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ENERGY INTENSITY ANALYSIS OF COAL AND ELECTRICITY IN THE MANUFACTURING INDUSTRY SECTOR IN INDONESIA 2007–2015

Olive Alexander Ambardhy
Program Studi Ekonomi Pembangunan Departemen Ilmu Ekonomi
Fakultas Ekonomi dan Bisnis
Universitas Airlangga
Jalan Airlangga 4-6 Surabaya
Email: olive.alexander.ambardhy-2017@feb.unair.ac.id

ABSTRACT

This study has two objectives, first to decompose and compare the energy intensity of coal and electricity in the manufacturing sector in Indonesia. The second is to analyze what factors influence the energy intensity of the manufacturing industry sectors. The methods used in achieving these objectives are decomposition analysis and panel data regression analysis. The results of the decomposition analysis show that the efficiency effect dominates changes in energy intensity than the activity effect. Furthermore, the results of panel data analysis show that the variables of energy prices, intensity of machine maintenance and repair, intensity of raw materials, and intensity of machines have a significant effect on changes in energy intensity in the manufacturing sector in Indonesia in the time span from 2007 to 2015.

Keywords: Energy Intensity, Coal, Electricity, Manufacturing Industry.

INTRODUCTION

Energy is a strategic item that has an essential role in the economy and acts as an indicator of development and welfare. The higher the income of a country, the higher the energy consumed. The higher the development of a country, the higher the energy used to carry out the development. Energy plays a role as a driver of economic activity, a source of state income, fuel, production inputs, and various other vital roles. The economy cannot run without energy. Increased economic growth and development of a country will lead to an increase in production output which will cause per capita income to increase and people's welfare to increase. Increasing people's welfare will increase energy consumption. The energy supply in Indonesia is currently still dominated by non-renewable fossil energy (37% oil, 32% coal, 18% natural gas) (Ministry of Energy and Mineral Resources, 2019). Based on the Indonesia Energy Outlook (2020), in 2018, the primary energy mix was still dominated by coal (32.00%), followed by petroleum (38.00%), natural gas (19,00%), and NRE (11.00%).

One of the energy problems in Indonesia mentioned in the Indonesian General Energy Plan – RUEN (2017) is the increase in energy consumption due to high population growth. However, its use is wasteful and less efficient. In addition, Indonesia's energy consumption in 2018 was still dominated by fossil energy consumption (BBM 39%, coal 11%, gas 11%) (Ministry of Energy and Mineral Resources, 2019). Increased energy consumption means increased extraction of fossil energy, reducing fossil energy reserves. To overcome the problem of limited energy supply, actions can take are switching to renewable energy sources or increasing efficiency in energy use.

The inefficiency of energy use reflects the level of energy intensity in Indonesia. Energy intensity is the total energy consumption per economic output. Energy intensity is a macroeconomic indicator to see energy efficiency (Bhattacharyya, 2011). The low energy intensity reflects the more efficient use of energy. Based on data from the Worldbank (2020), in 2015, the energy intensity in Indonesia was 3.53 MJ/ Dollar GDP. This condition means that to increase GDP by 1 USD, 3.53 Mega Joules of energy are needed. For comparison, Thailand's energy intensity is 5.41 MJ/USD GDP; Malaysia at 4.68 MJ/ Dollar GDP; Brunei Darussalam at 3.65 MJ/ Dollar GDP; and Singapore at 2.39 MJ/ Dollar GDP (Worldbank, 2020).

The manufacturing industry is the sector that has the most considerable contribution to GDP from year to year. In 2019, the contribution of the manufacturing industry sector to GDP was 19.70%. From 2011 to 2019, the average GDP growth of the manufacturing industry sector was 4.65% per year. Based on the contribution to GDP, the Ministry of Industry (2015) in the 2015-2035 National Industrial Development Master Plan (RIPIN) has set the manufacturing industry as a priority in developing a strong and highly competitive national industry. The government's step in accelerating industrialization is by intensifying import substitution policies.

Industrialization based on import substitution is a strategy for developing countries to reduce dependence on developed countries by protecting domestic industries so that domestically produced goods become more competitive than imported goods (Segal, 2021). The government has intensified the import substitution policy so that the industrialization process in Indonesia can take place more quickly. Due to the progress in industrialization, the Indonesian manufacturing industry will tend to be more capital intensive (high machine use intensity) than labor-intensive. However, on the one hand, the ample supply of labor can also make Indonesia's manufacturing industry more labor-intensive (high labor intensity). This condition will affect the efficiency of energy use in Indonesia.

The manufacturing industry is the most significant final energy user sector. Viewed from the level of energy consumption, the manufacturing industry has a share of final energy needs of 98% of the total final energy demand in the industrial sector as a whole (National Energy Council, 2016). Furthermore, when viewed from the type of energy, coal (29%), natural gas (27%), and electricity (19%) are still the primary energy sources for the manufacturing industry. However, based on the projections of the National Energy Council, in 2050, electrical energy consumption will be more dominant because it influences the

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substitution of the use of generators in the industrial sector that uses oil fuel to use on-grid electricity (National Energy Council, 2019).

Energy has a strategic nature, but on the other hand, energy prices are considered unaffordable for the lower middle class. Therefore, the Indonesian government has established a policy of energy subsidies for fuel, LPG, and electricity. Based on the 2019 APBN realization, the budget for energy subsidies is IDR 160.0 trillion (71.3% of the total subsidy budget) (Directorate General of Budget, 2019). The number of subsidies for fuel and LPG is Rp. 100.7 trillion, and for electricity is Rp. 59.3 trillion. Energy subsidies in 2017 amounted to Rp163.5 trillion, and in 2018 decreased to Rp160.0 trillion until, in 2019, the amount remained at Rp160.0 trillion.

In addition, according to the International Institute for Sustainable Development (IISD), Indonesia provides more than IDR 9.70 trillion (USD 0.70 million) of fiscal support per year for coal-fired power plant production (2016–2017 average). From March 2018 until now, the Indonesian government has regulated the maximum price of coal sold to power plants and requires coal producers to allocate 20–25% of their production for domestic needs. This policy acts as a subsidy for the State Electricity Company (PLN) to control market prices (Suharsono & Gençsü, 2019). Subsidies are felt like a burden when world energy prices increase. On the other hand, energy consumption in Indonesia is increasing due to economic growth, population growth, and lower energy prices due to subsidies. Subsidies on fossil energy cause the price of fossil energy to feel cheaper for the community so that it is more desirable. These subsidies tend to spoil consumers so that there is no incentive for consumers to save energy. As a result, subsidized energy tends to be inefficient (Pindyck & Daniel, 2013).

The use of coal and electricity energy, predominantly subsidized energy in the industrial sector, raises the question of which is more efficient in utilizing the two energy sources. Therefore, in addition to identifying the factors that influence the energy intensity of the two energy sources, this study also aims to compare the energy intensity of coal and electricity in the manufacturing industry.

The aims of this study are (1) to decompose and compare the energy intensity of coal and electricity in the manufacturing industry sector in Indonesia and (2) to analyze what factors influence the energy intensity of the manufacturing industry sector. This research is divided into five chapters that are related to one another. The five chapters are (1) introduction, (2) literature review, (3) research methods, (4) results and discussion, and (5) conclusion.

LITERATURE REVIEW

Economic Value-Added

GDP is the amount of remuneration for production factors used in the production process in a country within a certain period. The remuneration includes wages and salaries for workers; rent, interest, and depreciation on capital; and the return on risk, which can refer to as net value-added. Furthermore, the net value-added, which adds to indirect taxes, can be referred to as gross value added (BPS, 2021). This added value can use as an

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approach to measuring income. The value-added variable is used as a proxy to explain the effect of income on energy intensity.

Theory of Supply and Demand

In a market economy, the quantity of demanded goods is a function of the price of that good. Price is inversely proportional to the quantity demanded and directly proportional to the quantity supplied. In the context of energy, when energy prices increase, the amount of energy demand will decrease. On the other hand, when energy prices increase, the quantity supplied of energy will also increase. The energy balance price is pE*, and the amount of energy traded is Q*. Consumers willing to pay a minimum of pE* can buy the energy, and producers who set a maximum price at pE* can sell the energy. The balance between supply and demand is at point A0.

An increase in consumer income can increase consumers' WTP so that consumers are willing to pay a higher price for a certain amount of energy, or it can say that energy demand increases (vertical shift of the demand curve in Figure 1). The demand curve shifts towards a new equilibrium point at A1 with a higher price equilibrium, pE**>pE*, and a higher amount of energy traded, namely Q**>Q*. However, the energy supply is not very flexible in the short run, so the supply curve shifts vertically to point A0 causing the price to be equal to max. An increase in prices encourages producers to increase production, which causes prices to fall from Pmax to pE**, but the quantity supplied of energy increases to as much as Q**.

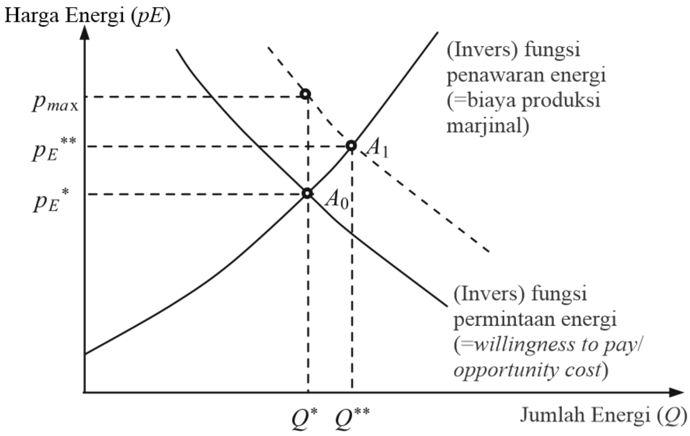

Figure 1. Energy Supply and Demand Curve
Source: Zweifel et al., 2017

Production Theory

Energy has received wide attention because it is an essential input in the production and consumption processes. Therefore, the role of energy can see from the supply side and the demand side. Viewed from the supply side, energy is one of the essential production factors required for the production process to run. On the other hand, from the demand side, energy is good that consumers can consume to maximize satisfaction.

Production activities can be interpreted as transforming matter from one form to another by involving the transformation of energy. Energy is one of the production inputs other than labor and capital (machinery and production equipment). The production process includes transforming raw materials from one form to another by workers who use equipment and machines and require energy so that the process of converting these goods can carry out. Therefore, the fewer workers who operate equipment and machines, the more it shows, and the higher intensity of mastery of technology in the industry. Production equipment and machines require a large amount of energy to operate. On the other hand, labor does not require a large amount of energy to carry out production activities. Therefore, energy intensity has a negative relationship with labor intensity and a positive relationship with machine intensity (Soni et al., 2017).

Energy is a strategic and vital item and is the center of economic activity that can control various economic activities. Neo-Classical economists excluded the production function to exclude the economic component with natural resources and energy components. The Neo-Classical view only includes factors of production in the form of capital (K) and labor (L) influenced by technological factors. The importance of the role of energy in the Neo-Classical view is considered not to affect production output, thus causing distortions in the framework of economic growth and sources of growth. Output and energy have a relationship that can write in the function Y = f (K, L, E, M), where Y is GDP or GRDP, K is capital, L is labor, E is energy, and M is non-material raw materials energy. The energy component (E) can act as complementary or complementary goods to other production factors; for example, labor in production requires energy and capital in the form of machines can only run if it has energy (Zweifel et al. 2017). Soni et al. (2017) used labor intensity variables, raw material intensity, labor intensity, machine maintenance, and machine intensity as a variable in the form of intensity representing labor, raw materials, and capital in the Cobb Douglas production function.

Energy Intensity Decomposition

Energy is the ability to do a job or as an embodiment of motion. Energy is one of the factors of production that has a vital role in running the production process. The higher the economic activity, the higher the energy required. High energy consumption must balance with efficient use. Energy efficiency can be measured using energy intensity. Energy intensity measures the amount of energy consumption required to produce each unit of economic output. That way, energy intensity can be referred to as the ratio of the amount of energy to production output. Changes in energy intensity can occur due to factors other than changes in energy efficiency.

Energy intensity depends not only on energy efficiency at the enterprise level but also at the industry level. The shift in economic structure that tends to be dominant in the manufacturing sector to the service sector can also cause a decrease in energy intensity. In addition, another factor that affects energy intensity is energy prices. When energy prices rise, energy intensity will decrease for a temporary period. However, if energy prices tend to be high in the long term, this will spur technological changes, which will result in a decrease in energy intensity which will last in the long term (Schwarz, 2018).

In research with this decomposition method, Metcalf (2008) divided the energy intensity into two. Efficiency refers to reducing energy use per unit of economic activity in a sector. In contrast, activity refers to changes in the mix of economic activity (shift from energy-intensive economic activities to less energy-intensive economic activities) assuming constant efficiency.

Boyd et al. (1987) were the first researchers to use index numbers to decompose energy. The methodology used is the Divisia Index Number based on the Laspeyres Index. Decomposition based on the Laspeyres Index (weighing factor in the base year) has a residue that can lead to a high level of variability in the index underlying changes in energy intensity or bias which refer to a downward bias (Fisher, 1921). Fisher's Ideal Index is the geometric mean of the Laspeyres and Paasche indices that have ideal properties or can decompose precisely without any upward or downward bias.

Table 1. Energy Intensity Literature Review

Authors	Research Period	Object of research	Research methods	Research result
Metcalf, G. E. (2008)	1970-2001	Energy intensity at the state and national level in the United States.	Fisher's Ideal Index decomposition method and panel data regression analysis.	An increase in energy prices and an increase in per capita income significantly decrease energy intensity in states in the United States.
Hasanbeigi dkk., (2012)	1997-2008	Fifteen manufacturing and two energy sector industries in California.	Logarithmic Average Division Decomposition (LMDI).	a) Changes in sectoral structure affect decreasing energy demand; b) Energy intensity played an essential role from 2000 due to an increase in energy prices; c) Energy-intensive sectors require more energy for each added value.
Kartiasiha, F. dkk., (2012)	1977-2010	The energy intensity of the Indonesian region in aggregate.	Fisher's Ideal Index Decomposition, Vector Autoregressive (VAR) or Vector Error Correction Model (VECM).	Energy intensity in Indonesia increased from 1977 to 2010. Factors that affect energy intensity at the national level are changes in economic activity, while at the sectoral level are the effects of efficiency.
Irawan, T. dkk., (2014)	2002-2006	The energy intensity of industry is large-medium throughout Indonesia.	Fisher index energy intensity decomposition analysis and econometric regression of panel data.	Although the energy intensity at the industrial level is higher than at the national level, the energy intensity in the industrial sub-sector varies. For example, wages, company age, capital intensity, and the percentage of capital owned by the private sector positively correlate with energy intensity. On the other hand, firm size, labor productivity, and technology intensity negatively correlate with energy intensity.
Soni dkk., (2017)	2005-2014	Five sub-sectors of the manufacturing industry in India.	Compound Panel Regression.	Variables of labor intensity, the intensity of machine maintenance and repair, the intensity of technology development, the intensity of raw materials, the intensity of professional labor, the intensity of software, the intensity of machine use, and profit after tax have a significant effect.

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Guo dkk., (2019)	2005-2016	Energy intensity in 289 cities in China.	Panel data regression and Granger Causality Test.	Investments in technology can reduce energy intensity and energy prices but do not affect energy consumption. In addition, the policy of changing the economic structure does not affect reducing energy intensity in China.

Metcalf (2008) identified the determinants that affect energy intensity using the Fisher Ideal Index decomposition method and panel data analysis. The variables used include energy prices, changes in economic activity (for example, a shift in the structure of the agrarian economy to an industrial economy), social variables (population growth and capital-labor ratio), and also weather variables (use of heating and air conditioning). The analysis results show that increasing energy prices and income per capita play a significant role in decreasing energy intensity in states in the United States.

According to Hasanbeigi et al. (2012), decomposition analysis aims to divide the sources that affect changes in energy intensity. These sources are 1) aggregate activity, which is a change in production output in industrial activity; 2) sectoral structure namely changes in the contribution of each sub-sector of industry; and 3) energy efficiency namely changes in energy intensity caused by technological developments.

A study conducted (Lam, Kenway, Lane, Islam, and de Berc, 2019) to investigate energy intensity in the industrial sector and energy flows from primary to final energy found that population growth and import demand played a dominant role in increasing energy intensity in Australia.

Kartiasiha et al. (2012) analyzed energy intensity and consumption, as well as the variables that affect energy intensity in Indonesia both in aggregate (national) and sectorally, by using the Fisher's Ideal Index to decompose changes in energy intensity (changes in economic activity and efficiency). In addition, Vector Autoregressive Analysis (VAR) or Vector Error Correction Model (VECM) is used to analyze the effect of economic variables on energy intensity. The results of this study indicate that the energy intensity in Indonesia increased the period 1977 to 2010. The main factor influencing energy intensity at the national level is changes in economic activity, while at the sectoral level, it influences by changes in inefficiency.

Irawan et al. (2014) analyzed the decomposition to estimate what factors influenced changes in energy intensity. In addition, this study also used panel data regression analysis to estimate the variables that influence changes in energy intensity. This study indicates that wages, company age, capital intensity, and the percentage of capital owned by the private sector have a positive relationship with energy intensity. On the other hand, firm size, labor productivity, and technology intensity negatively correlate with energy intensity.

Soni et al. (2017) conducted a study to identify the factors that influence energy intensity in the manufacturing industry in India. The results show that the energy intensity in the five sub-sectors of the manufacturing industry in India influences by the variables of machine repair intensity, capital intensity, and labor intensity. Improving the condition of the machines used in production will increase the efficiency of energy use and can reduce the level of energy intensity.

The study conducted by Guo et al. (2019) analyzes the factors that influence energy intensity. The findings in the study are that investment in technology can reduce energy intensity and energy prices but does not affect energy consumption. Furthermore, the policy of changing the economic structure has proven to reduce energy intensity in China. Energy price regulation can only reduce energy intensity in the long term but not in the short term. This condition is because consumers need time to respond to price changes. The availability of energy-producing natural resources also influences the energy intensity in China; namely, when the endowment factor of natural resources is increasingly abundant, it will lead to higher energy consumption. In summary, the previous studies can see in Table 1.

METHOD

This study aims to analyze and compare the energy intensity of coal and electricity in the manufacturing industry sector in Indonesia and to analyze the determinants that affect energy intensity in the manufacturing industry sector. To answer the first objective, the researchers use the Fisher's Ideal Index to estimate the factors that affect energy intensity (efficiency component or economic activity component). Then, the researcher used the panel data regression analysis to fulfill the second objective.

Empirical Model: Fisher's Ideal Index Decomposition Analysis

$$\frac{e_t}{e_0} = I_t = F_t^{act} F_t^{eff} \qquad (1)$$

e_{i0} is an energy efficiency index in sector i in the base year, e_{it} is an energy efficiency index in sector i in the most recent year F_t^{eff} is an energy efficiency index, and F_t^{act} is an index of economic activity. Fisher's Ideal Index in this study serves to decompose energy intensity because it does not contain residues; as with other decomposition methods, residues can cause difficulties in interpreting the effects of energy efficiency and economic activity.

Panel Data Regression

Model Coal Energy Intensity:

$$IEB_{it} = \alpha+\beta\ HEB_{it}+\beta 2ITK_{it}+\beta 3IPP_{it}+\beta 4IBB_{it}+\beta 5lnVA_{it}+\beta 6IM_{it}+\varepsilon_{it} \qquad (2)$$

Model Electricity Energy Intensity**:**

$$IEL_{it} = \alpha+\beta 1HEL_{it}+\beta 2ITK_{it}+\beta 3IPP_{it}+\beta 4IBB_{it}+\beta 5lnVA_{it}+\beta 6IM_{it}+\varepsilon_{it} \qquad (3)$$

Note:

IEB_{it}:	coal energy intensity	IBB_{it}:	raw material intensity
IEL_{it}:	electrical energy intensity	$lnVA_{it}$:	natural logarithm of value-added
HEB_{it}:	coal energy prices	IM_{it}:	machine intensity
HEL_{it}:	price of electric energy	ε_{it}:	error term
ITK_{it}:	labor intensity	i:	manufacturing industry sub-sector
IPP_{it}:	maintenance and repair intensity	t:	time period

The dependent variable of this research is energy intensity, which is the ratio between energy consumption and the amount of actual output. Therefore, several independent variables selected in this study (labor intensity, machine maintenance, repair intensity, raw materials, and labor productivity) were arranged into intensity units (divided by actual output) equivalent to the dependent variable. In addition, the value-added variable is changed to the natural logarithm so that it is equivalent to the dependent variable. The base year used in this research is 2007.

Energy Intensity

Energy intensity is the ratio between energy consumption in units of barrels of oil equivalent (SBM) and the production output of each sector of the manufacturing industry. The following formula can calculate the energy intensity:

$$\text{energy intensity}_{it} = \frac{energy\ consumption\ it}{output\ it} \quad (4).$$

Energy consumption is calculated based on the total amount of energy used. The types of energy used in this research are coal and electricity. Both types of energy convert into barrels of oil equivalent (SBM). On the other hand, the output used is the actual output of the manufacturing industry sector which adjust to the Wholesale Price Index (IHPB) of the industrial sector. The industrial sector IHPB was used as the base year of 2007. This situation is because the initial period of this research was in 2007. The following is the formula used to calculate the real value-added:

$$\text{real output}_{it} = \frac{output\ it}{IHPB\ industry\ t} \quad (5).$$

Energy Price (HE)

Energy prices calculate by dividing the total energy value in Rupiah by the total quantity of energy in BOE units. The energy price used is the actual price obtained by adjusting the IHPB for the industrial sector. The following is the formula for calculating energy prices:

$$\text{energy prices}_{it} = \frac{sum\ of\ the\ total\ value\ of\ energy\ it}{sum\ of\ the\ total\ quantity\ of\ energy\ it} \quad (6).$$

In addition, to calculate the actual price of energy, can use the following formula:

$$\text{actual price of energy}_{it} = \frac{\text{energy prices } it}{IHPB\ industry\ it} \quad (7).$$

Labor Intensity (ITK)

Labor intensity can calculate using the total expenditure on labor to actual output. Expenditure for actual labor kept constant using the industrial sector IHPB. The following is the formula for calculating labor intensity:

$$\text{labor intensity}_{it} = \frac{the\ amount\ of\ actual\ labor\ expenditure\ it}{actual\ output\ it} \quad (8)$$

the following is the formula for calculating actual labor expenditure:

$$actual\ labor\ expenditure_{it} = \frac{amount\ of\ labor\ expenditure\ it}{IHPB\ industry\ t} \quad (9).$$

Machine Maintenance and Repair Intensity (IPP)

The intensity of machine maintenance and repair can calculate using the ratio of expenses for maintenance and repair of real machines to the actual output value. The intensity of machine maintenance and repair is used to calculate model variables. This is because the capital variable in the IBS data is not completely available, so the variable intensity of maintenance and repair of the machine is used. Machine maintenance and repair costs are constantly using the industrial sector IHPB. Here is the formula for calculating the intensity of machine maintenance and repair:

$$\textit{intensity of machine maintenance and repair}_{it} = \frac{\textit{actual machine maintenance and repair costs it}}{\textit{actual output it}} \ldots\ldots (10)$$

Moreover, here is the formula for calculating actual machine maintenance and repair costs:

$$\textit{actual machine maintenance and repair costs}_{it} = \frac{\textit{machine maintenance and repair costs it}}{\textit{IHPB industry t}} (11).$$

Raw Material Intensity (IBB)

The intensity of raw materials can calculate by using the ratio of expenditures for all actual raw materials to actual output. Expenditure costs for raw materials are constantly using the IHPB for the industrial sector. The following is the formula for calculating the intensity of raw materials:

$$\text{raw material intensity} = \frac{\textit{actual raw material cost it}}{\textit{actual output it}} \ldots\ldots (12)$$

Moreover, here is the formula for calculating actual raw material costs:

$$\textit{actual raw material costs}_{it} = \frac{\textit{cost of raw material expenditure it}}{\textit{IHPB industry t}} \ldots\ldots (13).$$

Value-added (VA)

The value-added is the difference between the output and input values. The value-added used is constant using the IHPB for the industrial sector. The added value includes salary wages, interest rent, depreciation, and profit. Here is the formula for calculating actual value-added:

$$\textit{actual value-added}_{it} = \frac{\textit{value-added it}}{\textit{IHPB industry t}} \ldots\ldots (14).$$

Engine Intensity (IM)

Machine intensity is the ratio between spending on rent, machinery, and equipment (Rupiah) and the related industry's output. Here is the formula for calculating labor productivity:

$$\text{machine intensity it} = \frac{\text{machinery and equipment rental expenses}}{\text{actual output it}} \ldots\ldots (15),$$

where i is the sub-sector of the manufacturing industry and t is the observation period.

The data used in this study is a balanced panel of large-medium industry statistical data from 2007 to 2015. Indonesia's manufacturing industry data for 2007 to 2015 consists of the total consumption of coal and electricity energy, the value of coal and electricity consumption, the value of production output, the value added to production, the value of production raw materials, the value of expenses for maintenance and repair of production machinery and equipment, and rental expenses, machinery and equipment obtained from large-medium industry statistics (IBS) issued by BPS. In addition, GDP and IHPB data obtain from BPS macroeconomic indicators. Industrial companies in this study are classified as large and medium industries, which have a workforce of 20 people or more. The industrial classification used in this study is a classification based on the International Standard Industrial Classification of All Economic Activities (ISIC) revision 4, adapted to conditions in Indonesia under the name Indonesian Standard Classification of Business Fields 2015.

Analysis Techniques: Fisher's Ideal Index Decomposition

The first analytical technique used in this research is decomposing energy intensity into components of increasing energy efficiency and economic activity using the Fisher's Ideal Index such as research (Metcalf, 2008).

$$e_t \equiv \frac{E_t}{Y_t} = \sum_{i=1}^{n} \left(\frac{E_{it}}{Y_{it}}\right)\left(\frac{Y_{it}}{Y_t}\right) = \sum_{i=1}^{n} e_{it} s_{it} \quad \text{.......(16)}$$

e_t is energy intensity, E_t is total energy consumption, E_{it} is energy consumption in sector i in year t, Y_t is production output in year t, Y_{it} is production output in sector i in year t, e_{it} s efficiency component, s_{it} is component of economic activity, i is the sector, and t is the year.

$$\frac{et}{e0} = \sum_{i=1}^{n} \frac{e_{it} s_{it}}{e_{i0} s_{i0}} = Eff\,(e_{i0}, e_{it}, s_{i0}, s_{it})\,Act\,(e_{i0}, e_{it}, s_{i0}, s_{it}) \quad \text{.......(17)}$$

e_{it} is energy efficiency in sector i at time t, s_{it} is economic activity in sector i at time t, *Eff* is an index function that represents efficiency, and Act is an index function that represents economic activity.

The energy intensity index can decompose into the efficiency and economic activity index. For this reason, it is necessary to build an efficiency index consisting of the Laspeyres Index and the Paasche Index. The Laspeyres Index uses a weighted base period, while the Paasche Index uses the current period weighted.

$$L_t^{act} = \frac{\sum_{i=1}^{n} e_{i0} s_{it}}{\sum_{i=1}^{n} e_{i0} s_{i0}} \quad \text{.......(18)}$$

$$L_t^{eff} = \frac{\sum_{i=1}^{n} e_{it} s_{i0}}{\sum_{i=1}^{n} e_{i0} s_{i0}} \quad \text{.......(19)}$$

$$P_t^{act} = \frac{\sum_{i=1}^{n} e_{it} s_{it}}{\sum_{i=1}^{n} e_{it} s_{i0}} \quad \text{.......(20)}$$

$$P_t^{eff} = \frac{\sum_{i=1}^{n} e_{it} s_{it}}{\sum_{i=1}^{n} e_{i0} s_{it}} \quad \text{.......(21)}$$

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e_{i0} is an energy efficiency index in sector i in the base year, s_{i0} is an index of economic activity in sector i in the base year, e_{it} is an energy efficiency index in sector i in the most recent year, and s_{it} is an index of economic activity in sector i in the most recent year.

$$F_t^{act} = (L_t^{act} P_t^{act})^{1/2} \quad (22)$$

$$F_t^{eff} = (L_t^{eff} P_t^{eff})^{1/2} \quad (23)$$

$$\frac{e_t}{e_0} = I_t = F_t^{act} F_t^{eff} \quad (24)$$

F_t^{eff} is an index of energy efficiency, and F_t^{act} is an index of economic activity. After finding the effects that affect energy intensity, namely, increasing efficiency and economic activity changes as described in the Decomposition of Fisher's Ideal Index, panel data analysis is carried out to determine the determinants that affect energy intensity.

FEM Regression

FEM regression is not like usual regression, and panel data regression must go through the stages of determining the suitable estimation model. From determining the estimation model, testing assumptions, and model suitability to interpretation (Gujarati & Porter, 2009). The estimation method to determine the regression model using panel data can be done through three approaches, including:

1. The fixed Effect Model (FEM) assumes that differences in their intercepts can overcome differences between individuals. The existence of heteroscedasticity and autocorrelation problems in FEM can be overcome using the Robust Standard Error (Bertrand et al. 2004). FEM regression can be estimated using the following equation:
   $$Y_{it} = \alpha_1 + \beta_1 X_{1it} + \beta_2 X_{2it} + u_{it} \quad 25.$$
2. The Chow test is a test to determine what model is the most appropriate between the Common Effect (PLS) and the Fixed Effect Model (FEM). The hypothesis in the Chow test is H0 = Pooled Least Square Model (PLS) and H1 = Fixed Effect Model (FEM). Based on the Chow test, H0 is rejected because of the probability F<alpha, so the model chosen is the Fixed Effect Model (FEM).
3. Hausman test is a statistical test that determines the suitable model between Fixed Effect and Random Effect. The hypothesis in the Hausman test is H0 = Random Effect Model (REM) and H1 = Fixed Effect Model (FEM). Based on the Hausman Test, H0 was rejected because the probability value was F < alpha, so selecting the suitable model used the Fixed Effect Model (FEM).

RESULTS AND DISCUSSION

Description of Variable Statistics

Based on several previous studies, it can seem that several factors can influence the energy intensity of the manufacturing industry sector. In this study, the variables estimated to affect energy intensity are energy prices, labor intensity, maintenance and repair intensity of machines and equipment, raw material intensity, added value, and machine intensity. The data used is sourced from the survey of large and medium industries (IBS) by BPS. The data covers 20 sub-sectors of the manufacturing industry in Indonesia from 2007 to 2015, with 180 observations. The complete descriptive statistics on this study's variables can see in Table 2.

Table 2. Description of Energy Intensity Determinant Variables

Variable	Mean	Std. Dev.	Min	Max
Coal Energy Intensity	13,9600	12,0365	0,0004	277,1290
Electrical Energy Intensity	10,5947	7,9475	0,8820	40,6532
Coal Energy Price	2.430,1600	2.154,1040	5,8767	83.858,8800
Electric Energy Price	2.524,2410	1.370,1950	506,2971	7.912,1740
Labor Intensity	0,0411	0,0288	0,0043	0,1383
The intensity of Machine and Equipment Maintenance and Repair	0,2416	0,2268	0,0003	5,1708
Raw Material Intensity	0,2894	0,1295	0,0381	0,7513
Value-added (Ln)	10,1614	1,1403	7,1369	12,8263
Machine Intensity	0,0123	0,0104	0,0013	0,0611

Source: IBS Statistical Data, 2007-2015 (reprocessed)

Estimation Results and Hypotheses

Estimated Results

Energy intensity decomposition uses to identify the causes of changes in energy intensity from the base year to the current year. The decomposition was carried out using Fisher's Ideal Index. The decomposition in this study is divided into two components, namely, the effect of efficiency and the effect of economic activity. Efficiency refers to reducing energy use per unit of economic activity in a sector. In contrast, activity refers to changes in the mix of economic activity (shift from energy-intensive economic activities to less energy-intensive economic activities) assuming constant efficiency. The efficiency effect measures the increase in the efficiency of energy use that comes from technological developments and the combination of fuels in the production process. The effects of economic activity are related to changes in economic activity, such as changes from a labor-intensive production process to a capital-intensive one and vice versa.

Table 3. Coal Energy Intensity Decomposition

Sector	Code	Efficiency Effect	Activity Effect	Overall Effect	Energy Intensity
Food industry	10	1,45%	0,09%	1,54%	1,66%
Beverage Industry	11	9,91%	0,18%	10,09%	11,83%

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Tobacco Processing Industry	12	-0,74%	-0,14%	-0,88%	-0,77%
Textile industry	13	-0,41%	-0,11%	-0,52%	-0,48%
Apparel Industry	14	-0,42%	-0,04%	-0,46%	-0,44%
Leather and Footwear Industry	15	2,80%	0,22%	3,03%	3,65%
Wood, Bamboo, Rattan, and Similar Industries	16	5,89%	-0,30%	5,59%	3,81%
Paper Industry	17	-0,32%	-0,36%	-0,68%	-0,56%
Recording Media Printing and Reproduction Industri	18	-0,92%	-0,28%	-1,20%	-0,94%
Coal Products and Petroleum Refining Industry	19	-0,55%	-0,67%	-1,22%	-0,85%
Chemical Industry	20	-0,23%	0,34%	0,12%	0,04%
Pharmaceutical and Medicinal Products Industry	21	-0,74%	-0,47%	-1,21%	-0,86%
Rubber and Plastic Industry	22	-0,85%	-0,04%	-0,88%	-0,85%
Non-Metal Mineral Industry	23	2,36%	0,31%	2,67%	3,40%
Base Metal Industry	24	-0,93%	-0,50%	-1,43%	-0,97%
Non-Metal Machinery and Equipment Industry	25	-0,48%	-0,37%	-0,85%	-0,67%
Computer, Electronics, and Optical Industry	26	-1,00%	0,45%	-0,55%	-1,00%
Machinery and Equipment Industry	28	-0,76%	1,49%	0,73%	-0,40%
Furniture Industry	31	-0,88%	-0,31%	-1,19%	-0,92%
Other Processing Industry	32	-0,95%	-0,45%	-1,40%	-0,97%
Manufacturing Industry Sector		**12,25%**	**-0,97%**	**11,28%**	**13,69%**

The estimated decomposition of energy intensity from 2007 to 2015 can see in Table 3 for coal energy and Table 4 for electrical energy. The panel data regression estimation results can see in Table 5 for coal energy intensity and Table 6 for electrical energy intensity. The method used is the Fixed Effect Model (FEM) because the Chow test and Haussman test show that the correct model is FEM for both coal and electricity energy intensity. Based on the estimation results, the intensity of raw materials and the intensity of machinery significantly affect the intensity of coal energy. In contrast, the independent variables of coal energy prices, labor intensity, labor intensity, machine maintenance and repair intensity, and added value have no significant effect on the intensity of coal energy. On the other hand, the independent variables of electricity prices, the intensity of machine maintenance and repair, and the intensity of machines significantly affect the intensity of electrical energy. In contrast, the intensity of labor, the intensity of raw materials, and added value have no significant effect on the intensity of electrical energy.

Table 4. Electrical Energy Intensity Decomposition

Sector	Code	Efficiency Effect	Activity Effect	Overall Effect	Energy Intensity
Food industry	10	-0,55%	0,09%	-0,46%	-0,51%
Beverage Industry	11	-0,48%	0,18%	-0,30%	-0,39%

Tobacco Processing Industry	12	-0,10%	-0,14%	-0,24%	-0,23%
Textile industry	13	-0,47%	-0,11%	-0,58%	-0,53%
Apparel Industry	14	-0,19%	-0,04%	-0,24%	-0,23%
Leather and Footwear Industry	15	-0,61%	0,22%	-0,39%	-0,52%
Wood, Bamboo, Rattan, and Similar Industries	16	-0,65%	-0,30%	-0,96%	-0,76%
Paper Industry	17	-0,18%	-0,36%	-0,54%	-0,48%
Recording Media Printing and Reproduction Industri	18	-0,34%	-0,28%	-0,62%	-0,53%
Coal Products and Petroleum Refining Industry	19	-0,79%	-0,67%	-1,46%	-0,93%
Chemical Industry	20	0,10%	0,34%	0,44%	0,47%
Pharmaceutical and Medicinal Products Industry	21	1,09%	-0,47%	0,62%	0,10%
Rubber and Plastic Industry	22	-0,56%	-0,04%	-0,60%	-0,58%
Non-Metal Mineral Industry	23	-0,44%	0,31%	-0,13%	-0,26%
Base Metal Industry	24	-0,80%	-0,50%	-1,30%	-0,90%
Non-Metal Machinery and Equipment Industry	25	-0,76%	-0,37%	-1,13%	-0,85%
Computer, Electronics, and Optical Industry	26	-0,02%	0,45%	0,43%	0,42%
Machinery and Equipment Industry	28	-0,51%	1,49%	0,98%	0,23%
Furniture Industry	31	-0,25%	-0,31%	-0,56%	-0,48%
Other Processing Industry	32	-0,85%	-0,45%	-1,30%	-0,92%
Manufacturing Industry Sector		**-7,37%**	**-0,97%**	**-8,34%**	**-7,87%**

The R-Square value in the model (coal energy intensity) is 0.2896 (28.96%), which shows the independent variables of coal energy price, labor intensity, machine maintenance, and repair intensity, raw material intensity, added value, and machine intensity able to explain the intensity of coal energy in 240 sub-sectors of the manufacturing industry in Indonesia in the period from 2007-2015.

These results indicate that the independent variable is quite good in explaining the intensity of coal energy in the sub-sector of the manufacturing industry in Indonesia from 2007 to 2015, while the remaining 71.04% of the intensity of coal energy explain by variables outside the model or error term. More complete can see in Table 5.

Table 5. Results of Coal Energy Intensity Panel Data Test Estimation

Variabel Dependen: IEB				
Variabel Independen	Koefisien	Standard Error	Statistik-t	Probabilitas
HEB	-0,00042	0,0001	-0,04	0,969
ITK	54,18042	55,9918	0,97	0,345
IPP	-0,06492	2,1238	-0,03	0,976
IBB	19,27903 *	10,6526	1,81	0,086
lnVA	0,59132	1,1138	-0,53	0,602
IM	-17,61745 *	9,9731	-1,77	0,093
R-squared	0,2896		F(6,19)	1,33
Observasi (n)	180		Prob>F	0,2911

Signifikansi: ***p<0,001, **p<0,05, *p<0,1

Table 6. Results of Electrical Energy Intensity Panel Data Test Estimation

Variabel Dependen: IEL					
Variabel Independen	Koefisien		Standard Error	Statistik-t	Probabilitas
HEL	-0,00209	***	0,00060	-3,46	0,003
ITK	-15,50702		20,11456	-0,77	0,450
IPP	0,67494	*	0,38024	1,78	0,092
IBB	7,58972		7,67481	0,99	0,335
lnVA	-0,21631		1,46911	-0,01	0,988
IM	259,49670	***	95,16889	2,73	0,013
R-squared	0,3252			F(6, 19)	6,44
Observasi (n)	180			Prob>F	0,0008

Signifikansi: ***p<0,001, **p<0,05, *p<0,1

The R-Square value in the model (electrical energy intensity) is 0.3252 (32.52%), which shows the independent variables of electric energy prices, labor intensity, machine maintenance and repair intensity, raw material intensity, added value, and machine intensity describes the intensity of electrical energy in 20 sub-sectors of the manufacturing industry in Indonesia in 2007-2015. These results indicate that the independent variable is quite good in explaining the intensity of electrical energy in the sub-sector of the manufacturing industry in Indonesia from 2007 to 2015, while the remaining 67.48% of the intensity of electrical energy explain by variables outside the model or error term. More complete can see in Table 6.

Hypothesis

Energy Price (HE)

The estimation results show that the price of coal energy and the price of electrical energy negatively correlate with the intensity of coal and electricity energy. This result follows the hypothesis that the higher the energy price, the higher the energy intensity.

Labor Intensity (ITK)

The estimation results show that labor intensity positively correlates with coal energy intensity and negatively with electrical energy intensity. This result follows the hypothesis that the higher the labor intensity, the lower the energy intensity.

Maintenance and Repair Intensity (IPP)

The estimation results show that the intensity of machine maintenance and repair has a negative relationship with the intensity of coal energy and a positive relationship with the intensity of electrical energy. This result is consistent with the hypothesis that the higher the intensity of maintenance and repair of machinery and equipment indicates that the company is increasingly intensive in maintaining machinery and equipment. Therefore, the energy processed using these machines and equipment will be more efficient. This condition causes the energy intensity to decrease.

Raw Material Intensity (IBB)

The estimation results show that the intensity of raw materials has a positive relationship with the intensity of coal and electricity energy. This result follows the hypothesis that the higher the intensity of raw materials, the higher the energy intensity, both coal and electricity because high raw materials will lead to high energy use.

Value-Added (VA)

The value-added is the difference between the output value and the input value. The estimation results show that added value has a positive relationship with coal energy intensity and negative with electrical energy intensity. This result follows the hypothesis that the higher the added value, the higher the coal energy intensity, but the lower the electrical energy intensity.

Engine Intensity (IM)

The estimation results show that the intensity of the machine has a positive relationship with the intensity of electrical energy and negatively with the intensity of electrical energy. This result follows the hypothesis that the higher the intensity of the machine, the higher the energy intensity.

Interpretation of Results and Discussion

Decomposition of the Energy Intensity of Coal and Electricity in the Manufacturing Industry Sector

Based on Table 4.1, the overall level of the manufacturing industry sector, the efficiency effect has increased by 12.25%, which means a decrease in the efficiency of coal energy use from 2007 to 2015. On the other hand, economic activity experienced a small decrease of 0.97%, which means a small increase in economic activity from 2007 to 2015. Overall, the increase in coal energy intensity in the manufacturing industry is relatively high, namely 11.28%, because the negative impact of the efficiency effect is more significant than the positive impact of economic activity. The decline in the efficiency of coal energy use is due to indirect subsidies to coal energy prices. With the subsidies, the price of coal energy becomes cheaper so that it spoils its users. This results in inefficient use of energy.

Based on Figure 2, the overall level of the manufacturing industry sector, the efficiency effect decreased by 7.37%, which means an increase in efficiency of the use of electrical energy from 2007 to 2015. In line with that, the effect of economic activity experienced a small decrease of 0.97%, which indicates a small increase in economic activity from 2007 to 2015. Overall, the decreased intensity of electrical energy in the manufacturing industry was 8.34% due to the positive impact of the efficiency effect and the effect of economic activity.

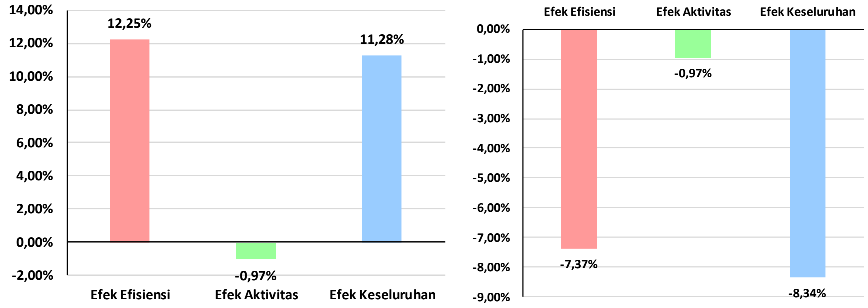

Figure 2. Coal Energy Intensity Decomposition (left) and Electricity (right) in the Industrial Sector
Source: IBS Statistical Data, 2007-2015 (reprocessed)

Panel Data Regression

The estimation results show that the intensity of raw materials and added value are positively and significantly related to the intensity of coal energy. The intensity of raw materials has a positive relationship with the intensity of coal energy. In contrast, the intensity of the machine has a negative relationship with the intensity of coal energy. The estimation results are not following the study (Soni et al., 2017), which shows that the raw material intensity variable has a negative but significant relationship with energy intensity. On the other hand, the machine intensity variable has a positive relationship with energy intensity (Irawan et al., 2014) and (Soni et al., 2017).

The estimation results show that the price of electrical energy, the intensity of machine maintenance and repair, and the intensity of the machine significantly influence the intensity of electrical energy. The price of electrical energy has a negative relationship with the intensity of electrical energy. The intensity of machine maintenance and repair has a positive relationship with the intensity of electrical energy. Finally, the intensity of the machine has a positive relationship with the intensity of electrical energy. The estimation results for energy prices follow the study (Karimu et al., 2016). In addition, these results indicate a lack of suitability for the variable intensity of machine maintenance and repair with Irawan et al. (2014) and Soni et al. (2017), which shows a negative relationship. However, the machine intensity variable showed conformity with Irawan et al. (2014) and Soni et al. (2017), which shows a positive relationship.

CONCLUSION

The source of energy intensity changes in Indonesia's manufacturing industry sector from 2007 to 2015 was dominated by efficiency effects for both coal and electricity energy intensity. The intensity of coal energy has increased, indicating that the manufacturing industry's use of coal energy is increasingly inefficient. In contrast, the intensity of electrical energy has decreased, indicating that the manufacturing industry's use of electrical energy is more efficient.

Factors that affect the intensity of coal energy in the manufacturing industry sector are the intensity of raw materials and the intensity of machines. Coal price intensity factor, machine maintenance and repair intensity, and machine intensity negatively correlate with coal energy intensity, while labor intensity, raw material intensity, and added value have a positive relationship with coal energy intensity.

On the other hand, the factors that influence the intensity of electrical energy in the manufacturing industry sector are electricity prices, machine maintenance and repair intensity, and machine intensity. The electricity price intensity factor, labor intensity, and added value have a negative relationship with the intensity of electrical energy, while the intensity of machine maintenance and repair, the intensity of raw materials, and the intensity of the machine have a positive relationship with the intensity of electrical energy.

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