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Analysis Productivity Chemical Industry in Indonesia

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A B S T R A C T

This research aims to determine Technical Efficiency Change (TEC), Scale Efficiency Change (SEC), Technological Change (TC), Total Factor Productivity (TFP) in the chemical industry in Indonesia. Using data form large anda medium manufacturing industries in Indonesia, the Stohastic Frontier method is used to determine TEC, SEC, TC, TFP. The results of the average TEC, SEC, TC, TFP show negative changes for productivity in the chemical industry in Indonesia. Based on the research results, the company must provide incentives in the form of subsidies or financial assistance to replace old machines with more efficient technology and maintain the stability of raw material prices. This study has limitations in large and medium manufacturing industries and assumptions in the Stochastic Frontier Analysis model that can affect the estimation results. Therefore, further research is recommended to consider small industries and use other approaches such as Data Envelopment Analysis. As a policy recommendation, the government needs to encourage investment in more efficient technology through incentives in the form of subsidies to update production machines. The contribution of this study is to provide insight into the factors that affect the productivity of the chemical industry in Indonesia and to offer policies to improve efficiency.

Keywords: *Productivity, Chemical Industry, Stohastic Frontier Analysis*
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INTRODUCTION

The Indonesia manufacturing industry shows significant growth in 2019-2023. This sector also contributes more than 18.67% to the national Gross Domestic Product (GDP) and one of the sectors with significant labor income. This proves that this sector not only makes a major contribution to economic growth but has a strategic role in supporting social stability through the creation of extensive job opportunities. Development can be defined as a clear economic, social and cultural transformation through processes and plans to achieve desired results (Digdowiseiso, 2019).

Referring to data from the Central Statistics Agency (BPS) in 2019, this industry shows a significant growth trend with increased investment in several strategic sub-sectors such as petrochemicals, basic chemicals, and special chemicals. Expansion of production capacity carried out by a number of major producers, coupled with the optimization of existing production facilities, contributed to an increase in overall industrial output. Referring to data from the Central Statistics Agency (BPS) Entering 2020, the COVID-19 pandemic is putting pressure on the performance of the national chemical industry, creating unprecedented innovation in the global supply chain and people's consumption patterns. According to (Sutrisno, 2001), production costs are costs used to manage raw materials to become finished products.

Restrictions on economic activity and community mobility implemented in various countries have caused a drastic reduction in demand from industrial users, while global logistics disruptions have resulted in instability in the supply of raw materials and increased production costs. A progressive national vaccination program is implemented, and social restrictions begin to gradually decrease, encouraging the normalization of industrial activity and recovery of demand from the user sector. Referring to data from BPS for 2022-2023, the trend in the use of chemicals in the manufacturing industry in Indonesia proves significant development, which is influenced by the need for sustainability, energy efficiency and improving product quality. The chemical manufacturing industry in Indonesia is starting to focus on greener and environmentally friendly technology, in line with increasing awareness of the issue of climate change and consumer demands for products that are more secure for health and the environment.

According to the Ministry of Industry, digital transformation 4.0, such as the Industrial Internet of Things (IIoT), will help chemical factories optimize the production of organic chemicals in large quantities, reduce waste, increase safety and sustainability, and become agile to respond quickly to fluctuations in supply and demand. The increase that occurred in the manufacturing industry in Indonesia sourced from the Central Statistics Agency (BPS) between 2019-2023 shows a significant increase despite various challenges, including the impact of the COVID-19 pandemic. The sector has successfully adapted by accelerating the adoption of digital technology and automation, which supports operational efficiency and competitiveness.

The growth rate of the manufacturing industry in Indonesia from 2019 to 2023. In 2019, the growth rate was 3.80%. Then, in the following year, namely 2020, growth decreased to -2.93% due to COVID-19. Then, in 2021 there was an increase to 3.39%. Furthermore, in 2022, the growth rate of the manufacturing industry will increase to 4.89% then, in 2023 there will again be a slight decline reaching 4.64%. Overall, this chart shows a fluctuating pattern with an increase at the beginning of the period, then a decrease, and a slight recovery at the end of the year.

Doherty et al (2013) productivity is an indicator that examines output (products and services) related to input (labor, raw materials, energy and other resources) that are used to produce these products and services.In the last year 2023, according to the Central Agency, the trend in the use of chemicals in the manufacturing industry in Indonesia shows significant development, which is influenced by the need for sustainability, energy efficiency and improving product quality. In addition, the trend of digitalization and industrial automation has also encouraged improvements in quality and production efficiency in the use of chemicals.

Production is all activities carried out to create and add utility value to goods and services using existing production factors. According to (Beattie & Taylor, 1994) production is a way to combine raw materials and labor in creating goods and services. The production process is described in the form of a production function. According to (Jones, 2014) the production function is an equation that embodies how inputs such as capital and labor are integrated to produce good output. Most of the production activities are called production factors or input. The production function shows the highest output that a company can produce for each specified combination of inputs (Pindyck & Rubinfels, 2013).

In order to test the relationship between production factors and production results, researchers apply the Cobb-Douglas Frontier production function. According to (Soekartawi, 2003) The Cobb-Douglas Frontier production function is a production function that is applied to determine how the current production function relates to its frontier position. In addition, the author also uses the theory of (Coelli, 1992) which states the stochastic frontier production function for panel data (unbalanced) that has a company effect and is assumed to be distributed and becomes a truncated normal random variable, also allowed to vary systematically over time.

Productivity is the comparison between the volume of output to the amount of input used. On the other hand, productivity is a performance indicator that describes the comparison between input, such as capital and labor, with the output produced. According to Sinungan (2014) productivity is an idea that aims to prepare more goods and services for use by all humans, by applying increasingly fewer real resources. Mathis & Jackson (2006) defines productivity as a measurement of the quantity and quality of work that has been done, to assess the costs of the resources used.

TFP components include Technical Efficiency Change (TEC), Technological Change, and Scale Efficiency Change. Pitt & Lee (1981) describe production activities, technical efficiency is the company's ability to realize the maximum total output from various inputs that are shared. Technical efficiency is also the average production ratio of a company (George & T, 1988). Technical efficiency is related to efficiency in the application of inputs. Farrell & M.j (1957) explain that when the level of efficiency is higher, the company will be more efficient in utilizing existing inputs.

One of the biggest challenges facing the manufacturing industry is dependence on imported raw materials, where when imported raw materials increase, production costs increase, thereby reducing productivity. From the definition of productivity above, the author uses the formula Total Factor Productivity (TFP), Technological Efficiency Changes (TEC), Scale Efficiency Changes (SEC), Technological Change (TC).

According to research from Wafi & Sari (2021). Total Factor Productivity (TFP) describes how well inputs such as capital, labor and raw materials are utilized to create output. Technological Efficiency Changes (TEC) refers to changes in technical efficiency to the extent to which a production system can realize maximum output from existing inputs. Scale Efficiency Changes (SEC) is used to measure the extent to which production size affects efficiency in input utilization.

The results of (Ulkhaq, 2022) using the Data Envelopment Analysis (DEA) technique, from 23 data studied, 5 were considered the most efficient, but according to Titik (2024) from 24 data studied, 11 were considered the most efficient. In addition, Attaqi (2022) using the Classical Assumption Test Technique, the variables of Education Level, Wages, Age, Work Experience, and working hours simultaneously affect Labor Productivity. According to research by Azzahra Tarbiyah Islamiya et al (2022) using the Stochastic Frontier Analysis (SFA) Technique, the CPO Industry has remained inefficient for five years. The low efficiency score stems from the small number of trained workers and the small increase in research and development in important aspects.

In addition, Machmud et al (2018), market share variables significantly and negatively affect technical efficiency. Company age, business ownership, ratio concentration, and capacity utilization have an effect and are not significant. Harianto & Sari (2020), uses the Common Effect (CE), Random Effect (RE), and Fixed Effect (FE) techniques which have results The estimation results show that the presence of manufacturing companies in similar industries (horizontal spillover).

Technological Change (TC) shows advances in technology to support production processes to be more efficient. The chemical manufacturing industry can achieve efficiency through a combination of automation, digitalization, energy savings and the application of sustainable technology. Quality improvement is also needed from the workforce, because it is very important to improve local regional capabilities (Wijaya & Utama, 2016).

Therefore, based on the phenomena already described. The main objectives on the research to be carried out TFP in Chemical Industry in Indonesia. The organization of this paper proceeds as follows: Section 2 discusses data sources and variable construction for panel data. It is continued by analysis of empirical results. The summary of findings and policy implications are given in the final section.

METHODOLOGY

The data obtained from Large and Medium Manufacturing Industries originating from the BPS in 2010-2014. This research uses quantitative methods with the Stochastic Frontier Analysis (SFA) approach. The SFA method is used to analyze data through a production function approach. The data obtained was summarized in tabulation form, then processed using the FRONTIER 4.1 computer program.

The operational definition of the variables applied in this study is as follows:

1. Production Function

1.1 Output

This production variable is calculated based on various indicators related to efficiency, effectiveness, and total output value. If calculating efficiency and effectiveness, then use the percentage unit (%).

1.2 Input

a. Capital is calculated based on fixed assets such as: buildings, production machines, and company equipment that will be used during production. If used buildings, production machines, then use the rupiah unit (Rp).

b. Labor is calculated based on the amount of productivity, and labor costs. If to calculate and labor costs, then calculate how many hours per week.

c. Material is calculated from the raw materials needed in the production process. If to calculate raw materials, then calculate in kilograms (Kg).

d. Energy is calculated based on the company's total expenditure from the use of fuel oil, gasoline, and electricity to help the production process. If to calculate electricity usage, then calculate in kWh (Kilowatthours).

2. TFP (Total Factor Productivity)

TFP (Total Factor Productivity) is a company's measure of all inputs used in the production process. TFP has four components, namely, TEC (Total Efficiency Changes), SEC (Scale Efficiency Changes), TC (Technological Change). Increased TFP is associated with efficiency and increased production processes. If the TFP value <1 then the production process is not running optimally and if the TFP value> then the production process tends to increase and is efficient. If TFP = 0 then the production process is still using old machines. The following are the components of TFP:

a. TEC (Total Efficiency Changes) is calculated based on changes in technical efficiency in the production system.

b. SEC (Scale Efficiency Changes) is calculated based on changes in efficiency resulting from changes in the scale of operations in the production unit.

c. TC (Technological Change) is calculated based on changes in the ability of technology to increase productivity, which comes from shifts in the production function.

The standard Stochastic Frontier Analysis function using the production approach has a general form Coelli (1992) describe a stochastic frontier production function for panel (unbalanced) data that has strong effects and is assumed to be distributed as a truncated normal random variable, and allowed to vary systematically over time. Namely as follows:

$$y_{it} = \alpha + \beta' x_{it} + \tau' z_i + v_{it}$$

where y_{it}: firms output, x_{it}: input vector, z_i is firms characteristic vector. α and β' are the parameters that will be predicted when v_{it} shows random errors. This model shows a fixed time, $\tau' z_i$ in $\beta' x_{it}$ and the model becomes:

$$y_{it} = \alpha + \beta' x_{it} + v_{it} - u_{it}$$

where uit is the inefficiency term. Estimating efficiency by establishing this framework begins with predicting technological parameters (α, β, σ_u and σ_v) so that the compositional deviation can be measured, formulated as follows:

$$\varepsilon_{it} = v_{it} - u_{it} = y_{it} - \alpha - \beta' x_{it}$$

However, the aim of this study is primarily to predict the time course of inefficiency (uit), and not firm-specific heterogeneity (εit). The measurement of inefficiency in this research is based on the measurement of inefficiency carried out with (Jondrow, j., 1982) (JLMS), formulated as follows:

$$E[uit \mid \varepsilon it] = \frac{\sigma\lambda}{1+\lambda^2}\left[\frac{\phi\,(a_{it})}{1-\Phi\,(a_{it})} - a_{it}\right]$$

The Stochastic Model can distinguish whether poor performance is caused by company inefficiency or by independent external factors. The model used can be shown in the following equation:

$$\text{Lny}_{it} = \beta0 + \beta1\ln K_{it} + \beta2\ln L_{it} + \beta3\ln M_{it} + \beta4\ln E_{it} + \beta5\ln½(K_{it})^2 + \beta6\ln½(L_{it})^2 + \beta7\ln½(Mi)^2 + \beta8\ln½(E_{it})^2 + \beta9\ln(K_{it})\ln(L_{it}) + \beta10\ln(K_{it})\ln(M_{it}) + \beta11\ln(K_{it})\ln(E_{it}) + \beta12\ln(L_{it})\ln(M_{it}) + \beta13\ln(L_{it})\ln(E_{it}) + \beta14\ln(M_{it})\ln(E_{it}) + \beta15_{it} + ½\,\beta16_{it}^2 + \beta17\ln K_{it} + \beta18\ln L_{it} + \beta19\ln M_{it} + \beta20\ln E_{it} + v_{it} - u_{it}$$

where y is total output while the independent variables K (value of company capital), L (labor), M (materials), E (energy) are used in the input process. V_{it} means random error and u_{it} is technical inefficiency. The subscripts *i* and t refer to the ith company and the tth year, respectively. β means prediction coefficient. In this research, output and input variables are transformed into natural logarithms, the deviation of each observation from the geometric mean is calculated. For example, Kit modal geometric mean is $\bar{K}$, which is replaced by the natural logarithm (ln($\bar{K}$)). Each observation in the capital variable is transformed into the natural logarithm ln(K¯) before being subtracted from the calculated geometric mean. The formula is as follows:

$$K_{it} = \ln(K_{it}) - \ln(\bar{K})$$

In general, subtranslog production function models consist of the Hicks-neutral model, no technological progress, and the Cobb-Douglas model. Each of these models was tested, and the most appropriate model was used as the production function model for this analysis. First, we carried out hypothesis testing using the Hicks-neutral (H_0) and translog (H_1) tests. The Hicks-neutral model is defined by ignoring the interaction of input parameters and time. ($\beta_{nt} = 0$) in equation (5). Below, a test is carried out between no technological progress (H_0) and translog (H_1) The non-technological model assumes that the time factor is excluded ($\beta_t = \beta_{tt} = \beta_{nt} = 0$) from the translog model. The third test is Cobb Douglas (H_0) against the translog (H_1) production function. The null hypothesis consists of input parameters ($\beta_{nm} = \beta_{nt} = \beta_t = \beta_{tt} = 0$). This hypothesis test is estimated consistently using general likelihood ratio statistics with the following formula:

$$\lambda = -2\,[l(H0) - l(H1)]$$

$l(H_0)$ represents the estimated log-likelihood value from the restricted frontier model, while $l(H_1)$ represents the estimated log-likelihood value from the translog model. If the calculated l is smaller than the critical value x2 of the distribution, then the null hypothesis is not rejected.

This research analyzes total factor productivity (TFP), according to Comin, (2006) defining TFP as the part of output that cannot be described by the amount of input applied to the production process. Therefore, the size of TFP depends on how efficiently the inputs are applied to the production process. TFP is calculated by adding up its components, namely technical efficiency changes (TEC), scale efficiency changes (SEC), and technological changes (TC). The TFP growth formula is as follows:

$$TFPg_{it,t-1} = TEC_{it,t-1} + SEC_{it,t-1} + TC_{it,t-1}$$

where

$$TEC_{it,t-1} = \ln\left(\frac{TE_{it}}{TE_{it,t-1}}\right) \times 100$$

$$SEC_{it,t-1} = \frac{1}{2}\sum_{n=1}^{N}\left[\left(\frac{\varepsilon_{Tit}-1}{\varepsilon_{Tit}}\varepsilon n_{it} + \frac{\varepsilon_{Tit-1}-1}{\varepsilon_{Tit-1}}\varepsilon n_{it-1}\right)(xn_{it} - xn_{it-1})\right] \times 100$$

$$TC_{it,t-1} = 0.5\left[\left(\frac{\partial y_{it-1}}{\partial t}\right) + \left(\frac{\partial y_{it}}{\partial t}\right)\right] \times 100$$

TE_{it} is technical efficiency and ε_{Tit} is the elasticity of total output towards each input. Yit is the output and xnit is the input used in the production function. The subscripts i and ta are the company and time indices, respectively. TEC proves managerial improvement and TE_{it} is technical efficiency. SEC reflects progress towards the most optimal production scale. TC is a change in production limits through the use of advanced technology (Arora, 2017).

TEC reflects changes in technical efficiency, that is, how close the company operates compared to the production frontier. If TEC increases, it means the company or industry is getting closer to the production frontier, which proves an increase in technical efficiency and if it decreases, it means the company is experiencing a decline in technical efficiency. SEC is achieved when the company operates at the point where average total costs are at their lowest level. If SEC increases, it means the company is approaching optimal operating scale and if it decreases the company is too small or too large in its operations, so it becomes inefficient.

TC reflects a shift in the position of

the production frontier, allowing the industry to realize more output with the same input. If TC increases, it means the technology used is getting better and more efficient and if TC decreases, then the technology used is stagnant or less efficient.

RESULTS AND DISCUSSION

Based on table 1, it is explained that the description of the model results from the translog production function submodel to the translog production function model. Based on the results of the generalized likelihood-test, the null hypothesis in the three translog submodels was rejected, which means that the submodels included did not meet the requirements to represent the data. Therefore, the production function model chosen is the translog production function.

Technical efficiency itself is an advantage for a company to realize maximum total output with some of the inputs used. Referring to the calculation results in Table 2, it proves that the average value of TEC growth in the Chemicals industry in 2010–2014 was negative. In 2011–2012, the highest TEC value was found in the shellac industry with a value of 8.2248, while in 2013–2014 the lowest TEC value was found in the artificial rubber industry with a value of -9.9816. The average value of TEC growth for the Chemicals industry is 2.8966 per year. This suggests that while some subsectors achieved significant improvements in technical efficiency, others experienced notable setbacks, indicating an uneven performance across the industry.

Table 1.
Estimation Maximum-Likehood in Stohastic Frontier

Variables	Coefficient	Model 1	Model 2	Model 3	Model 4
k	β_k	0.1909***	0.1619***	0.1493***	0.0861
		(0.0292)	(0.0267)	(0.0277)	(0.0040)
l	β_l	0.1450***	0.1482***	0.1654***	0.1085***
		(0.0512)	(0.0511)	(0.0532)	(0.0061)
m	β_m	-0.1913***	-0.1830***	-0.2236***	0.5487***
		(0.0399)	(0.0395)	(0.0409)	(0.0065)
e	β_e	0.8811***	0.8889***	0.9257***	0.2815***
		(0.0347)	(0.0348)	(0.0359)	(0.0064)
k^2	β_{kk}	-0.0019*	-0.0125***	-0.0232***	
		(0.0047)	(0.0039)	(0.0037)	
l^2	β_{ll}	0.00149**	0.0161***	0.0205**	
		(0.0088)	(0.0087)	(0.0090)	
m^2	β_{mm}	0.2959***	0.2859***	0.3071***	
		(0.0119)	(0.0116)	(0.0120)	
e^2	β_{ee}	0.2090***	0.2211***	0.2321***	
		(0.0126)	(0.0124)	(0.0128)	
$k \times l$	β_{kl}	0.0096*	0.0130*	0.0145**	
		(0.0069)	(0.0063)	(0.0065)	
$k \times m$	β_{km}	-0.0445***	-0.0279***	-0.0298***	
		(0.0058)	(0.0050)	(0.0051)	
$k \times e$	β_{ke}	0.0549***	0.0438***	0.00484***	
		(0.0058)	(0.0050)	(0.0052)	
$l \times m$	β_{lm}	-0.0154***	0.0185***	-.0.0239***	
		(0.0056)	(0.0053)	(0.0055)	
$l \times e$	β_{le}	-0.0006*	-0.0007**	-0.0004	
		(0.0005)	(0.0005)	(0.0005)	

Table 1. (*continue*)

Variables	Coefficient	Model 1	Model 2	Model 3	Model 4
m x *e*	β_{me}	-02529***	-0.2544	-0.2684***	
		(0.0107)	(0.0107)	(0.0110)	
t	β_t	-0.0797***	-0.0429**		
		(0.0165)	(0.0028)		
t^2	β_{tt}	-0.0545***	-0.0651***		
		(0.0050)	(0.0043)		
k x *t*	β_{kt}	-0.0124***			
		(0.0032)			
l x *t*	β_{lt}	0.0034*			
		(0.0035)			
m x *t*	β_{mt}	-0.0144***			
		(0.0037)			
e x *t*	β_{et}	0.0213***			
		(0.0040)			
b0	β_0	3.0231***	3.0520***	3.1067***	2.0376***
		(0.1724)	(0.1685)	(0.1844)	(0.0250)
sigma squared	δ_0	0.0947***	0.0955***	0.1022***	0.1202***
		(0.0020)	(0.0020)	(0.0022)	(0.0026)
gamma	Γ	0.0001	0.0001	0.0000	0.0001
		(0.0033)	(0.0033)	(0.0029)	(0.0027)

Note: * Significant at level 1%, ** Significant at level 5%, and *** Significant at level 10%

Table 2.
Descriptive Statistics of Research Data

Variables	Units	Obs	Mean	Std.dev	Min	Max
Y (Output)	million	3040	10,51	2,00	4,52	18,24
K (Capital)	million	3040	6,93	2,24	-0,56	15,96
L (Labour)	million	3040	4,44	1,09	3,00	9,94
M (Material)	million	3040	8,80	2,95	3,00	17,51
E (Energy)	million	3040	7,08	2,10	-0,05	14,52

Referring to the results of the SEC calculations presented in Table 3, it can be observed that the average SEC value in the Chemicals industry experienced negative growth throughout the 2010–2014 period. Although there were periods where positive growth occurred, overall trends indicate inefficiencies in scaling production. The average annual SEC growth in this industry was recorded at 80.9878. A notable increase in scale efficiency was seen in the 2011–2012 period, particularly in the machinery and equipment industry, which recorded the highest SEC growth at 785.8555. This suggests that, during that period, firms in this subsector were likely operating at or approaching optimal production scale.

Conversely, the most significant decline in SEC was observed in the 2013–2014 period, where the other fertilizer industry recorded the lowest SEC growth value of -877.7987. The overall negative growth in SEC across the Chemicals industry indicates a broader issue related to declining production performance and inefficiencies associated with inappropriate scale usage. This inefficiency may be attributed to excessive use of inputs or a mismatch between production capacity and actual operational needs. As a result, many firms within the industry may not be operating at the most productive scale, thereby limiting their potential for cost efficiency and output maximization.

Table 3.
Technical Efficiency Change Chemical Industry in Indonesia

Industries	TEC 1	TEC 2	TEC 3	TEC 4
Chlorine and alkali	0,0005	-0,0003	5.1246	-0,0005
Industrial gas	-7,5164	2,5798	-0,0001	0,0001
Pigment	0,0005	-0,0022	0,0009	0.0001
Other inorganic basic chemistry	0,0002	-0,0001	-0,0003	-0,0003
Agricultural product	-0,0007	0,0006	-0,0003	0,0006
Dyes and pigments	-1,0841	0,0003	-0,0016	0,0012
Natural gas and coal	0,0003	-0,0008	0,0004	-0,0004
Special chemicals	-9,8237	0,0005	-0,0005	-0,0001
Other basic organic chemistry	0,0001	4,6364	-9,1551	-0,0002
Primary macro nutrient natural fertilizer	0,0002	-0,0003	0,0001	0,0004
Single primary macro nutrient artificial fertilizer	-4,7479	0,0006	-0,0003	0,0006
Primary macronutrient compound fertilizer	0,0005	-0,0002	0,0004	0,0004
Other fertilizers	0,0017	0,0001	-0,0026	0,0012
Artificial resin and plastic raw materials	0,0003	-0,0004	-6,8773	0,0001
Artificial rubber	0,0002	-9,9816	-0,0004	0,0010
Pest control raw materials	2,3856	-0,0013	0,0016	0,0001
Pest control	0,0007	0,0005	-0,0013	0,0007
Paint and printing ink	0,0003	4,8025	-0,0004	0,0006
Varnish	0,0006	5,4320	-0,0003	7,6971
Machines and equipment	-0,0012	0,0008	-0,0011	0,0005
Lacquer	8,2248	0,0001	-0,0001	0,0001
Cosmetics for humans	0,0007	-0,0005	-9,3471	0,0739
Adhesive/glue	-0,0003	0,0007	-0,0001	0,0005
Explosives	-0,0003	0,0007	-0,0011	-0,0005
Ink	-0,0003	0,0007	-0,0001	0,0003
Essential oil	4,9701	-1,6859	-0,0004	0,0006
Match	3,7331	-0,0005	0,0005	-0,0002
Other chemical goods	-0,0001	0,0003	-0,0003	0,0002
Artificial filament fiber/yarn/strip	-0,0021	-0,0008	0,0013	0,0011
Artificial staple fiber	0,0007	0,0006	-0,0010	0,0009

Referring to Table 4, the results of the Technological Change (TC) calculation reveal significant variations across subsectors within the Chemicals industry during the 2010–2014 period. In particular, the highest TC value was recorded in the artificial fiber, yarn, and strip filament industry in 2011–2012, reaching 2.2369. This positive growth indicates that this subsector experienced technological advancements that potentially improved production efficiency. Conversely, in 2013–2014, the lowest TC value was found in the other fertilizer industry, with a sharp decline to -31.4996. This substantial negative growth highlights the challenges faced by this subsector, likely stemming from outdated machinery and equipment that require modernization.

The negative TC growth observed suggests that technological stagnation or regression can significantly impede overall productivity. According to Lipsey and Carlaw (2004), technological development or growth in total factor productivity is considered a residual factor in the production function, reflecting improvements in the efficiency of input use beyond mere capital or labor increases. Therefore, continuous investment in technology upgrades and innovation is essential for sustaining productivity growth and competitiveness within the Chemicals industry. Addressing the lag in technological advancement, particularly in subsectors with declining TC values, should be a priority to prevent further efficiency losses.

After obtaining the results from the calculation of each part of TFP. by adding up the results from TEC. TC. and SEC. we then get the results of the growth value of the Total Productivity Factor in the chemical chemical industry which is shown in Table 4.

TFP growth in the chemical industry decreased from 2011-2012 and then increased in 2013-2014. The average value of TFP growth in the chemical industry was 67.9169 per year. In 2011-2012 the highest TFP value was found in the artificial fiber/yarn/strip filament industry with a value of 1680. 4603. while in 2013-2014 the lowest TFP value was found in the other fertilizer industry with a value of 876.8723.

Table 4.
Scale Efficiency Change Chemical Industry in Indonesia

Industries	SEC 1	SEC 2	SEC 3	SEC 4
Chlorine and alkali	732.7909	-28.5471	1.7354	-28.2134
Industrial gas	444.2129	0.6843	-10.9141	-10.5917
Pigment	188.8389	-1.1056	-4.9822	-27.4945
Other inorganic basic chemistry	479.2132	-0.5457	-0.1746	-0.1486
Agricultural product	615.1061	-0.6480	1.3266	-2.0054
Dyes and pigments	742.4646	-8.8193	14.3704	-14.4970
Natural gas and coal	523.2082	2.7791	-2.0120	-38.8872
Special chemicals	602.5909	-11.4452	-9.1308	-15.3731
Other basic organic chemistry	328.3717	-5.6364	-2.7760	-15.4252
Primary macro nutrient natural fertilizer	356.1527	-1.0891	2.1052	7.8829
Single primary macro nutrient artificial fertilizer	608.0426	10.3555	2.7539	-19.7472
Primary macronutrient compound fertilizer	156.7446	-13.9294	4.0152	-20.4179
Other fertilizers	-877.7987	-10.8639	-27.8353	2.7477
Artificial resin and plastic raw materials	664.3494	-3.4214	-3.3283	-13.7791
Artificial rubber	-655.3983	2.0512	-5.2980	8.1114
Pest control raw materials	765.7461	5.5801	-24.6284	-16.1344
Pest control	244.9010	-7.6366	9.7669	-18.8998
Paint and printing ink	332.7698	-9.0358	2.9957	-4.3815
Varnish	115.3906	6.7166	-9.7746	-8.3957
Machines and equipment	785.8555	-1.0144	10.2115	7.7781
Lacquer	312.6458	-7.9002	0.0668	-6.1038
Cosmetics for humans	131.2987	5.3720	1.1535	-4.1811
Adhesive/glue	470.7553	-5.4010	3.2498	-6.4144
Explosives	-289.4963	-3.7343	5.2289	14.5704
Ink	573.8520	5.0460	-0.2247	16.4892
Essential oil	186.7559	3.7882	-1.6070	1.3285
Match	-50.8085	4.1555	-1.7784	5.8865
Other chemical goods	499.9322	4.4580	-5.5801	-11.5846
Artificial filament fiber/yarn/strip	1678.2254	11.5557	-13.0220	-35.9973
Artificial staple fiber	-561.8983	10.9668	-0.6074	-18.4953

Table 5.
Technological Change Chemical Industry in Indonesia

Industries	TC 1	TC 2	TC 3	TC 4
Chlorine and alkali	0.9396	-10.3051	-18.7041	-26.8341
Industrial gas	1.5173	-9.1461	-17.6440	-26.0801
Pigment	1.0649	-9.0028	-17.3805	-25.7505
Other inorganic basic chemistry	0.9260	-9.7767	-18.3126	-25.9985
Agricultural product	1.9457	-8.8286	-17.2794	-26.2007
Dyes and pigments	1.6864	-9.6738	-17.1095	-25.6250
Natural gas and coal	1.1873	-10.4353	-18.4193	-26.7288
Special chemicals	1.5768	-10.3060	-18.6627	-26.2533
Other basic organic chemistry	1.2458	-10.1104	-18.3364	-26.7557
Primary macro nutrient natural fertilizer	1.0872	-8.6688	-16.5542	-26.3246
Single primary macro nutrient artificial fertilizer	1.2304	-10.4746	-19.0497	-27.3166
Primary macronutrient compound fertilizer	1.2501	-9.2163	-16.9784	-27.0934
Other fertilizer	0.9246	-9.8980	-16.7208	-31.4996
Artificial resin and plastic raw materials	1.0921	-9.9911	-18.1362	-25.5893
Artificial rubber	-0.4360	-9.4345	-17.6971	-24.7835
Pest control raw materials	1.7273	-9.1672	-18.0300	-26.3093
Pest control	1.1960	-9.6478	-17.8669	-26.1812
Paint and printing ink	1.1484	-9.4666	-17.8827	-26.1183
Varnish	1.2027	-9.3292	-17.5739	-26.4723
Machines and equipment	1.9703	-8.6361	-16.7704	-25.2419
Lacquer	1.1167	-8.9062	-17.4379	-26.1150
Cosmetics for humans	0.9875	-8.9405	-17.1403	-25.7716
Adhesive/glue	1.2328	-10.0632	-17.7652	-26.2180
Explosives	1.8565	-5.9227	-13.6315	-25.7217
Ink	0.0745	-10.5139	-18.4478	-26.9379
Essential oil	1.0264	-8.7879	-16.7218	-25.5361
Match	0.9670	-9.0214	-17.1605	-25.7488
Other chemical goods	1.4172	-8.5971	-17.3942	-26.6469
Artificial filament fiber/yarn/strip	2.2369	-10.4931	-18.1655	-24.6908
Artificial staple fiber	0.1465	-10.7986	-19.2103	-28.2512

In general. the national chemical industry has a low average productivity growth value. due to the three parts of TFP. namely growth in technical efficiency. technological change. and scale efficiency of the Chemical Industry in 2010-2014. which grew negatively. although in some periods there was positive growth. This proves that the chemical industry still needs a lot of improvements and innovation to increase productivity.

TFP growth in the national chemical industry was negative from 2011-2012 and then increased in 2013-2014. The average value of TFP growth in the chemical industry was 67.9169 per year. The highest TFP value was found in the artificial fiber/yarn/strip filament industry with a value of 1680.4603 in 2011-2012. while the lowest TFP value was found in other fertilizer industries with a value of 876.8723 in 2013-2014. The negative decline in TFP growth was caused by some of the obstacles faced by the chemical industry.

Starting from the import trend in the chemical industry. It has proven a significant increase with an average of 4.5% per year. This situation is exacerbated by the high dependence on imported raw materials. where more than 85% of the need for main raw materials. such as basic chemicals and petrochemical materials. It still depends on supplies from abroad. This high dependency makes the chemicals industry vulnerable to international price fluctuations and global supply chain disruptions. In 2011. one of the problems in the Chemical Industry was the availability of raw materials. At that time. The national chemical industry needed 1.7 million tons of NAFTA per year. but most of it had to be imported. All components of TFP include TEC. TC. and SEC in measuring productivity which plays a very large role. In 2010-2014. These three components proved that the productivity and efficiency of the

Table 6.
Total Factor Productivity Chemical Industry in Indonesia

Industries	TFP 1	TFP 2	TFP 3	TFP 4
Chlorine and alkali	733.7311	-38.8526	-16.9687	-55.0479
Industrial gas	445.7302	-8.4617	-28.5583	-36.6716
Pigment	189.9045	-10.1107	-22.3618	-53.2448
Other inorganic basic chemistry	480.1395	-10.3227	-18.4876	-26.1474
Agricultural product	617.0511	-9.4761	-15.9532	-28.0556
Dyes and pigments	743.6333	-18.4929	-2.7408	-40.1208
Natural gas and coal	524.3959	-7.6570	-20.4309	-65.6165
Special chemicals	604.1678	-21.7507	-9.5324	-41.6271
Other basic organic chemistry	329.6178	-15.2445	-21.1126	-42.1806
Primary macro nutrient natural fertilizer	357.2402	-9.7582	-14.4489	-18.4411
Single primary macro nutrient artificial fertilizer	609.2729	-20.8295	-16.2962	-47.0632
Primary macronutrient compound fertilizer	157.9955	-23.1459	-12.9636	-47.5109
Other fertilizers	-876.8723	-20.7618	-44.5588	-28.7506
Artificial resin ad plastic raw materials	665.4420	-13.4129	-21.4646	-39.3686
Artificial rubber	-655.8341	-7.3833	-22.9956	-16.6711
Pest control raw materials	767.4735	-3.5885	-42.6568	-42.4437
Pest control	246.0979	-17.2838	-8.1014	-45.08026
Paint and printing ink	333.9186	-18.5203	-14.8875	-30.4992
Varnish	116.5939	-2.6125	-28.3489	-34.8682
Machines and equipment	787.8246	-9.6498	-6.5601	-17.4632
Lacquer	313.7626	-16.8062	-17.3712	-32.6324
Cosmetics for humans	-287.6394	-9.6564	-8.4037	-11.1517
Adhesive/glue	573.9262	-5.4671	-18.6727	-10.4482
Explosives	-289.4963	-3.7343	5.2289	14.5704
Ink	573.8520	5.0460	-0.2247	16.4892
Essential oil	187.7824	-4.9996	-18.3203	-24.2070
Match	-49.8414	-4.8663	-18.9384	-19.8625
Other chemical goods	501.3493	-4.1387	-22.9747	-38.2313
Artificial filament fiber/yarn/strip	1680.4603	1.0617	-31.1862	-60.6869
Artificial staple fiber	-561.7511	0.1687	-19.8189	-46.7456

chemical industry was still low. These results are in accordance with research by Wafi & Sari (2021) which proves that TFP growth in the textile industry in Indonesia is negative, namely -19.163%. Therefore. to maximize productivity. It is necessary to update technology. improve the quality of labor. and improve production processes to overcome existing obstacles. in order to compete in the global market.

This low productivity and efficiency indicate the need for improvement strategies so that the national chemical industry can compete in the global market. Some steps that can be taken to overcome this problem include updating technology to increase production efficiency, improving the quality of the workforce through training and education, and improving the production process to be more effective. With continuous improvement efforts, the chemical industry is expected to reduce dependence on imported raw materials, increase competitiveness, and contribute more to the national economy.

CONCLUSIONS

Referring to the results of data analysis and data discussion. The conclusion that can be drawn is that TEC has experienced negative changes. The cause of the decline in changes in technical efficiency is due to a lack of optimization during the production process and fluctuations in the price of the raw materials used. There was a negative change in SEC. The reason for the negative value in the change in efficiency in the scale in the chemical industry was due to a decrease in productivity in that industry. There was a negative change in TC. The reason for the negative value in technological changes in the chemical industry was due to the use of old machines. TFP experienced negative changes. the cause of the decline in changes in existing productivity factors.

Referring to the research results. discussion and conclusions above. Companies must provide incentives in the form of subsidies or financial assistance to replace old machines with more efficient technology and maintain the stability of raw material prices. Because machine updates can increase efficiency in the use of inputs and reduce waste and maintain the stability of raw material prices. Companies can focus more on increasing efficiency and innovation. So, firms need to build adequate infrastructure. such as technology laboratories and machines. For further researchers, they can conduct a more in-depth analysis of each TFP component (TEC, SEC, TC) by focusing on the sector to specifically understand the decline in productivity.

The limitations of this study focus on the topic of the Chemical Industry and Chemical Products in Indonesia in 2010-2014. 2. The author presents data from the Central Statistics Agency.

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