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Article

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Analysis of Energy Efficiency on the Manufacturing Industry in Indonesia

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ABSTRACT

The use of fossil energy in Indonesia has been constantly increasing, especially on the manufacturing industry, the largest contributor to Indonesia's gross domestic product (GDP). Meanwhile, Indonesia's fossil energy reserve has been declining. Energy efficiency is one of the solutions to maintaining the industry's output. This research looks into the structures of Indonesia's manufacturing industry based on its energy use and how the industry has been conducting energy efficiency policies from time to time.

Keywords: Energy Efficiency, Decomposition Analysis, Indonesia, Manufacturing Industry
JEL Classifications: L60, Q28, Q4

1. INTRODUCTION

Energy is a crucial factor in the economic development and growth of a country, supporting economic activities like production and consumption. Moreover, some of energy's strategic roles are as fuel and input of the industrial sector, which helps advance economic activities and is a source of state revenue in the form of exports. However, limited energy source has remained a hurdle in long-term economic development and growth (Sagala, 2000). Energy intensity's important role and its connection to growth is generally demonstrated by causal relations in several studies (Chontanawat et al, 2008; Emir and Bekun, 2019). The positive correlation between energy intensity and growth shows that when the latter increases, energy use will become intensified. Generally, developing economies such as Indonesia tend to consume more energy compared to developed economies, especially in the industrial sector (Fatai et al., 2004).

Indonesia is home to various non-renewable, fossil energy sources such as oil, gas, and coal, as well as new and renewable energy sources such as hydro, geothermal, wind, and biomass. Indonesia is the world's largest archipelago with large reserves of various energy sources in all areas. However, its energy use is concentrated mainly in Java Island. The Directorate General of New and Renewable Energy and Energy Conservation (DGNREEC) of the Indonesian Ministry of Energy and Mineral Resources (2019) said that the national energy mix as of 2019 consisted of coal (60.4%), gas (23.11%), new and renewable energy (12.36%), and fossil fuel (+biofuel) (4.03%). These amounted to 61.1 gigawatts (GW) worth of energy generation capacity in total in that year.

Indonesia is faced with ever-increasing energy consumption issue, which is dominated by oil, gas, and coal. Up to this day, Indonesia is still utilizing these non-renewable resources as primary energy sources in vital sectors, such as electricity, industry, and transportation. Energy use from 1990 to 2018 increased by 4.99% per year (International Energy Agency (IEA), 2019), in line with the average annual economic growth of 5.03%. Unfortunately, this has brought Indonesia closer and closer to fossil energy scarcity, pushing it to import more oil and gas. The Ministry of Energy and Mineral Resources (MEMR) (2009) stated that fossil energy reserve in the country will be exhausted in 23 years (oil), 59 years (gas), and 82 years (coal). These calculations assume that no more new sources will be discovered, which otherwise will improve and prolong the energy reserve.

The energy use in each sector is determined by several factors, namely activity, structure and pure energy intensity (Rustandi, 2016). Figure 1 shows that in each factor, energy consumption in the manufacturing industry would overall provide a positive impact. The positive score of the activity factor shows that the contribution of the manufacturing industry towards the Indonesian gross domestic product (GDP) was due to changes in total production costs (excluding the structural and technological factors). Further, the positive score from the structure effect shows the contribution of energy use in the manufacturing industry towards economic growth. The positive trend in the structure effect also reflected how higher GDP growth required more energy. Meanwhile, the positive score from the pure energy intensity shows high use of energy in each variable of the GDP, while also reflecting the lack of energy efficiency.

In general, the manufacturing industry is divided into 3 categories in terms of energy consumption, namely energy-intensive, nonenergy-intensive, and non-manufacturing. Based on MEMR's data and information center, in 2018, the transportation and industrial sectors dominated the final energy use in Indonesia. The industrial sector is a primary focus in the government's energy conservation policies, one of which mandates industries with annual energy consumption over 6000 tons of oil equivalent (TOE) to conduct energy conservation management.

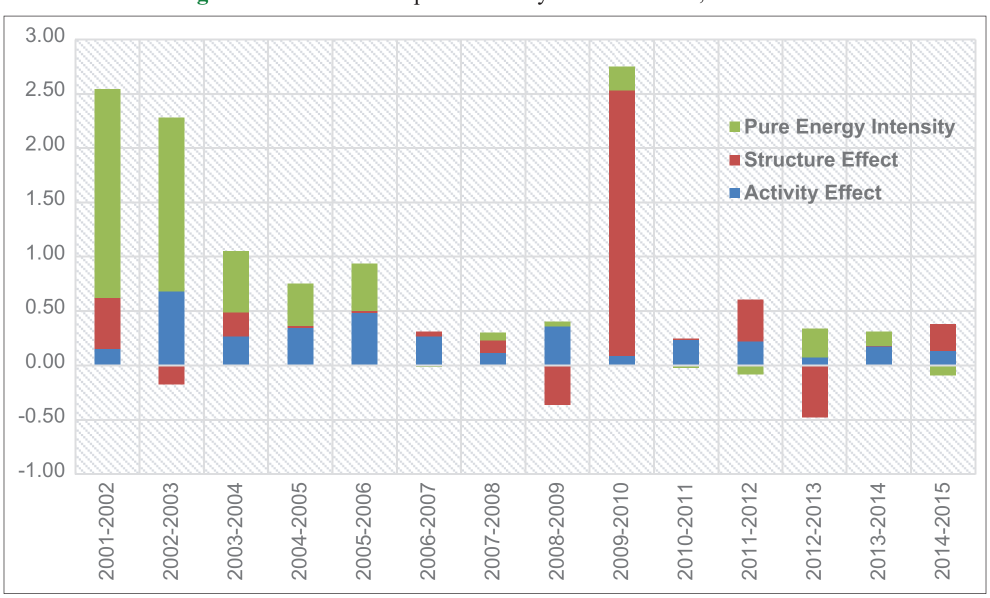
In dealing with the aforementioned challenges, Indonesia has established its own national energy policies (Kebijakan Energi Nasional/KEN), one being the energy conservation policy. This policy has been established since 1982 through the Presidential Instruction No. 9 concerning Energy Efficiency. Today, the MEMR is currently preparing a bill on the industrial sector which will stipulate green industry and industrial production that prioritizes efficiency and effectivity in sustainable use of natural resources. Going ahead, this research will attempt to look into energy efficiency measures that have been undertaken in Indonesia's manufacturing industry sub-sectors.

Based on the predetermined research objects, this paper will be divided into five chapters, namely the introduction, literature review, data and methodology, results, and finally, conclusion and recommendation based on the research's results.

2. LITERATURE REVIEW

Many ecological economists criticize particularly classic and neoclassic growth theories that only focus on institutional limitations in regards of growth (Cleveland and Stern, 1998). They emphasize the need for more understanding in micro aspects such as the substitutional boundary between input and technological development as an important factor to overcome the issue of limited natural resources. According to Cleveland and Stern, 1998, by looking into the connection between energy and aggregate output in production functions, Q = f (K, L, E, t), there are several factors that can contribute to that connection, among which are: (1) substitution/complementary between energy and other input variables (capital, means of production, and labor); (2) substitution/complementary between inputs other than energy (labor intensive, capital intensive and so on);(3) technological changes (innovation, intensity, energy efficiency etc.); (4) shift in energy input composition (variants, qualities etc.); and (5) shift in output composition (sectoral/disaggregated output). Within substitutional limitations such as energy source itself, these limitations consist of different categories, characteristics, as well as efficiency values. Each has distinguishable characters that can help increase efficiency in economic activities. Substitutional limitations can also hopefully be solved through increased role of human capital and research and developments in science and technology. Economic development in developing nations still has a difficult time replicating structural economic shifts that had taken place in developed nations. This may be closely related to the operating mechanisms of the aforementioned factors (Cleveland and Stern, 1998).

Figure 1: Annual decomposition analysis in Indonesia, 2001-2015



Source: Authors' calculations based on Statistics Indonesia (Badan Pusat Statistik) data

Indicators of energy intensity measure the required energy to run certain activities (Worrell et al., 2001). These indicators can be stated both in physical units (energy consumption that is directly linked to production output) or in economic scale (energy consumption linked to economic production values). These indicators can be used for various purposes from monitoring energy efficiency through policy analysis and evaluation to socio-economic research.

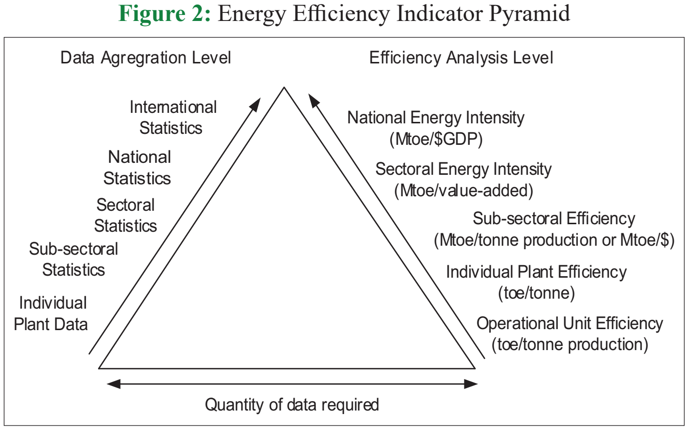
Figure 2 below shows that energy intensity indicators can be formed from the highest to lowest aggregate levels. In the highest level, the indicator is stated in macroeconomic scale (million tons of oil equivalent (Mtoe)/$GDP), and in the lowest level, it is stated in physical units (tons of oil equivalent (toe/production in tons). In the highest aggregate level, energy efficiency measurement done by looking into the energy efficiency indicators might be biased. For instance, energy intensity measurement using national statistics in several Asia-Pacific Economic Cooperation (APEC) countries is resulting in a downward trend. Nevertheless, that decrease may not be directly translated into an increase in energy efficiency, but may be due to changes in economic structure etc. (IEA, 2019).

The lower the aggregate level, the less economic structure and other variables get factored into. In the lowest level, energy intensity indicator as stated in physical units can be directly linked to the technology used in a given scenario. This means that the more sophisticated the technology gets, the more efficient its energy use will become (IEA, 2019).

Decreasing energy intensity is usually a reason for growth that is no longer manufacturing-oriented and indicating a shift towards the services sector. Because intensity is an average concept and not a marginal one like elasticity, it cannot describe energy efficiency. The elaboration on energy intensity is limited to domestic consumption in one country's development. If both are compared, one can see the superiority of elasticity over energy use intensity (Yusgiantoro, 2019).

The shift in economic activities due to energy structure change has been a subject in numerous research. Decomposition analysis has been widely used to study the forces of change in aggregate indicators from time to time (Su and Ang, 2012). Decomposition

Figure 2: Energy Efficiency Indicator Pyramid



Source: Phylipsen et al. (1998)

analysis consists of activity effect, structure effect and pure energy intensity. Activity effect describes how industrial activities respond to economic growth. If industrial activities show a positive trend, that sector or subsector will respond well to growth, and vice versa. Structure effect describes intensity change caused by composition changes in the manufacturing subsector. If the change is positive, the industry's gross value added (GVA) share will increase compared to base year, and the opposite when the change is negative. Meanwhile, pure intensity effect describes energy consumption resulted from energy efficiency, technological changes, change in fuel composition in industry structure and activities. If the change is negative, it means that energy consumption is becoming more inefficient, and if the change is positive, it means that energy consumption per GVA unit is becoming more efficient.

Decomposition analysis method is used to analyze the impact of several economic sub-sectors and is divided into three factors of energy use, namely activity, intensity, and structure effect. These factors sequentially represent economic growth, change in economic patterns and efficiency in energy use. There are previous research that used this method on both developed and developing economies. Xu and Ang (2013) in their research conducted an analysis towards several previous research that used Index Decomposition Analysis (IDA) and attempted to reveal the relative contribution between principal effects and the change in aggregate carbon intensity. From 80 journals observing various factors and countries, it could be concluded that IDA had been recognized by researchers as an analysis tool to study the driving factors of CO_2 emission. Some of those journals showed that energy intensity change that serve as a proxy of energy efficiency became the main factor in decreasing aggregate carbon intensity in several sectors and countries. Furthermore, the change in structure effects in the transportation and housing sub-sectors generally enhanced carbon intensity in industrial and/or developing countries.

Research by Khosruzzaman et al., (2010) used the decomposition model to discover the connection between energy consumption and economic growth. The analysis was done using the activity, structure, and intensity effects toward various economic sectors in Bangladesh from 1990 to 2007. It was concluded that the structural effect in the agriculture and services sectors showed negative trends, but positive trends were seen in the industrial sector. This positive trend indicated Bangladesh's transition phase from agriculture to industry. Meanwhile, in terms of energy consumption, activity effect in the industrial sector saw a swifter increase compared to the agriculture sector. In this research, it was also concluded that activity effect had a more dominant role in energy consumption, showing that groups with higher energy intensity was more responsible in improving their energy efficiency.

Another research by Sumabat et al. (2016) used index decomposition analysis to reveal the driving factors of CO_2 emission from fuel combustion and power plants in the Philippines. This research used four factors, namely the population effect, activity effect, structure effect, and intensity effect. Its analysis results showed that there was a positive trend from the population dan activity effects, while the opposite was seen in intensity effect, indicating an increase in energy efficiency. In the structure effect, meanwhile, the trend was inconsistent.

Zaekhan et al. (2019) identified measures to reduce CO_2 emission in Indonesia's manufacturing industry. The result stated that manufacturing growth was the main driver of increasing CO_2 emissions. This growth was in regard to increases in industrial economic activity and industrial energy intensity.

Further, Tanoto and Praptiningsih (2013) used the decomposition analysis to reveal the decomposing factors in the household sector based on electricity consumption. By using two pricing references, activity, structure, and intensity effects all positively impacted the use of electricity in Indonesia's household sector.

Research by Salamah et al. (2019) analyzed the textile sector using the decomposition analysis and found that this industry was improvident energy-wise.

These aforementioned research are used as a foundation for this research to utilize the decomposition analysis in studying the condition and contributions of energy use in the manufacturing industry towards economic growth in Indonesia.

3. DATA AND METHODOLOGY

The data used in this research are secondary data compiled from several sources, such as Statistics of Medium and Large Industries by Statistics Indonesia (Badan Pusat Statistik/BPS), Handbook of Energy and Economic Statistics of Indonesia by MEMR, and various other sources. The specific data used in this research is the GDP generated by the manufacturing industry, particularly its energy intensity data processed from energy use in each sector/subsector from 2000 to 2015.

Decomposition analysis in this research is using the Divisia index approach that refers to one used and elaborated by the Asia Pacific Energy Research Centre (APERC), which observes energy consumption trend among APEC member countries. Energy consumption analysis using decomposition analysis has been widely used as a tool to study the driving forces of change in aggregate indicators (Su and Ang, 2012). Meanwhile, the Divisia index approach makes it possible for this research to break down the percentages of change in energy use to a separate change in the overall activities, economic structure and energy intensity (Liu et al., 1992). The formula used in this research to find the total of energy consumption is as follows:

$$E_t = \sum_i E_{it} \quad (1)$$

E_t = total energy consumption
E_{it} = energy consumption in subsector i during t

E_t as total energy consumption is a function consisting of three variables, namely Level of Output (A_t), Energy Intensity of Sub sectoral (I_{it}) dan Structural Parameter (S_{it}). The formula of each variable can be written down as follows:

$$A_t = \sum_i A_{it} \quad (2)$$

Level of Output (A_t) is the sum of sectoral activities, which consist of the total added values of all sub-sectoral (A_{it}) inputs.

$$I_{it} = \sum_i \frac{E_{it}}{A_{it}} \quad (3)$$

Energy Intensity of Sub sectoral (I_{it}) is sub-sectoral energy consumption (E_{it}) per unit of activity (A_{it}). This calculates the amount of energy consumption divided by the added value in each sub-sector. Therefore, I_{it} sums up the required energy in the manufacturing industry during year t in order to sum the GDP contribution made by that industry in the same t year.

$$S_{it} = \sum_i \frac{A_{it}}{A_t} \quad (4)$$

Structural Parameter (S_{it}) calculates and defines the comparison between sub-sector activities against the total activities. Therefore, Structural Parameter attempts to calculate sub-sector contributions against the total GDP of the manufacturing industry.

Next, based on APERC (2019), the three equations above can serve as indicators of the formation of an equation for total energy consumption from the activity, structure and energy intensity side. The formula is as follows:

$$E_t = \sum_i (A_t \text{ x } S_{it} \text{ x } I_{it}) = \sum_i A_t \text{ x} \left(\frac{A_{it}}{A_t}\right) \text{x} \left(\frac{E_{it}}{A_{it}}\right) \quad (5)$$

In decomposition analysis approach, in order to find out about changes in energy consumption between base year and t year, the activity, structure and intensity effects can be additions to the small residual period. Mathematically, it can be written down as follows:

$$\Delta E_{0t} = E_t - E_0 = \sum_i \begin{pmatrix} [A_0 + \Delta A_t]\text{x} \\ [S_{i0} + \Delta S_{it}]\text{x} \\ [I_{i0} + \Delta I_{it}] \end{pmatrix} - \sum_i (A_0 + S_{it} + I_{it}) \quad (6)$$

ΔE_{0t} is used to see the annual movements of energy consumption against base year. Besides that, this equation is used to measure the changes in activities, structures and energy intensity.

Next on, aggregating energy intensity during t can be done by summing up intensity products and energy shares in each sub-sector against total activities (Ang, 1995) using the following formula:

$$I_t = \sum_i S_{it} \times I_{it} \quad (7)$$

I_t is the sum of energy intensity, and S_{it} is the share of industry sub-sector i against the total GVA $\left(A_{it} / A_i \right)$, while I_{it} is the energy intensity of the sub-sector i $\left(E_{it} / A_{it} \right)$.

4. RESULTS

4.1. Analysis of Energy Intensity based on Sub-sectors of the Manufacturing Industry

Some uses of energy intensity can describe indicators like changes in energy uses and components, thus explaining to the general public about the cause of change in energy intensity, providing inputs for programs and policy analysis, as well as increasing understanding on the importance of efficiency improvement.

Figure 3 shows that in aggregate, energy intensity tended to decrease and showed a positive trend. This indicates that the manufacturing industry had improved its energy efficiency, meaning that the ratio between energy consumption and production output had been narrowing.

In the sub-sector level, it is known that the sector with the highest energy intensity is the miscellaneous goods industry, which recorded the highest rate at 5.02% in 2003. It is followed by the cement industry at 0.98% in both 2008 and 2009. For the cement industry, the clinker process in its production consumed the largest amount of energy. The process requires the burning of cement's raw material into nodules or clumps.

Next, the paper and printed material industry, which made up four percent of the GDP, showed an upwards trend in energy intensity. In 2000, its energy intensity was recorded at 0.15 thousand barrels of oil equivalent (BOE), and in 2015, the figure more than doubled to 0.34 thousand BOE. This increase might have been caused by raising energy costs. The Best Available Techniques (BAT) Reference Document (Gianluca et al., 2017) stated that energy costs in this sector made up 16 percent of its overall production costs, where the majority of it was deployed on the pulp drying process (Sugiyono, 2004), the final stage of production where it would then become paper.

4.2. Analysis of Economic Activities that Influence Energy Consumption

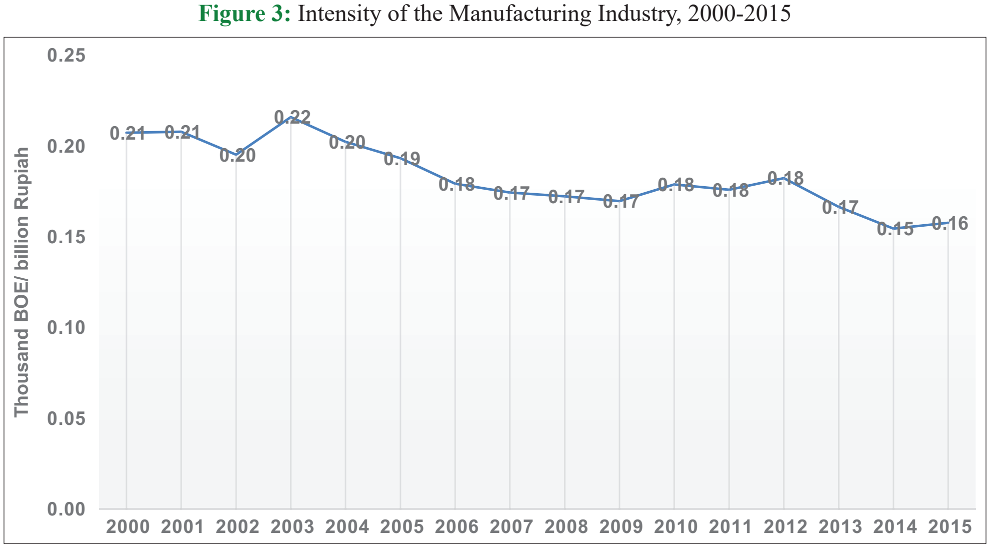
In this analysis, three factors were used to elaborate the decomposition analysis approach in the sub-sectors of manufacturing industry between the 2000-2015 period. Those factors are activity effect, structure effect and pure energy intensity. The calculations of these three factors are shown in Figure 4.

4.2.1. Activity effect

Textile and transportation sub-sectors are the largest contributors of based on the calculation of activity effect (Figure 5). Throughout the research period, the activity effect in these sub-sectors showed positive values of between 0.09 and 0.68. There were three periods where activity effect was the largest observed compared to other periods, which was in 2002-2003, 2004-2005, and 2006-2007. Besides that, the cement, paper, fertilizer and food and beverages sub-sectors also all showed positive trends. It demonstrated how added values in these sub-sectors would be able to respond well to economic growth.

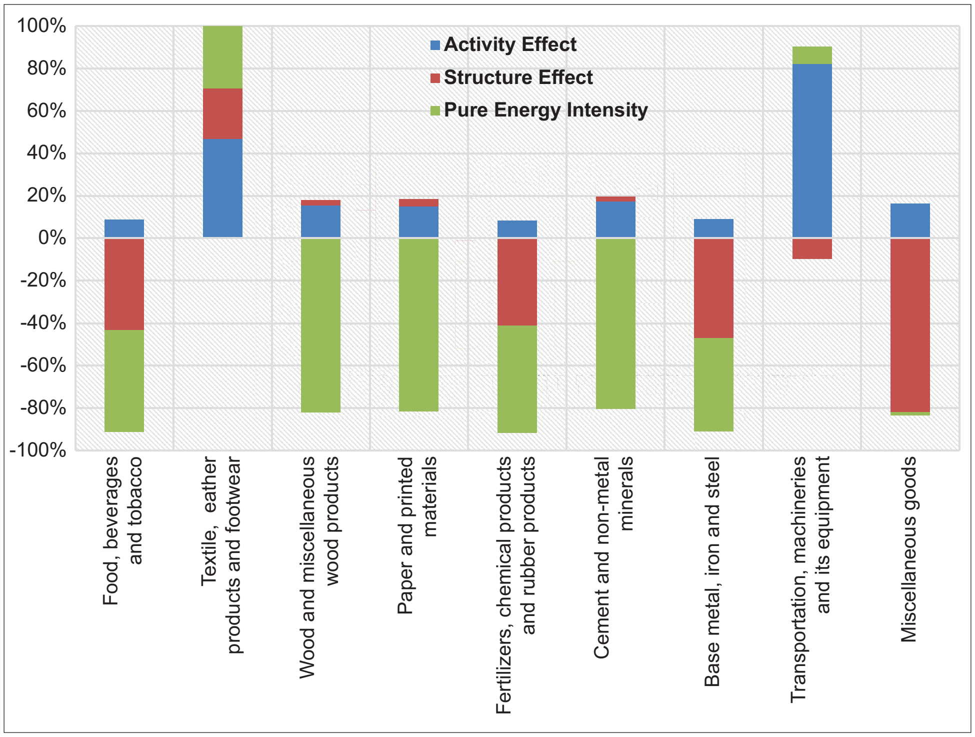
Between the 2000 and 2009 period, the metal industry sub-sector saw a negative trend in activity effect, where its added value in 2009 was lower than during base year (2000). The national steel industry had not been able to maximize its installed capacity, most likely due to less encouraging domestic steel demand and lack of domestic customers. Besides that, domestic steel producers had not been able to make products according to consumers' needs (Hasni and Manulang, 2011). In the next period of 2010-2015, the industry's added value had finally become positive. This might have been due to increasing global steel prices.

Figure 3: Intensity of the Manufacturing Industry, 2000-2015



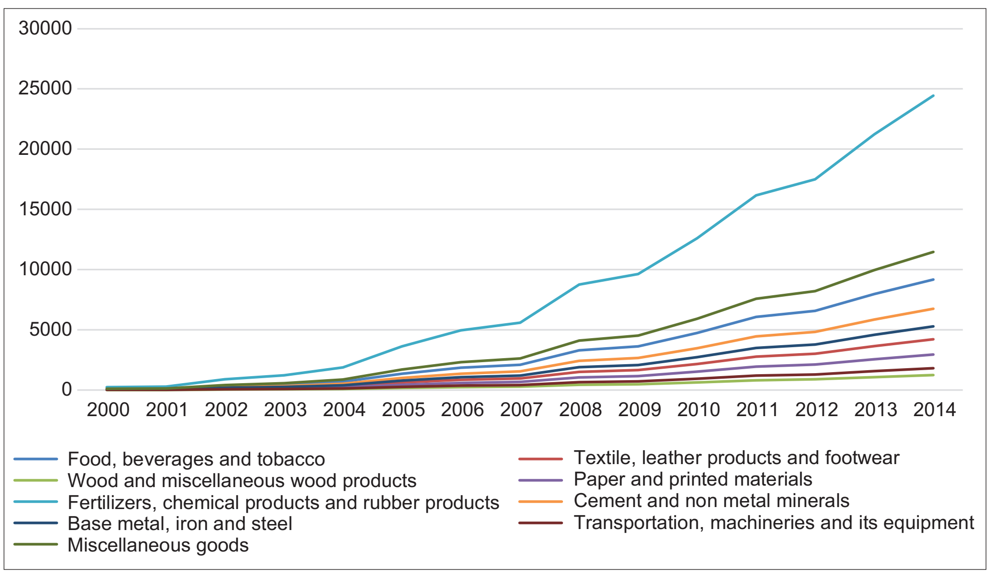
Source: Authors' calculations based on Statistics Indonesia data. BOE = barrels of oil equivalent

Figure 4: Calculation result of decomposition analysis based on the sub-sectors of manufacturing industry



Source: Authors' calculations based on Statistics Indonesia data

Figure 5: Calculation result of activity effect based on the sub-sectors of manufacturing industry



Source: Authors' calculations based on Statistics Indonesia data

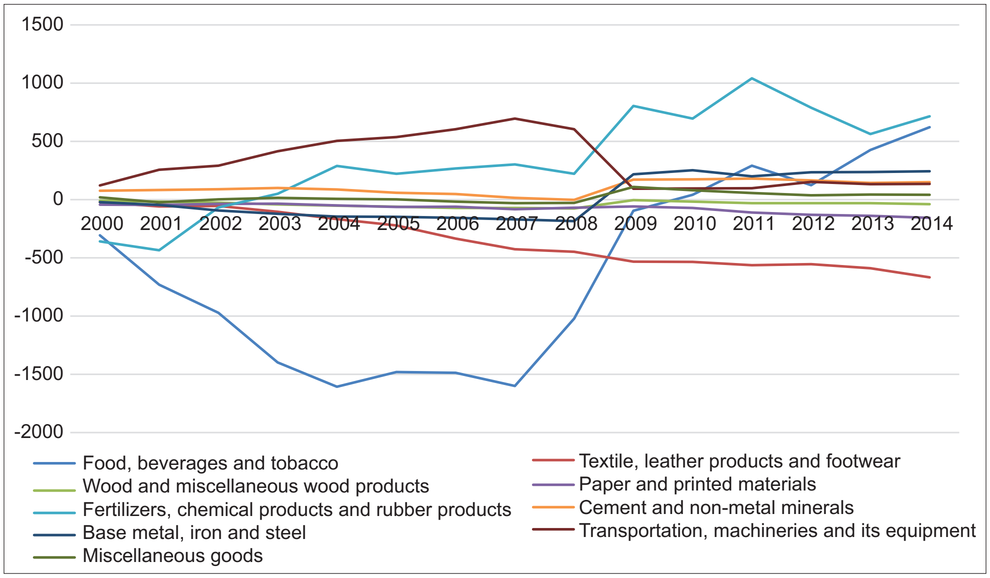
4.2.2. Structure effect

Figure 6 shows that the overall calculations of structure effect resulted in negative trends during the 2002-2003, 2008-2009, and 2011-2013 periods. This explains how the share of manufacturing industry was smaller than its GDP output in base year. Four sub-sectors that showed particular negative structure effect were food and beverages, fertilizer and chemicals, base metal and iron and steel, and miscellaneous goods.

On the other hand, the remaining periods showed a positive trend, demonstrating that intensity change had taken place because the manufacturing industry GDP was increasing compared to its base year. In energy-intensive sub-sectors such as iron and steel, the earlier periods showed a negative trend all the way to 2009, but changed trajectory to positive since 2010. This change was due to growing steel demands worldwide since 2009. In this sub-sector, upwards price movement and production increase were among the driving factors of the change in this structure effect.

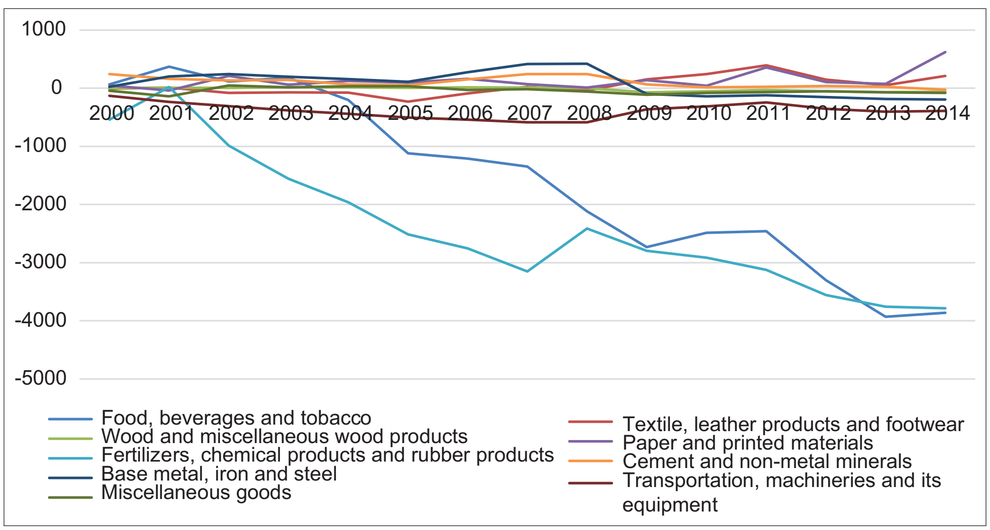
A similar trend was seen in the food and beverages sub-sector, which trends changed to positive between 2010 and 2011. This

Figure 6: Calculation result of structure effect based on the sub-sectors of manufacturing industry



Source: Authors' calculations based on Statistics Indonesia data

Figure 7: Calculation result of pure energy intensity based on the sub-sectors of manufacturing industry



Source: Authors' calculations based on Statistics Indonesia data

change might have been caused by increasing productivity, improved capacity, the opening of new plants/factories, the adoption of latest technology and the implementation of breakthrough investment policies (National Development Planning Agency (Sektoral, 2010).

The cement sub-sector showed a positive trend all throughout the research period. Despite of a downturn in 2009, the trend rebounded in 2010 and saw a positive growth in structure effect. According to the Indonesia Cement Association, the rebound was caused by improving debt-to-equity ratio during the 2000-2010 period, and in particular after the global financial crisis. Increased production capacity and exports in the cement sub-sector contributed to its GDP (Investor Daily, n.d.).

Interesting results were seen in the pulp and paper and textile sub-sectors, which saw bigger negative values toward the end of the research period than in the beginning. This indicates that the GDP shares of these sub-sectors were lower compared to base year. The negative trend in pulp and paper sub-sector, in particular, might have been caused by shifting lifestyle of printing hard copies into electronic copies, thus affecting demands in the sector. However, a deeper look into this is still needed, considering that paper production in that period had actually been increasing. Another possible factor is that energy costs, which as has previously been mentioned in section 4.1, made up 16 percent of its overall production costs.

4.2.3. Pure energy intensity

Figure 7 shows that several periods showed a negative value in pure energy intensity, which was 2003-2004, 2006-2007, 2007-2008. 2011-2012, and 2014-2015. That negative value shows decreasing energy intensity against the GDP of each sub-sector.

Of all sub-sectors, textile and transportation saw positive changes, but energy-intensive industries such as iron and steel, cement, and paper saw negative changes. This was due to high percentage of energy costs, which could make up 15-3% of the overall production costs. Additionally, in 2008-2009 and 2014-2015, global crude oil price hit US$100 per barrel, further suppressing these energy-thirsty sub-sectors. The increase in crude oil price reduced the industries' added value while stressing energy intensity at the same time. However, higher crude oil price might have also improved efficiency in these industries.

Figure 7 shows that the food, beverages and tobacco industry, along with fertilizer, chemicals, and rubber products showed a significantly negative pure energy intensity value. This can be translated as less energy were being required for higher production outputs in these sub-sectors.

5. CONCLUSION

The following sub-sectors showed a positive trend in activity effect:
- Textile
- Cement
- Pulp and paper
- Fertilizer
- Transportation
- Food and beverages
- Miscellaneous goods.

This shows that added values in these sectors would be able to respond well to economic growth.

Meanwhile, the following sub-sectors showed a negative trend in structure effect:
- Food and beverages
- Fertilizer and chemicals
- Base metal, iron and steel
- Miscellaneous goods.

The GDP output in each sub-sector was bigger in base year compared to its shares throughout the research period.

For energy-intensive industries (cement, iron and steel, and pulp and paper), structure effect tended to show negative trends, thus demonstrating how in these sub-sectors, GDP outputs were smaller compared to their shares in base year.

Finally, the food, beverages and tobacco industry, along with fertilizer, chemicals, and rubber products showed a significantly negative pure energy intensity value. This can be translated as less energy were being required for higher production outputs in these sub-sectors.

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