DIGITALES ARCHIV

Zaekhan; Nachrowi, Nachrowi D.; Lubis, Andi Fahmi et al.

Article

Decomposition of energy consumption and decoupling analysis in the Indonesian industry : an analysis of Green industry

Provided in Cooperation with:
International Journal of Energy Economics and Policy (IJEEP)

This Version is available at:
http://hdl.handle.net/11159/5104

Decomposition of Energy Consumption and Decoupling Analysis in the Indonesian Industry: An Analysis of Green Industry

Zaekhan Zaekhan[1], Nachrowi Djalal Nachrowi[1]*, Andi Fahmi Lubis[1], Widyono Soetjipto[1], Tita Rosita[2], Nona Widharosa[3]

[1]Graduate Program in Economics, Faculty of Economics and Business, Universitas Indonesia, Indonesia, [2]Polytechnic AKA Bogor, Ministry of Industry, Indonesia, [3]Centre for Data and Information, Ministry of Industry, Indonesia. *Email: nachrowi@ui.ac.id/ gnachrowi@gmail.com

ABSTRACT

This study aims to identify ways that efficiently reduce the energy consumption of the industrial sector. We use the logarithmic mean divisia index method to measure the impact of the various driving forces of energy consumption during the period 2010-2014. We then apply the index decoupling to analyze the correlation between energy consumption and industrial growth. The findings indicate that industrial growth is a major driver of energy consumption, while reductions in energy intensity and industrial structure play an important role in limiting energy consumption. In addition, energy consumption and energy intensity follow different patterns in each sub-sector; we therefore conclude that the application of different sub-sector policies is preferred over global policies. Globally, decoupling has not been identified during the period 2010-2014, however, decoupling occurs for more detailed year periods.

Keywords: Energy Consumption, Logarithmic Mean Divisia Index, Decoupling
JEL Classifications: L52, L60, O25, Q43

1. INTRODUCTION

Energy consumption in Indonesia continues to increase, in the period 2000 and 2015 increased by 44% (MEMR, 2016). The increase in energy consumption is predominantly derived from industrial and transportation sectors, with a total share of over 75% (MEMR, 2016). Industry sector contribution is around 35-40%. The cause of this increase is a sustained expansion of economic activity by increasing gross domestic product (GDP). Fossil fuels of oil, gas and coal still dominate and represent 95% of Indonesia's primary energy consumption total (MEMR, 2016). The high energy consumption of fossil fuels in this energy mix in the industrial and transport sectors causes high CO_2 emissions in the sector (Ministry of Industry, 2012). Even in the industrial sector, fossil fuel energy consumption increased by more than

100%, accompanied by an increase in CO_2 emissions between 2010 and 2014 (Statistics Indonesia, 2016). This drastic increase in fossil fuel energy consumption will be very worrying in terms of energy availability and environmental sustainability, especially climate change. Industrialization will result in such proportions will continue to increase significantly in the future. On the other hand, Indonesia's energy resources reserves are worried and feared that they can not meet domestic demand for energy over the long term (MEMR, 2018).

Energy efficiency becomes a key element in achieving safe energy supplies as the country faces an energy crisis, rising energy costs and rising concerns about climate change (Duran et al., 2015). Energy efficiency can be considered as an additional energy source resulting from a reduction in energy consumption while maintaining a given level of output. This reduction in energy

consumption is achieved by improving technology or process efficiency. In the energy economy literature, changes in energy intensity are often used as a proxy of changes in energy efficiency (Choi and Ang, 2010) while energy intensity is defined as the amount of energy consumed per unit of output. Increased energy efficiency enables industries to reduce energy intensity to achieve a certain level of output at lower costs and less pollution (Reddy and Ray, 2011; Duran et al., 2015). The International Energy Agency (IEA) has stated that improving the energy efficiency of the industrial sector is vital in maintaining a sustainable energy supply. To achieve this, the Indonesian government promotes decoupling between energy consumption growth and economic growth (MEMR, 2016). The industrial sector is expected to achieve the highest levels of energy saving and CO_2 mitigation among all other priority areas (buildings, equipment, lighting and transportation) if appropriate measures are implemented (IEA, 2011).

Decoupling is an important concept to connect between economic variables, energy variables and environmental impacts (Enevoldsen et al., 2007). Initially, the term decoupling was used to describe the relationship between economic activity and environmental degradation (Freitas and Kaneko, 2011). The growth of economic activity and the growth of environmental pressure (e.g., CO_2 emissions) over a period of time has become a feature of decoupling (Freitas and Kaneko, 2011). Specifically, the definition of decoupling refers to the relative growth rate of an environmental pressure and an economic variable that is easily linked. According to the Organization for Economic Cooperation and Development (OECD), decoupling is the relationship between "economic goods" and "environmental crime" and began presenting decoupling as an indicator of sustainable development in 2002.

There are several different definitions of decoupling and so are the measurement methods. At present there is no consensus about the relative strengths and weaknesses of each (Zhong et al., 2010). OECD (2002) developed the concept of measurement to distinguish between absolute decoupling and relative decoupling. In the case of absolute decoupling, decoupling occurs when the growth variable of economic activity increases, the environment variable shows a stable trend or the trend decreases over time. However, relative decoupling occurs when the growth rate of environmental variables shows a positive trend but at a lower level than the growth of economic activity. Climent and Pardo (2007) then use this concept to examine the correlation of GDP and energy consumption in Spain. Diakoulaki and Mandaraka (2007) adopted it to evaluate progress in reducing CO_2 emissions from industrial growth in 14 European Union countries. Freitas and Kaneko (2011) used it to examine CO_2 emissions and the growth of economic activity in Brazil during 2004-2009. According to Freitas and Kaneko (2011), this decoupling analysis method (specifically index) is more effective when combined with other analytical methods such as decomposition analysis methods.

This study aims to help identify the focus of energy efficiency policy in the future to achieve a reduction in cost-effective energy consumption and CO_2 emissions mitigation in the Indonesian industrial sector. A more specific objective of this study is to analyze the factors that explain changes in energy consumption in various Indonesian industrial sub-sectors. This information can help policy makers to determine which sub-sectors and which firms should prioritize to focus policy, reduce energy consumption, minimize costs and mitigate CO_2 emissions. The international energy agency recommends the use of the index decomposition analysis (IDA) to isolate the impact of changes in energy intensity from other factors that affect energy consumption, given that energy intensity can be affected by government through energy policies (Duran et al., 2015). This information can help gauge the real impact of energy policies and focus these policies on strategic sectors, based on their energy reduction potential (IEA, 2014).

Index decomposition analysis especially logarithmic mean Divisia index method (Ang, 2005) was used in this study to identify and analyze the relative impact of various factors on energy consumption, especially changes in energy intensity in various Indonesian industrial sub-sectors. The benefits of the logarithmic mean divisia index (LMDI) method are simple to use, complete decomposition possible without residual, can accept additive decomposition and multiplication, and can be applied for short time series (Su and Ang, 2012). Decoupling concept analysis (decoupling) is also used to identify industrial sub-sectors that have efficiency in using energy.

The main contributions of this study to the existing literature are: (1) Expansion of analysis for inclusion of characteristics of the company such as sub-sector and energy intensity in energy policy design; (2) applying the concept of decoupling index in analyzing energy efficiency, that is correlation of energy consumption and economic activity. This information helps policy makers in better subsectoral and cost-effective policy design. Previous studies using the IDA only consider different sub-sectors based on the classification of industrial activity (Ma and Stern, 2008; Xu and Ang, 2014). To our knowledge, have considered the decoupling index in energy efficiency analysis.

The organization of this paper is as follows. Section 1 introduction. Section 2 methodolgy, presenting the IDA framework, LMDI approach and decoupling analysis. Section 3 describes the data used. Section 4 shows the LMDI decomposition and decoupling analysis of Indonesian industrial energy consumption based on industry sub-sector. Finally, Section 5 concludes the paper and presents policy recommendations.

2. METHODOLOGY

2.1. Energy Decomposition
We used the LMDI method in this study. LMDI is the most widely adopted and preferred method in the context of index decomposition analysis, IDA (Shao et al., 2011) because of its ease of formulation. Some of the practical advantages of the LMDI method are: Easy to use and applicable for short time series (Su and Ang, 2012; Ang and Liu, 2001), perfectly decomposed, no residuals (Tunç et al., 2009), zero values in the set of datasets can be replaced by a small positive constant value (Liu et al., 2007), consistent in aggregation, this means sub-group results can be added to aggregate results (Ang and Liu, 2001; 2007), strong theoretical basis, adaptability, which is clear between additive

and multiplicative versions, the results do not depend on the base year, and use a rather simple formula with direct interpretation of the results (Ang, 2004). Ang (2005) provides a practical guide to using this method.

IDA estimates the effects of three different effects on changes in energy consumption. These effects are:
1. Activity effects. This effect considers changes in the scale of economic activity or in the overall economic output level, assuming that this increase in output levels involves an increase in energy consumption.
2. Economic structure effects. This effect considers changes in the mix of economic activity. These changes have an impact on energy consumption because each activity has a different energy intensity.
3. Intensity effects. This effect considers the impact on energy consumption from changes in energy intensity. This is considered a proxy for a good energy efficiency change.

The decomposition presented in equation 1 describes the total energy consumption. Sub-section i becomes sub-category of aggregate energy consumption whose changes in economic structure are studied:

$$E = \sum_i E_i = \sum_i Q \cdot \frac{Q_i}{Q} \cdot \frac{E_i}{Q_i} = \sum_i Q \cdot S_i \cdot I_i \qquad (1)$$

Where E is the total energy consumption in the industry, $Q\,(=\sum_i Q_i)$ is the total industry activity output level, $S_i\,(=Q_i/Q)$ is the industrial economic activity share and $I_i\,(=E_i/Q_i)$ is the energy intensity of the sub-category i.

For IDA additive, the change in energy consumption (E) between two periods $(0, T)$ as follows:

$$\Delta E_{tot} = E^T - E^0 = \Delta E_{act} + \Delta E_{str} + \Delta E_{int} \qquad (2)$$

Where,

$$\Delta E_{act} = \sum_i \frac{(E_i^T - E_i^0)}{(\ln E_i^T - \ln E_i^0)} \ln\left(\frac{Q^T}{Q^0}\right) \qquad (3)$$

$$\Delta E_{str} = \sum_i \frac{(E_i^T - E_i^0)}{(\ln E_i^T - \ln E_i^0)} ln\left(\frac{S_i^T}{S_i^0}\right) \qquad (4)$$

$$\Delta E_{int} = \sum_i \frac{(E_i^T - E_i^0)}{(\ln E_i^T - \ln E_i^0)} \ln\left(\frac{I_i^T}{I_i^0}\right) \qquad (5)$$

The subscripts act, str, and int each show the effect of activity, the effect of the economic structure and the intensity effect. The interpretation of the effects of the economic structure depends on the categorization applied and considers the impact on energy consumption of the changes in the division of different components in each of the sub-categories mentioned above.

2.2. Index Decoupling Formulation
We apply decoupling index method to analyze decoupling of energy consumption and growth of industrial economic activity of Indonesia. Based on the definitions given by Diakoulaki and Mandaraka (2007), decoupling is a measure of measures to reduce

energy intensity (lower energy intensity), switch to fuels (cleaner energy consumption), and shift toward industries with more energy use slightly (improvement of industrial economic structure) by referring to any action that directly or indirectly uces the reduction of CO_2 emissions associated with energy consumption. Thus, assuming the same trend pattern and the correlation between energy consumption and high CO_2 emissions, the index decoupling formulation for CO_2 emissions would be similar to the decoupling formulation for energy consumption. Therefore, the total absolute effort (ΔF^T) during the period from 0 to T can be explained as the difference between changes in total energy consumption and changes in energy consumption due to the influence of industrial economic activity or as the amount of energy consumption of 2 (two) effect factors in Eq. (2). Therefore, we use ΔF^T to represent the total effect of decreasing energy consumption as follows:

$$\Delta F^T = \Delta E_{tot}^T - \Delta E_{act}^T = \Delta E_{str}^T + \Delta E_{int}^T \qquad (6)$$

If the amount of change in energy consumption of the two negative effect factors, then ΔF^T will be negative which means resulting in a decrease in energy consumption. To assess the extent to which this effort is effective in terms of separating energy consumption from the growth of industrial economic activity, the D^T decoupling index during the period from base year 0 to year T is defined as follows:

If $\Delta E_{act}^T \geq 0$, then

$$D^T = -\frac{\Delta F^T}{\Delta E_{act}^T} \qquad (7)$$

If $\Delta E_{act}^T < 0$, then

$$D^T = \frac{\Delta F^T - \Delta E_{act}^T}{\Delta E_{act}^T} \qquad (8)$$

Since Equation (7) refers to the influence of positive industrial economic activity, the decoupling index can be determined for each equation effect, and the value obtained can help to identify the relative contribution of each of the effect factors to the overall decoupling process. Thus, the decoupling index of the whole process will be equal to the number of partial decoupling ices (Eq. 9).

$$D^T = -\frac{\Delta F^T}{\Delta E_{act}^T} = -\frac{\Delta E_{str}^T}{\Delta E_{act}^T} - \frac{\Delta E_{int}^T}{\Delta E_{act}^T} = D_{str}^T + D_{int}^T \qquad (9)$$

Where D^T is the total industry decoupling index; D_{str}^T and D_{int}^T is the decoupling index of each influence of the economic structure of the industrial economy, the energy intensity of the industry. If $D^T \geq 1$, showing the absolute decoupling effect, we can say that the amount of effect factor that energy efficiency is greater than the effect factor of industrial economic activity. Meanwhile, if $0 < D^T < 1$, it indicates a relative decoupling effect and we can conclude that the effect of energy efficiency seems to be weaker than the effect factor of industrial economic activity. Finally, if $D^T < 0$, it shows no decoupling and we conclude that the number of energy efficiency effect factors is not strong enough to significantly reduce energy consumption. If the value of D_{str}^T and $D_{int}^T > 0$, we can say that the efficiency factors of energy

consumption such as economic structure of industrial economy and industrial energy intensity are substantive enough to contribute to decoupling. Conversely, if less than 0 (<0), these factors do not contribute to decoupling (Wang et al., 2013; Zhang and Da, 2015).

3. DATA

This study uses data from industrial Annual Statistics Indonesia 2010-2014 period. This data provides information about all manufacturing firms with 20 or more workers employed for at least 6 months and includes more than 20,000 firms each year. This survey contains information on energy consumption, outputs and other characteristics at the enterprise level, such as industry sub-sector and technology intenstiy. This survey provides a unique identifier for each company, which does not change over the period 2010-2014.

Energy consumption data is available in physical units with fuel types: Coal, gasoline, natural gas, liquefied petroleum gas (LPG), kerosene, diesel (ADO) and electricity. To obtain total energy consumption by a company, the physical values are standardized to a barrel of oil equivalent (BOE) using coefficients issued by the Ministry of Energy and Mineral Resources (MEMR, 2016) and then converted again to tons of coal equivalent (TCE). Output is measured as an added value in Indonesian rupiah based on 2000 constant prices. Based on the Indonesian Standard Classification of Business Enterprises (ISIC, 2009), adjusted to International Standard industrial Classification Rev.4 (ISIC Rev.4), the firms are grouped into 24 sub-sector, as shown in Table 1.

4. RESULTS AND DISCUSSION

4.1. Results of Decomposition Analyisis

This section presents the results of additive decomposition analysis of changes in energy consumption in Indonesian industry. We report aggregate decomposition results in the study period, which includes all firms. The results of the report are presented using graphical instruments. Figure 1 presents the results of decomposition analysis of changes in total energy consumption for Indonesian industries sector and the contribution of each securities component in the period 2010-2014. Changes in total energy consumption show fluctuations but tend to increase after 2012. Total energy consumption increased sharply during 2010-2011, slightly increased during 2011-2012, and smaller during 2012-2013, and then there is a high increase again during 2013-2014. The activity effects component is always positive indicating that an increase in the level of output is important to the increase in energy consumption; but there are negative effects of energy intensity which indicate a decrease in energy consumption during the period under study, especially the period 2011-2012 and 2012-2013. The component effects of the economic structure of the industry are also negative in the period 2012-2013 which means a decrease in energy consumption, but in other periods have a positive effect. However, the trend of all components of the securities is unclear as these results indicate that all components of the securities fluctuate throughout the period 2010-2014. These results indicate that the main drivers of

Figure 1: Results of additive decomposition of energy consumption change (2010-2014)
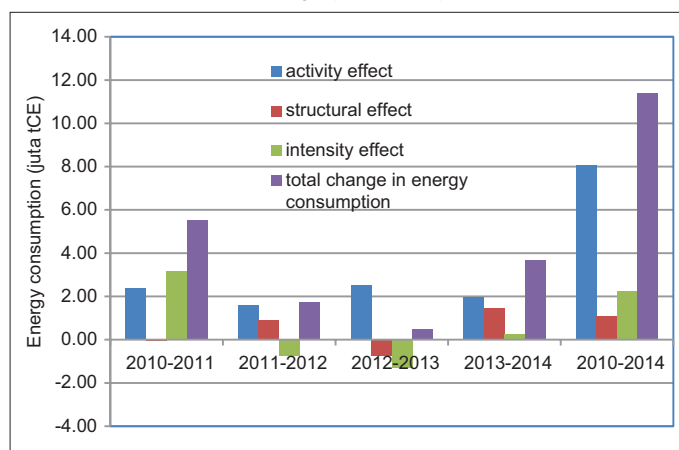
energy consumption dynamics are changes in industrial economic activity and industrial energy intensity.

Over the past few years, the possibility of decoupling growth in economic activity and growth in energy consumption has not occurred. Our results show that energy consumption has continued to increase significantly over the last few years in the industrial sector, which can be indexplained by the high increase in output. This means that energy efficiency improvements have not occurred yet. Thus, it is possible that energy consumption will increase steadily as economic activity increases if energy efficiency does not occur.

4.2. Decomposition Analysis by Sub-sector

In this section, we present descriptive results according to the industry standard classification (sub-sector). This sub-sector classification considers firms with the same business line (ISIC, 2009). Based on ISIC (2009), the company is classified into 24 industry sub-sectors. For explanation, we divide this sub-sector into three (3) groups based on the average intensity of energy usage; (1) sub-sectors with high intensity energy consumption (HEI), (2) sub-sectors with medium intensity energy consumption (MEI), and (3) sub-sectors with low intensity energy consumption (LEI).

Figure 1 shows the decomposition of changes in energy consumption for Indonesian industrial; Figure 2 of high intensity, Figure 3 of medium intensity, Figure 4 low intensity. In the period 2010-2014, the effects of positive activity in all sub-sectors resulted in an increase in energy consumption. In terms of energy intensity, in HEI (Figure 2), there is a decrease in energy consumption due to changes in energy intensity in the non-metallic minerals sub-sector (10), chemicals (20), textiles (13); in MEI (Figure 3), in the sub-sector of metal goods not machinery (25), garments (14), leather and footwear (15); and on LEI (Figure 4), in the sub-sector of machinery and equipment (28), beverage (11), repair and installation services of machinery (33). In the HEI, the effects of economic structure show significant changes in sub-sector output share, thus reducing energy consumption in rubber and plastic sub-sectors (22), paper (17), basic metals (24). The effects of economic structure also occur in all MEI sub-sectors indexcept

Table 1: Sub-sector and code of Indonesian industry

Code	Description	Code	Description
10	Food	22	Rubber and plastic
11	Beverage	23	Non-metallic minerals
12	Tobacco processing	24	Basic metals
13	Textile	25	Metal goods, not machinery
14	Garments	26	Computers, electronics and optics
15	Leather and footwear	27	Electrical equipment
16	Wood, bamboo, and rattan	28	Machinery and equipment
17	Paper	29	Motor vehicles and trailers
18	Printing and reproduction of media	30	Other transport equipment
19	Products from coal and petroleum	31	Furniture
20	Chemicals	32	Other processing
21	Pharmaceuticals and medicine	33	Repair and installation machinery

Figure 2: Results of additive decomposition of energy consumption change by industrial sub-sector high energy intensive (HEIs). Period: 2010-2014
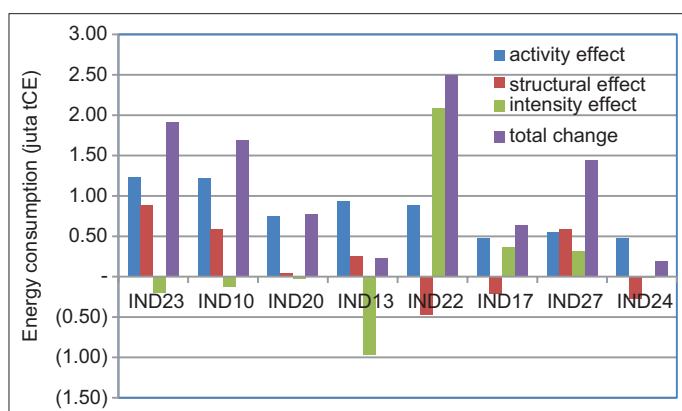
Figure 3: Decomposition of energy consumption change by industrial sub-sector medium energy intensive (MEIs). Period: 2010-2014
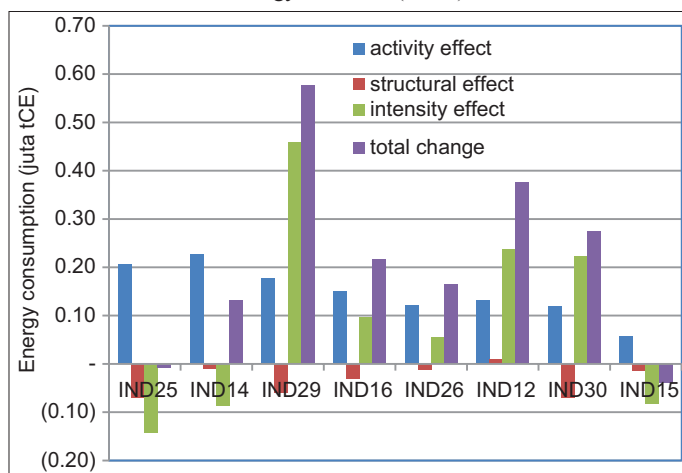
tobacco processing (12). In LEI, the effects of economic structures occur in the sub-sector of pharmaceuticals and medicine products (21), printing and reproduction of recording media (18), repair and installation services of machinery (33), other processing (32), products from coal and petroleum refineries (19).

4.3. Results of Decoupling Analysis

The result of decoupling analysis between energy consumption and economic activity of Indonesian industry along with the influence

Table 2: Results of decoupling effect analysis

Period	D_{str}	D_{int}	D_{tot}	Decoupling effect
2010-2011	0.01	−1.33	−1.31	No decoupling
2011-2012	−0.56	0.47	−0.08	No decoupling
2012-2013	0.30	0.52	0.81	Relative decoupling
2013-2014	−0.73	−0.13	−0.87	No decoupling
2010-2014	−0.14	−0.28	−0.41	No decoupling

of each economic structure of industrial economy and industrial energy intensity on decoupling effect index or decoupling effect in 2010-2014 period in aggregate is presented in Table 2. The total decoupling index was negative (<0) for most of the study period, indicating that there was no decoupling effect between energy consumption and industrial economic activity. The decline in energy consumption derived from the inhibiting effect factor is less strong than the effect factor caused by the growth of industrial economic activity. That is, as industrial economic activity grows, energy consumption also increases. The inhibiting factors, that is, the economic structure of the industrial economy and the energy intensity of the industry have no role in reducing energy consumption and instead contribute to the increase of energy consumption along with the growth of industrial economic activity. In particular, in the period 2010-2011, 2011-2012 and 2013-2014, the increase in energy consumption is 5.5 million tce, 1.75 million tce and 3.68 million tce respectively with an average of 2.85 tce in the entire study period 2010-2014.

However, it should be noted that the decoupling index in the period 2012-2013 is 0.81 (0<D^T<1); it shows that there is a relative decoupling effect in this period, which means the growth of industrial economic activity acfirms the reduction of energy consumption. However, the reduction in energy consumption derived from inhibiting effect factors such as industrial energy intensity and industrial economic structure appears to be weaker than the effects of industrial economic activity. To that end, the Indonesian government is committed to reducing energy consumption by issuing Presidential Regulation no. 22 of 2017 on the National General Energy Plan. The government's energy efficiency target is to achieve a 17% reduction in energy consumption by 2025 (efficiency) projected from 2015 (BaU). To meet this target, the new action plan requires that 10-30% of the expected reductions occur in the industry (MEMR, 2016). Implementation of this commitment is very important because in the nindext period, 2013-2014, the decoupling index again becomes negative.

Figure 4: Decomposition of energy consumption change by industrial sub-sector low energy intensive (LEIs). Period: 2010-2014
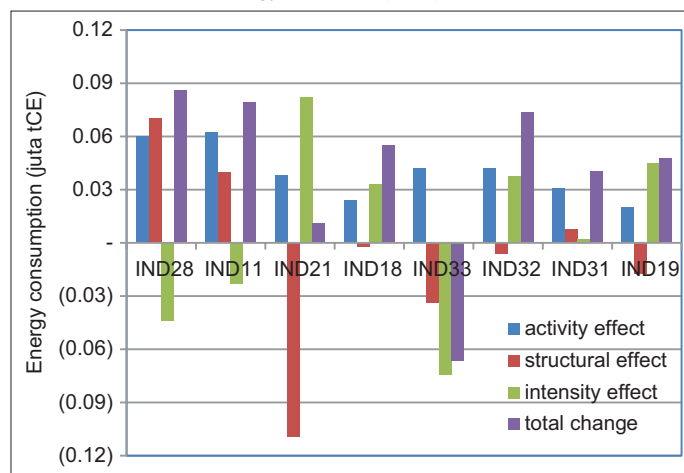
The effect of changes in industrial energy intensity on decoupling (D_{int}) is negative during 2010-2014, which implies that decoupling between energy consumption and economic activity or growth in manufacturing industry economic activity has not occurred. Overall D_{int} accounted for 67.22% of total decoupling index (D_{tot}) during 2010-2014. In particular, the contribution of industrial energy intensity fluctuates in the decoupling process, emerging significantly in the period 2011-2012 and 2012-2013 with relative decoupling effects over other periods. In 2011-2012, there has not been decoupling because it is not supported by industrial economic structure while in 2012-2013, decoupling is relatively due to the decrease of industrial energy intensity with index 0.52 and supported by industrial structure structure with index 0,3 (Table 2). This means that energy intensity is the most important energy inhibiting factor and the largest contributor to the decoupling process.

The effect of changes in the economic structure of the industrial economy on decoupling (D_{str}) is negative during the period 2011-2012 and 2013-2014. This suggests that the economic structure of the industrial economy does not contribute to the decoupling between energy consumption and economic activity or the growth of the manufacturing industry's economic activity. During the period 2010-2011 and 2012-2013, the effect of changes in the economic structure of the industrial economy in positive decoupling is 36.27% of the total index. The effect of changes in the economic structure of the industrial economy on decoupling is relatively weak against the effect of industrial energy intensity, which represents only 32.78% of the total index over the period 2010-2014.

Finally, there is a relative decoupling effect between energy consumption and growth in industrial activity of Indonesia in the period 2012-2013, although in other periods it does not occur (Table 2). This shows that the growth of industrial economic activity that affects decoupling over time. Therefore, it is important to utilize the target factors that contribute to the decoupling of energy consumption and the growth of industrial sector economic activity. So the Indonesian government must take effective measures to reduce energy intensity, change industry (industrial

economic structure), and support the transition of economic change to low carbon energy sources.

4.4. Results of Decoupling Analysis by Sub-sector

The result of decoupling analysis of energy consumption and industrial economic activity of Indonesia and the influence of decoupling of industrial economic structure and industrial energy intensity on decoupling index or decoupling effect in detail of industrial sub-sector in 2010-2014 period is shown in Table 3. Most of the total decoupling index is negative (<0) except for textiles (13), basic metals (24), metal goods, not machineries (25), garments (14), leather and footwear (15), pharmaceuticals (21), and repair and installation services (33) which is positive (>0). Sub-sectors that have a positive decoupling index are valued between 0 and 1; and there is a value>1. The sub-sectors whose decoupling index is worth between 0 and 1 are textiles (13), basic metals (24), garments (14), and pharmaceuticals (21) and sub-sectors of which decoupling value >1 is metal goods, not machinery (25), leather and footwear (15) and repair and installation machinery (33).

The textile sub-sector (13), basic metals (24), garments (14), and pharmaceuticals (21) show a relative decoupling effect between energy consumption and industrial economic activity, which means growth in industrial economic activity accompanied by decreased consumption energy, although the decline in energy consumption derived from the inhibiting effect factor is still weaker than the effect factor caused by the growth of industrial economic activity. While metal goods, not machineries (25), leather and footwear (15) and repair and installation services (33) show the absolute decoupling effect between energy consumption and industrial economic activity which means decreased energy consumption derived from more inhibiting effect factors stronger than the effect factor caused by the growth of industrial economic activity. Industrial economic activity grows, energy consumption decreases. The inhibiting factors, that is, the economic structure of the industrial economy and the energy intensity of the industry have contributed in reducing energy consumption even though each sub-sector is different. The contribution of these two inhibiting factors is in the sub-sectors of basic metals (24), metal goods, not machinery (25), garments (14), leather and footwear (15), repair and installation services (33) in sub sector tindextile (13) the main contribution is energy intensity and in sub sector pharmaceuticals (21) the main contribution is industrial economic structure.

5. CONCLUSIONS AND IMPLICATIONS

The aggregate results show that changes in total energy consumption fluctuate but tend to increase in the period 2010-2014. This fluctuation is caused by the main drivers of the dynamics of energy consumption, namely changes in industrial economic activity (output) and industrial energy intensity. This result can be explained by the increase in the level of economic activity (output) is high and unstable and even low increase in energy intensity (efficiency of energy) or it can be said efficiency has not happened. This is an important fact because it shows that decoupling between industrial economic activity (output) and energy consumption does not occur. Thus, the possibility of energy consumption will

Table 3: Results of decoupling effect by sub-sector

Sub-sector indindustry (ISIC 2 digit)	D_{str}	D_{int}	D_{tot}	Decoupling effect
Non-metallic minerals (23)	−0.72	0.17	−0.55	No decoupling
Food (10)	−0.48	0.10	−0.38	No decoupling
Chemicals (20)	−0.06	0.03	−0.03	No decoupling
Tindextile (13)	−0.27	1.03	0.76	Relative decoupling
Rubber and Plastic (22)	0.54	−2.34	−1.81	No decoupling
Paper (17)	0.43	−0.75	−0.32	No decoupling
Electrical equipment (27)	−1.08	−0.58	−1.65	No decoupling
Basic metals (24)	0.56	0.04	0.60	Relative decoupling
Metal goods, not machinery (25)	0.34	0.69	1.04	Absolute decoupling
Garments (14)	0.04	0.38	0.42	Relative decoupling
Motor vehicles and trailers (29)	0.33	−2.59	−2.26	No decoupling
Wood, bamboo, and rattan (16)	0.20	−0.65	−0.45	No decoupling
Computers, electronics and optics (26)	0.09	−0.44	−0.35	No decoupling
Tobacco processing (12)	−0.07	−1.81	−1.88	No decoupling
Other transport equipment (30)	0.58	−1.86	−1.28	No decoupling
Leather and footwear (15)	0.25	1.43	1.68	Absolute decoupling
Machinery and equipment (28)	−1.17	0.74	−0.43	No decoupling
Beverage (11)	−0.64	0.36	−0.27	No decoupling
Pharmaceuticals and medicine products (21)	2.87	−2.16	0.72	Relative decoupling
Printing and reproduction media (18)	0.08	−1.38	−1.30	No decoupling
Repair and installation machinery (33)	0.80	1.78	2.58	Absolute decoupling
Other Processing (32)	0.14	−0.89	−0.76	No decoupling
Furniture (31)	−0.24	−0.06	−0.30	No decoupling
Products from coal and petroleum (19)	0.87	−2.24	−1.37	No decoupling
Total	−0.14	−0.28	−0.41	No decoupling

continue to increase when the economic activity of the industry increases. Therefore, to achieve and realize the occurrence of decoupling, energy efficiency policy must be implemented and realized in more detail and carefully.

More detailed results are based on sub-sectors. The role played by potential energy intensity factors varies across industry sub-sectors. Therefore, energy efficiency policies that take into account the specific behavior of firms in each sub-sector need to be addressed. To date, the Indonesian energy agenda considers only a single, homogeneous energy efficiency policy for the industry as a whole. Our results show that focusing policies on the most energy-intensive and least efficient firms, the non-metallic minerals sub-sector (23) will be cheaper and more efficient. Cogeneration is one of the policies considered by the government; however, each sub-sector requires completely different cogeneration technologies.

The IDA (LMDI) method provides a detailed overview of industrial energy consumption in Indonesia. Different corporate characteristics can help policy makers to focus energy efficiency policies in the future only on certain sub-sectors, the most intensive and inefficient firms. Different policies should reduce implementation and targeted costs. However, different policies can face several obstacles. The application of policies to particular groups can be seen as an injustice to some firms. The policymaker must balance the benefits with the target. Mandatory energy efficiency targets should be applied to specific sub-sectors. Corporate identification is another challenge of different policies. However, as sustainable development has become an important global topic, the Indonesian government should not only focus on economic efficiency but also improve energy conservation and environmental quality. Based on the results obtained in this study, the strategic measures for sustainable development should aim

to (1) Reduce the intensity of energy consumption, especially in the energy-intensive industrial sector, (2) promote shifting industrial to industrial structures with less energy intensive, (3) promoting low-carbon energy sources in energy mixed structures, and (4) encouraging the import of energy-dense products.

6. ACKNOWLEDGMENT

REFERENCES

Ang, B.W. (2004), Decomposition analysis for policy making in energy: Which is the preferred method. Energy Policy, 32(9), 1131-1139.

Ang, B.W. (2005), The LMDI approach to decomposition analysis: A practical guide. Energy Policy, 33(7), 867-871.

Ang, B.W., Liu, N. (2001), A new energy decomposition method: Perfect in decomposition and consistent in aggregation. Energy Journal, 26, 537-548.

Ang, B.W., Liu, N. (2007), Handling zero values in the logarithmic mean divisia index decomposition approach. Energy Policy, 35(1), 238-246.

Choi, K.H., Ang, B.W. (2010), Attribution of changes in divisia real energy intensity index-an indextension to index decomposition analysis. Energy Economics, 34, 171-176.

Climent, F., Pardo, A. (2007), Decoupling factors on the energy-output linkage: The Spanish case. Energy Policy, 35, 522-528.

Diakoulaki, D., Mandaraka, M. (2007), Decomposition analysis for assessing the progress in decoupling industrial growth from CO_2 emissions in the EU manufacturing sector. Energy Economics,

29(4), 636-664.

Duran, E., Aravena, C., Aguilar, R. (2015), Analysis and decomposition of energy consumption in the Chilean industry. Energy Policy, 86, 552-561.

Enevoldsen, M.K., Ryelund, A.V., Andersen, M.S. (2007), Decoupling of industrial energy consumption and CO_2 emissions in energy-intensive ustries in Scandinavia. Energy Economics, 29(4), 665-692.

Freitas, L.C., Kaneko, S. (2011), Decomposing the decoupling of CO_2 emissions and economic growth in Brazil. Ecological Economics, 70(8), 1459-1469.

International Energy Agency (IEA). (2011), Energy Efficiency Policy Recommendation. Paris: International Energy Agency.

International Energy Agency (IEA). (2014), Energy Efficiency Icators: Essentials for Policy Making. Paris: International Energy Agency.

ISIC. (2009), Indonesian Standard Industrial Classification (ISIC). Indonesia.

Lim, H., Yoo, S., Kwak, S. (2009), Industrial CO_2 emissions from energy use in Korea: A structural decomposition analysis. Energy Policy, 37, 686-698.

Liu, L.C., Fan, Y., Wu, G., Wei, Y.M. (2007), Using LMDI method to analyze the change of China's industrial CO_2 emissions from final fuel use: An empirical analysis. Energy Policy, 35, 5892-5900.

Liu, N., Ang, B.W. (2007), Factors shaping aggregate energy intensity trend for industry: Energy intensity versus product mix. Energy Economics, 29, 609-635.

Ma, C., Stern, D.I. (2008), China's changing energy intensity trend: A decomposition analysis. Energy Economics, 30, 1037-1053.

Ministry of Energy and Mineral Resouce (MEMR). (2016), Handbook of Energy and Economic Statistics of Indonesia (HEESI). Indonesia: Ministry of Energy and Mineral Resouce.

Ministry of Energy and Mineral Resouce (MEMR). (2018), Handbook of Energy and Economic Statistics of Indonesia (HEESI). Indonesia: Ministry of Energy and Mineral Resource.

Ministry of Industry (MI). (2012), Green Industry Development Master Plan (GIDMP). Indonesia: Ministry of Industry.

Organisation for Economic Co-operation and Development (OECD). (2002), Indicators to Measure Decoupling of Environmental Pressure from Economic Growth. Sustainable Development. Paris: OECD Publications.

Reddy, B.S., Ray, B.K. (2011), Understanding industrial energy use: Physical energy intensity changes in ia manufacturing sector. Energy Policy, 39, 7234-7243.

Shao, S., Yang, L., Yu, M., Yu, M. (2011), Estimation, characteristics, and determinants of energy-related industrial CO_2 emissions in Shanghai (China), 1994-2009. Energy Policy, 39, 6476-6494.

Statistics Indonesia. (2016), Indonesia's Annual Large-Scale Statistics Indonesia. Indonesia.

Su, B., Ang, B.W. (2012), Structural decomposition analysis applied to energy and emissions: Some methodological developments. Energy Economics, 34(1), 177-188.

Tunç, G.I., Türüt-Ask, S., Akbostancı, E. (2009), A decomposition analysis of CO_2 emissions from energy use: Turkish case. Energy Policy, 37, 4689-4699.

Wang, W., Liu, R., Zhang, M., Li, H. (2013), Decomposing the decoupling of energy-related CO_2 emissions and economic growth in Jiangsu Province. Energy for Sustainable Development, 17(1), 62-71.

Xu, X.Y., Ang, B.W. (2014), Multilevel index decomposition analysis: Approaches and applications. Energy Economics, 44, 375-382.

Zhang, Y., Da, Y. (2015), The decomposition of energy-related carbon emission and its decoupling with economic growth in China. Renewable and Sustainable Energy Reviews, 41, 1255-1266.

Zhong, T.Y., Huang, X.J., Han, L., Wang, B.Y. (2010), Review on the research of decoupling analysis in the field of environments and resource. Journal Natural Resource, 25, 1400-1412.