularly for small and medium enterprises, alongside measures to strengthen local input industries and align human capital development with industrial needs. Supporting industrial clusters, improving logistics infrastructure, and enhancing inter-firm linkages can further mitigate scale inefficiencies and promote sustainable productivity growth. Despite these contributions, this study is subject to several limitations. The DEA–Malmquist approach provides relative productivity measures that are sensitive to model specification, variable selection, and sample composition. In addition, data constraints limit the incorporation of environmental factors, energy intensity, and firm-level heterogeneity, while the descriptive nature of the analysis precludes causal inference regarding policy impacts. Future research could address these limitations by integrating environmental and energy-related variables, using micro-level data, and combining DEA-based productivity measures with econometric methods to strengthen causal interpretation.

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