ENERGY
DOI: 10.24910/jsustain/5.2/2129

International Journal
Sustainable Future for Human Security
J-SustaiN Vol. 5 No. 2 (2017) 21-29
http://www.j-sustain.com

The Identification of Key Sector in CO_2 Emissions in Production Perspective of Indonesia: An Input-Output Analysis

Muhammad Handry Imansyah [a*], Titi Putranti[b]

[a]Lambung Mangkurat University, Jl Brigjen H. Hasan Basry, Banjarmasin 70123, Indonesia
[b]University of Indonesia, Depok Campus, Depok , Indonesia

Received: September 28, 2015 / Accepted: December 5, 2017

Abstract

The objective of this paper is to identify the key sector of CO_2 emissions in the production sectors of Indonesia using input-output analysis. CO_2 emissions are one of the major contributors of climate change and global warming. Indonesia, as one of the emerging market economies, is accelerating its development and as a result, manufacturing sectors have developed rapidly. Most of the energy used in these sectors comes from non-renewable energy such as oil and coal. However, there is limited knowledge and details of which sectors are contributing high CO_2 emissions and how sensitive they are to income change.

The method used for this study looks at the supply perspective which can measure the impact of an increase in the value added of different productive sectors on total CO_2 emissions. It can also identify the productive sectors responsible for the increase in CO_2 emissions when there is an increase in the value added of the economy. The data used are based on Input-Output Energy Tables of 1990, 1995 and 2010.

During the 15 years of 1995-2010, the contribution of CO_2 emissions in the ten key sectors increased significantly from 39.57% of total emissions in 1995 to 89.75% of total emissions in 2010. During these periods, the trend shows that three sectors are still in the ten most sensitive sectors in CO_2 emissions due to income change, crude oil and natural gas, coal and petroleum refinery products.

The implication of the results of this study is to make appropriate policy for reducing CO_2 emissions by using the most efficient technology in those sensitive manufacturing sectors. With regard to this phenomenon, fiscal incentives and disincentives might be used to drive business community in manufacturing sectors to use the most efficient energy systems and low carbon energy sources.

Keywords: *CO_2 emission, key productive sector, input-output analysis.*

1. Introduction

There is still a debate whether economic growth and CO_2 emissions have a positive relationship. Appropriate policy will help sustainable development by reducing CO_2 emissions. The reduction of CO_2 emissions related to sustainable development as the increase of CO_2 emissions will cause global climate change. The implementation of target CO_2 reduction based on the Paris Climate Change Summit will keep global rises to ≤ 2° C (Wagner et.al. 2006 [1]. CO_2 emissions are the major factor of GHG (green house gas) which is the cause of climate change (Cioca, et. Al. 2015 [2]. Therefore, CO_2 reduction will influence climate change significantly. Some researchers showed that CO_2 emissions are not sensitive to average economic growth (Holtz-Eakin and Seldena, 1995 [3]; Zhan and Cheng, 2009[4]). However, to some extent, there is diminishing marginal propensity to emit (MPE) carbon dioxide as GDP per capita rises [3]. On the other hand, Zhan and Cheng (2009) found that neither carbon emissions nor energy consumption leads to economic growth in China [4].

Fei, Donga, Xuea, Liang, and Yang (2011) showed that there is a positive long-run relationship between real GDP per capita and CO_2 emissions [5]. It generally seemed that carbon emissions will increase as income grows via demand for carbon-intensive goods and services like air transport and also car transport in many developing countries (Giorgetti, 2007[6]).

Indonesia as a developing country, of course, faces similar problems to other developing countries. Imansyah et. al. (2013) found that the growth of CO_2 emissions during 1990-1995 is 92.82%, from 33,704.31 thousand tonnes to 64,987.37 thousand tonnes [7]. The acceleration of economic development to achieve a higher GDP growth in order to increase income of people can cause a higher CO_2 emission.

The Government of Indonesia made a National Action Plan on Green House Gas Reduction and set up the greenhouse gas reduction target of 26% in 2020 with national action of self-effort and to 41% reduction with international support. One of these efforts is to reduce emissions from major contributors in the manufacturing industry. The Ministry of Industry has identified eight manufacturing sectors that contribute the highest towards CO_2 emissions, namely, cement, steel, pulp and paper, petrochemical, fertilizer, ceramic, textiles, and food and beverage sectors, each of which consume more than 6000 TOE [7]. Therefore, these eight sectors were determined as sectors to be the highest priority for CO_2 reduction.

* Corresponding Author: Phone: +628118838200; E-mail: mhandryi@indo.net.id

However, it should not only be the highest contributing sectors that are the target of policy action, but also the most sensitive sectors of CO_2 emissions due to the increase of income.

Generally, the identification of key sectors of CO_2 emissions can help policy makers create climate change mitigation policies. The objective of this paper is to identify the most sensitive sectors of CO_2 emissions due to the increase of income or value added. The period of study is 1990-1995 and 1990-2010.

2. Literature Review

The energy use of carbon-based fuel has become a major concern in recent years because the CO_2 emissions are the key factor in the greenhouse effect and the resulting climate change. Much research has tried to identify the production structure using energy of carbon-based fuel to estimate the contribution of CO_2 emissions of energy use by using input-output analysis (see for example Tunç, Türüt-Aık and Akbostancı [8]; Alcántara and Padilla [9]; Mukhopadhyay [10], [11]).

Input-output analysis is a powerful analytical tool that can be used to estimate the contribution of CO_2 as well as the impact of energy use in CO_2 emissions in disaggregated sectors. There have been many studies conducted to analyze energy use and the impact of CO_2 emissions in the input-output analysis context (see Lee, Lin and Lewis [10]; Casler and Rose [14]; Matthews, Weber and Hendrickson [15]; Hondo, Sakai and Tanno [16]; Hikita, Shimpo and Shukla [17]). However, the studies varied in terms of approach, sectors and region.

Mukhopadhyay [10] studied the sources of CO_2 emissions changes in India and found that CO_2 emissions from coal consumption account for almost 65%. He also found that the primary factors for the increase of CO_2 emissions changes by the rate of added value and changes in final demand during 1973-74 to 1996-1997. However, he argued that the effects of CO_2 intensity observed was a reducing factor. Indonesia has the fourth largest population in the world which becomes an important factor when considering CO_2 emissions. Indonesia as a developing country, of course, will face high demand for energy to accelerate its development. Consequently, CO_2 emissions will increase significantly if there is no technology development in reducing CO_2 emissions or in energy saving. The price of energy also plays an important role in reducing energy use. For example, during the financial crisis, the use of energy declined substantially and consequently the CO_2 emissions dropped. However, this is not the case in the long run, as Indonesian development needs more energy. Based on the estimation of Boden, Marland and Andres [12] from Carbon Dioxide Information Analysis Center, the increase of CO_2 emissions per capita was significant, even though the CO_2 emissions per capita are relatively low compared to those of other developed countries and emerging market economies. Therefore, Indonesia has to reduce CO_2 emissions by using energy saving technology or introducing renewable energy sources.

In Spain, Alcantara and Padilla [9] found that the productive sectors that deserve more attention are electricity and gas, land transport, manufacture of basic metals, manufacture of non-metallic mineral products, manufacture of chemicals, manufacture of coke, refined petroleum products and nuclear fuel, wholesale and retail trade, and agriculture. These sectors are the key sectors of CO_2 emissions. In Brazil, Imori and Guilhoto [18] also found that the key sectors cover machinery industries, electric equipment, transportation equipment, textiles and construction sectors.

Meanwhile, Indonesia faces a lack of energy supplies such as electricity to accelerate the development. The result of development is the increase of income. However, the increase of income causes the increase of energy use as well. Alcantara and Padilla [9] found that the increase of income cause increasing energy demand as well as the increase of CO_2 emissions. Therefore, the policy of generating income should take into account the design of energy and the impact of CO_2 emissions. Grubb, Butler and Feldman [19] argued that there is a relationship between income and CO_2 emissions. However, they found that the relationship between income and CO_2 emissions is highly complex and cannot be generalized. On one hand, they found that the growth of GDP per capita was likely to be associated with the growth of CO_2 emissions, and differ significantly depending on other factors specific to each country. On the other hand, the growth of income and CO_2 emissions in OECD countries has been stabilizing. Therefore, the results are mixed. In the case of Turkey, the domestic production process contributed to 66% of CO_2 emissions in 1996 and sectors that most responsible for those emissions are the manufacturing industry, energy and mining, other services, and agriculture and animal husbandry (Tunç, Türüt-A_ık and Akbostancı [8]). Technology plays an important role in reducing CO_2 emissions in the production process. Okushima and Tamura [20] found that technological change is of great importance for curtailing energy use and CO_2 emissions in Japan. They argued that CO_2 emissions increased during 1970-1995 primarily because of the economic growth. In contrast, the effects such as technological change for labor or energy mitigated the increase in CO_2 emissions. Meanwhile, foreign trade may contribute to CO_2 emissions like in Brazil due to trade liberalization (Machado [21]).

In the US, CO_2 emissions decreased by 2.38% during 1972 and 1982 (Casler and Rose [14]). However, the use of a more pollutant energy source like coal increased. The result is not a good example for a developed country that should use less polluting energy sources in their production processes. Their finding also provided some doubt on the strength of autonomous conservation. The actual conservation was more due to price pressure rather than previously thought during 1972 to 1982. They indicated that even though economic growth alone would have generated an increase in CO_2 emissions, this source was offset by the changes in the mix of final demand, inter-fuel substitution, and the KLEM (capital labor energy material) substitution.

Regarding the Indonesian context as one of the emerging market economies, the energy use with a lower price energy source due to subsidy is a rational choice in its policy. In contrast with the US case as a developed country that is still using a lower price energy source like coal, Indonesia is likely to follow this pattern as well. Therefore, a precise identification of the energy use will help policy makers to adopt an appropriate policy to reduce CO_2 emissions especially in the key sectors of CO_2 emissions.

3. Methodology

An input-output table is a description of the linkages between sectors, i.e. transactions between sectors, as reflected by the flow / movement of goods between sectors or between the input transactions (e.g. from sector j to sector i). Intra-sector flows can also occur, i.e. from sector i to i itself.

For example:

Xi is the total output of sector i,

zij is the dollar value of the flow of goods or the value of the transaction - from sector i to sector j

Yi is the total final demand for sector i.

If there are n sectors in the economy then;

Xi = zi1 + zi2 + zi3 + . . . zin + Yi

There are n-unit (i.e. n-rows) equations as above, which can be expressed in a system such as the following:

$$\begin{aligned} X_1 &= z_{11} + z_{12} + .. + z_{1n} + Y_1 \\ X_2 &= z_{21} + z_{22} + .. + z_{2n} + Y_2 \\ &. \\ .X_n &= z_{n1} + z_{n2} + .. + z_{nn} + Y_n \end{aligned} \quad (1)$$

- The rows represent the structure of the intermediate output distribution of each sector between the user and the end user
- The columns represent the distribution of input between each sector.

Table 1 General Form of Input-Output Transaction Table

		Production Sector		Final Demand				Total Output
		1	2	C	I	G	E	X
Production	1	z11	z12	C1	I1	G1	E1	X1
Sector	2	z21	z22	C1	I2	G2	E2	X2
Value	**L**	L1	L2	Lc	Li	Lg	Le	L
Added	**N**	N1	N2	Nc	Ni	Ng	Ne	N
Imports	**M**	M1	M2	Mc	Mi	Mg	Me	M
Total Input	**X**	X1	X2	C	I	G	E	X

There are 3 base matrices as follows:

$$Y = \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} C_1 + G_1 + I_1 + E_1 \\ C_2 + G_2 + I_2 + E_2 \end{bmatrix} \quad (2)$$

$$W = \begin{bmatrix} L_1 & L_2 \\ N_1 & N_2 \end{bmatrix} \quad (3)$$

$$Z = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix} \quad (4)$$

- All the information about the structure of production input and output tables have been placed
- The table is an image of the economy at a particular point in time
- input-output coefficients or any other name is are direct input coefficients:

$$a_{ij} = \frac{z_{ij}}{X_j} \quad (5)$$

- Suppose $a_{32} = 0.3$, it means that to produce each 1 dollar output in sector 2, it needs intermediate input from 3 at 30 cents.
- Therefore, the technology matrix is as follows:

$$A = \begin{bmatrix} a_{11} & a_{12} & .. & a_{1n} \\ a_{21} & a_{22} & .. & a_{2n} \\ .. & .. & .. & .. \\ a_{n1} & a_{n2} & .. & a_{nn} \end{bmatrix} \quad (6)$$

- If there are *n* sectors, it will be an *nxn* matrix of input-output coefficients aij.
- All of the coefficients are shown in Matrix A.
- One of the calculations of input-output coefficients is as follows:

$$a_{ij} = \frac{z_{ij}}{X_j} \Leftrightarrow z_{ij} = a_{ij} X_j \quad (7)$$

zij = aij . Xj

With some manipulation, the previous equation can be rewritten as the following:

$$\begin{bmatrix} 1-a_{11} & -a_{12} & \dots & -a_{1n} \\ -a_{21} & 1-a_{22} & \dots & -a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ -a_{n1} & -a_{n2} & \dots & 1-a_{nn} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix} \quad (8)$$

or it can be rewritten in matrix form as follows:

$$\mathbf{(I - A)X = Y} \quad (9)$$

Alcantara and Padilla's method [9] will be used in the analysis of the paper. This method can identify the key sector of CO_2 emissions. This concept is derived from the concept of the key sector of Rasmusen [22] and Hirschman [23]. Based on that concept, the key sectors are regarded as the highest impact determined by the multiplier effects of final demand. However, the concept of Alcantara and Padilla [9] emphasizes on the supply perspective rather than demand perspective. This approach identifies the relationship between CO_2 emissions and income generation (in this term, the value-added generated inside a country). The term 'key sectors' means the highest impact on CO_2 emissions due to the increase of income (value-added).

By using this method, one can identify the most sensitive sector in producing CO_2 emissions due to the rise of income.

This concept is based on the concept of elasticity. This method was adapted from Alcántara and Padilla [9] with the parameter and variable as follows:

x: (n x 1) total production vector.

v: (n x 1) valued added vector.

A: (n x n) technical coefficient matrix.

s: (n x 1) value added coefficient matrix. This is to show the relationship between the value added from sector i (vi) and production of sector i; that is: vi/xi.

u: (n x 1) unitary vector.

c: (n x 1) vector of sectoral direct emissions.

C: scalar that shows level of total CO_2 emission

^: diagonal vector, it denotes a matrix whose out-of-the diagonal elements are zeros.

'indicates the transpose matrix or vector.

The input-output table used in this paper is based on the development by BPS (Central Statistics Agency). The most recent energy input-output tables available are from 1990, 1995 and 2010. As discussed previously, the discussion is based on the supply side input-output table. Therefore, the identity of the supply equation is as follows:

$$x = \hat{x}A'u + v \quad (10)$$

Both sides of (10) are divided by $\hat{x}^{-1}$ then, the following can be obtained:

$$u = A'u + s \quad (11)$$

This can be written as follows:

$$u = (I - A')^{-1} s \quad (12)$$

Those expressions are related to production sectors. The distribution is based on productive structure and the weight of income produced from related production itself. If **c** is a vector denoting the emissions of CO_2 as defined previously and if both sides of equation 3 are multiplied by vector **c**, the following will be obtained:

$$c = \hat{c}(I - A')^{-1} s \quad (13)$$

If **g**' = (g1, ..., gn) is the distribution of total emissions to all productive sectors *n*, then $\sum_{i=1}^{n} g_i = 1$

Then vector **c** can be rewritten as follows:

$$c = Cg \quad (14)$$

Then

$$c = C\hat{g}(I - A')^{-1} s \quad (15)$$

By multiplying both side of (6) with **u**', the following can be obtained:

$$C = Cg'(I - A')^{-1} s \quad (16)$$

The proportionality of α in value added will cause, *ceteris paribus*, the increase in total emissions is:

$$\Delta C = Cg'(I - A')^{-1} s\alpha \quad (17)$$

By dividing both sides with total emissions of C, then:

$$C^{-1}\Delta C = g'(I - A')^{-1} s\alpha \quad (18)$$

By diagonalizing **s** in (18) the following vector will be obtained:

$$\varepsilon' = g'(I - A')^{-1} \hat{s}\alpha \quad (19)$$

The characteristic of element εj shows the proportional change in (direct and indirect) total sectoral emissions related to the proportional change of income. This can be interpreted as elasticity. In fact, proportional change of α in income is equal to the ratio of Δvi/vi for each sector. Thus, ε′ vector can be rewritten as follows:

$$\varepsilon_i = \frac{\Delta C / C}{\Delta v_i / v_i} = \frac{\Delta C}{\Delta v_i}\frac{C}{v_i} \quad (20)$$

Therefore, the elements of the vector obtained from equation (19) represent the proportional change of total emissions if any percentage change occurs in value added of each sector. In other words, income elasticity of total emissions can be regarded as a measurement of sectoral impact. For a more accurate interpretation, g vector should be diagonalized and it is assumed that α = 1%:

$$E^v = \hat{g}(I - A')^{-1}\hat{s} \quad (21)$$

Characteristic of matrix element E^v, E^v_{ij}, shows the percentage increase of emissions in sector i (to total emission) in response to 1% increase of value added which is produced in sector j and can be interpreted as elasticity.

The summation of column vector $\sum_i^n E^v_{ij}$ j represents the percentage variation in CO_2 emissions that is expressed in the economy due to 1% growth of value added in sector j (total impact). The summation of each sector`s emissions (direct impact) $\sum_j^n E^v_{ij}$ shows the sectoral distribution of emissions as an indicator of the impact that 1% increase of total impact can cause on emissions of each sector (direct impact). The data of this research is based off the Energy Input-Output Table 1990, 1995 and 2010 produced by Central Statistics Agency.

4. Empirical Result

The ten highest sectors in production value contributed 55.75% to total production out of 76 sectors in 1990. The ten sectors contributed 47.33% to total CO_2 emissions. Meanwhile, in 1995, the contribution of the highest 10 sectors in production value was 49.09% while the contribution of CO_2 emissions in these sectors was only 29.34%. In 2010, however, the contribution of CO_2 emissions of these sectors was only 1.71%. This means that there was an improvement in production technology of those sectors during 15 years since 1995. Even though there was a relative improvement, in absolute value there was a significant increase of 36 fold from 19,069,288 tons in 1995 to 10,373,638,472 tons in 2010 for the highest 10 sectors of production value.

Table 1 Percentage Production Value, Final Demand and CO_2 Emissions in 1990

Rank	Sector	Production Value	Final Demand	CO_2 Emission
1	Other foods	13.78%	9.79%	1.83%
2	Buildings	9.92%	7.20%	8.16%
3	Civil engineering	6.97%	6.77%	12.76%
4	Petroleum refinery	5.08%	1.66%	2.01%
5	Eating and drinking place	4.34%	4.44%	1.95%
6	Spinning and weaving	3.77%	1.84%	1.97%
7	Crude oil and Natural gas	3.48%	8.29%	1.25%
8	Commerce	3.09%	7.06%	2.78%
9	Timber & Wooden	2.69%	1.77%	5.79%
10	Road transport	2.63%	2.61%	8.84%
	Total	55.75%	51.43%	47.33%

Source: BPS, Input-Output Energy Table 1990, calculated by authors.

Table 2 Percentage of Production Value, Valued Added, Final Demand and CO_2 Emissions in 1995

Rank	Sector	Production Value	Final Demand	CO_2 Emission
1	Other foods	12.83%	10.16%	3.52%
2	Buildings	8.22%	6.70%	5.10%
3	Civil engineering	6.60%	7.51%	6.44%
4	Eating and drinking place	4.53%	4.56%	1.70%
5	Commerce	3.68%	7.21%	2.92%
6	Spinning and weaving	3.52%	1.77%	2.47%
7	Timber and Wooden products	2.84%	1.42%	4.68%
8	Business services	2.39%	1.56%	1.50%
9	Petroleum refinery products	2.32%	0.75%	0.71%
10	Financial and insurance services	2.17%	2.74%	0.30%
	Total	49.09%	44.39%	29.34%

Source: BPS, Input-Output Energy Table 1995, calculated by authors.

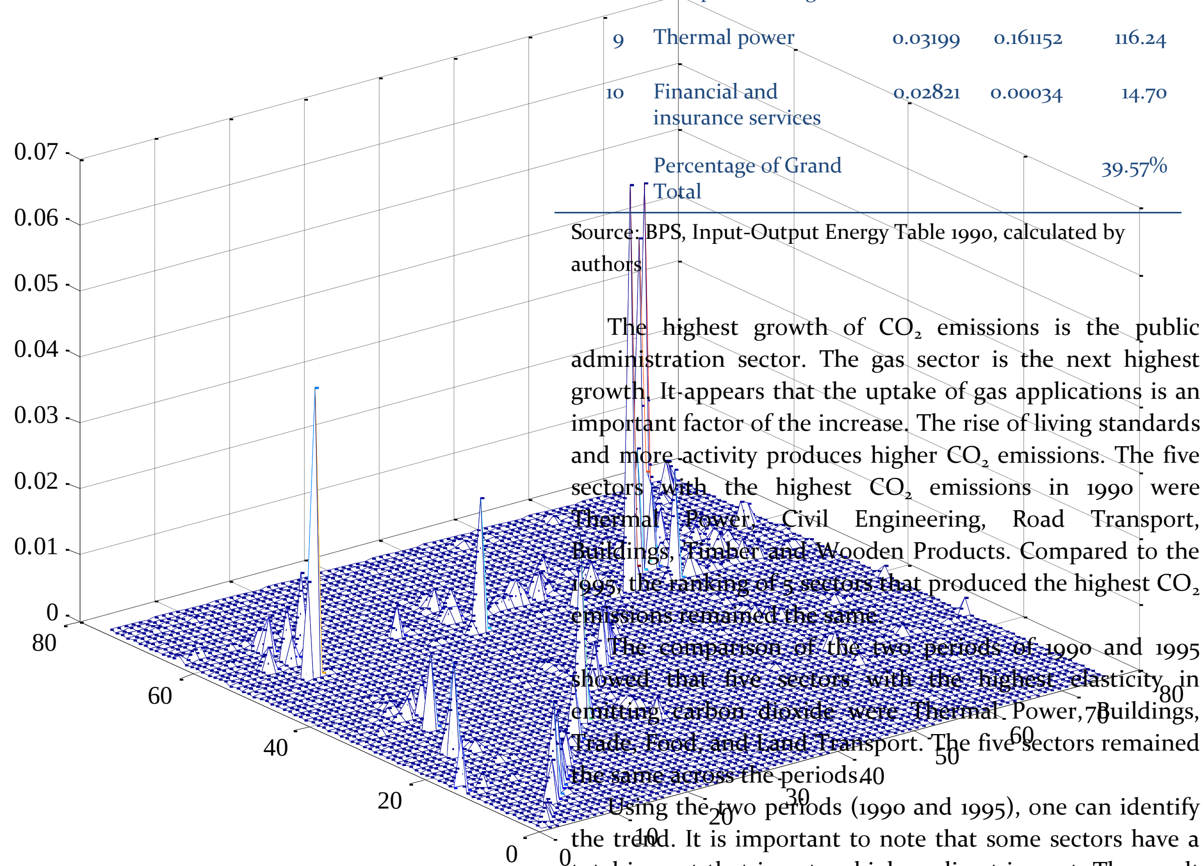
Table 3 Percentage of Production Value, Valued Added, and CO_2 Emissions in 2010

Ran k	Sector	Productio n Value	Value Adde d	CO_2 Emissio n
1	Civil engineering	10.58%	4.60%	0.28%
2	Other foods	10.58%	4.49%	0.04%
3	Buildings	9.23%	4.92%	0.12%
4	Commerce	5.61%	10.43%	0.28%
5	Oth. elect. machn. and apprts	3.59%	1.99%	0.06%

Table 5 The Key Sectors in CO_2 Emissions 1995

Rank	Sector	Total Impact	Direct Impact	CO_2 (000
1	Crude oil and Natural	0.25097	0.00222	1,890.74
2	Non-metallic ores	0.07963	0.00357	1,830.55
3	Business services	0.07605	0.00268	7.24
4	Coal	0.06900	0.02225	1,896.90
5	Commerce	0.06289	0.00100	58.89
6	Petroleum refinery	0.06103	0.00429	298.41
7	Road transport	0.03660	0.00892	56.88
8	Other transport and transport relating	0.03371	0.00216	48.17
9	Thermal power	0.03199	0.161152	116.24
10	Financial and insurance services	0.02821	0.00034	14.70
	Percentage of Grand Total			39.57%

Source: BPS, Input-Output Energy Table 1990, calculated by authors



The highest growth of CO_2 emissions is the public administration sector. The gas sector is the next highest growth. It appears that the uptake of gas applications is an important factor of the increase. The rise of living standards and more activity produces higher CO_2 emissions. The five sectors with the highest CO_2 emissions in 1990 were Thermal Power, Civil Engineering, Road Transport, Buildings, Timber and Wooden Products. Compared to the 1995, the ranking of 5 sectors that produced the highest CO_2 emissions remained the same.

The comparison of the two periods of 1990 and 1995 showed that five sectors with the highest elasticity in emitting carbon dioxide were Thermal Power, Buildings, Trade, Food, and Land Transport. The five sectors remained the same across the periods.

Using the two periods (1990 and 1995), one can identify the trend. It is important to note that some sectors have a total impact that is not as high as direct impact. The result of this phenomenon is the policy formulation to reduce CO_2 emissions. For example, Thermal Power is the sector with the highest elasticity. This sector ranked 9^{th} in the position in 1995. For example, thermal power has an elasticity of 0.03% in global impact but coal has higher elasticity of direct impact of 0.16% than that of the global elasticity.

In 1995, the ten most sensitive sectors of CO_2 emissions due to income change were Crude Oil and Natural Gas, Commerce, Thermal Power, Coal, and Wooden Furniture (Table 5). The percentage of CO_2 emissions of those sectors were 39.65% of the total. The total amount of CO_2 emissions of the ten most sensitive sectors were 25,766.77 thousand tonnes in 1995 which amounts to an increase of 89.19% compared to that of the ten most sensitive sectors in 1990 due to income change. However, the change of CO_2 emissions is 92.8%. This means that the ten most sensitive sectors dominated the change of CO_2 emission. This shows that the proportion is relatively stagnant. This is due to similar growth rates of all sectors during 1990-1995.

Civil Engineering sector experienced negative growth. This might be due to an improvement of production technology. On the other hand, Thermal Power sector increased significantly by 109.03% which is above the average growth (92.82%). The growth of the five sectors of the highest CO_2 emissions is only 55.81% (below the average). This indicated that there were relative improvements in production technology in CO_2 emissions on key sectors.

In 2010, five key sectors of the most sensitive for CO_2 emissions due to income change are Crude Oil and Natural Gas, Commerce, Thermal Power, Coal, Wooden Furniture, Non-Metallic Ores Mining, Petroleum Refinery Products, Forestry (Inc. Hunting) and Road Transport (Table 6). Percentage of CO_2 emissions is 89.75% of total CO_2 emission. The amount of CO_2 emissions of the ten most sensitive sectors is 10,373,638 thousand tonnes in 2010 which is an increase of 36 times the average during 15 years since 1995. This means that the ten most sensitive sectors did not dominate the change of CO_2 emissions compared to the period of 1990-1995.

During the 15 years of 1995-2010, the trend shows that three sectors are still in the ten most sensitive sectors in CO_2 emissions due to income change, Crude oil and Natural gas, Coal and Petroleum refinery products. These three sectors have global impact in the highest ten sectors during the period of 1995-2010. It is important to note that some sectors have high global impact such as Crude Oil and Natural Gas with the value of 0.23. This means that an income change of 1% will increase CO_2 emissions by 0.23%. Table 6 shows that most of Chemical Industry such as Chemical Manufacturing, Heavy Manufacturing and Cement Manufacturing are the sectors with the highest elasticity of CO_2 emissions due to income change. This means that the increase of income will increase CO_2 emissions due to the increase of those industries. Brazilian economic structure from productive sectors showed that the key sectors are similar with Indonesian economic structure, those are Transport, Agriculture, Metallurgy, Food Industries, Industrial Services of Public Utility, and Services, and coincidentally, the key sectors of productive and demand perspective are similar in Brazil [15].

Table 6 Key Sectors in CO_2 Emissions in 2010

Rank	Sector	Total Impact	Direct Impact	CO_2 (000) ton
1	Crude oil and Natural gas	0.23399	0.033	386,665
2	Metal ores mining	0.10255	0.000	143
3	Plastic products	0.07197	0.289	3,340,668
4	Other chemical products	0.07034	0.001	14,531
5	Other fab. metal products	0.06011	0.1553	1,795,450
6	Coal	0.05547	0.002	28,851
7	Cement	0.05174	0.125	1,453,896
8	Iron and steel products	0.04508	0.1815	2,097,960
9	Iron and steel	0.04130	0.108	1,255,434
10	Petroleum refinery prod.	0.03408	0.00000	36
	Percentage of total			89.75%

Source: BPS, Input-Output Energy Table 2010, calculated by authors.

5. Conclusion and Policy Implications

Generally, during 1990-1995, CO_2 emissions in the key sector decline slightly which dropped from 40.41% to 39.57% in 1995. Seven of ten sectors are still in the key sectors. These seven sectors are crude oil and natural gas, commerce, thermal power, coal, non-metallic ores mining, petroleum refinery products, and road transport. The comparison of two periods of 1990 and 1995 showed that 10 sectors with the highest elasticity in emitting carbon dioxide are Crude Oil and Natural Gas, Commerce, Thermal Power, Coal, Wooden Furniture, Non-Metallic Ores Mining, and Petroleum Refinery Products.

However, during the 15 years of 1995-2010, CO_2 emissions in the highest ten key sectors increased significantly from 39.57% in 1995 to 89.75% in 2010. During these periods, the trend shows that three sectors are still in the ten most sensitive sectors in CO_2 emissions due to income change, namely, Crude Oil and Natural Gas, Coal and Petroleum Refinery Products. These three sectors have global impact in the highest ten sectors during the period of 1995-2010. It is important to note that some sectors have high global impact such as Crude Oil and Natural Gas with the value of 0.23. This means that an income change of 1% will increase CO_2 emissions by 0.23%. The result shows that most of the Chemical Industry such as Chemical Manufacturing, Heavy Manufacturing and Cement Manufacturing are sectors with the highest elasticity of CO_2 emissions due to income change. This means that the increase of income will increase CO_2 emissions due to the increase of those industries. The implication of this research is that the high elasticity of CO_2 emissions industries should get more attention. Because these sectors provide significant influence on CO_2 emissions if an appropriate policy can be made. The restraint of rising global temperature to ≤ 2^o C as the target of Paris Climate Change Summit is important for sustainable development.

Therefore, policy makers should concentrate on sectors with high income elasticity of CO_2 emissions. This policy can be concentrated on business players, as they are producers of goods and services, to encourage the use of better technology to lower CO_2 emissions. Fiscal incentives or a carbon tax might be introduced to change producer behaviour in producing goods and services. It is suggested that demand perspective of the key sectors of CO_2 emissions should be identified as well in the future, to formulate an appropriate public policy to change consumer behaviour using goods and services which are environmentally friendly.

Acknowledgement

This research was assisted by Dean Affandi, Maria Tambunan, Nidaan Kafian, Buyung Airlangga, Rudiansyah, Suryadiningrat, and Budi Prawoto and funded by research grant of BOPTN for Faculty of Political and Social Sciences, University of Indonesia.

References

[1] Wagner, Liam, Ian Ross, John Foster and Ben Hankamer, *Trading O_ Global Fuel Supply, CO2Emissions and Sustainable Development,* MPRA Paper No. 69941, posted 16 March 2016 00:16 UTC, at https://mpra.ub.uni-muenchen.de/69941/

[2] Cioca, Lucian-Ionel, Larisa Ivascu, Elena Cristina Rada, Vincenzo Torretta and Gabriela Ionescu, *Sustainable Development and Technological Impact on CO2 Reducing Conditions in Romania*, in Sustainability, ISSN 2071-1050, at http://www.mdpi.com/journal/sustainability.

[3] Holtz-Eakin, Douglas, and Thomas M. Seldena. Stocking the fires? CO_2 emissions and economic growth, *Journal of Public Economics*, Volume 57, Issue 1, May 1995:85–101.

[4] Zhang, Xing-Ping, and Xiao-Mei Cheng. Energy consumption, carbon emissions, and economic growth in China, *Ecological Economics*, Volume 68, Issue 10, 15 August 2009:2706–2712.

[5] Fei , Li, Suocheng Dong, Li Xue, Quanxi Liang, and Wangzhou Yang. Energy consumption-economic growth relationship and carbon dioxide emissions in China, *Energy Policy*, Volume 39, Issue 2, February 2011:568–574.

[6] Giorgetti, Annabelle. A Discussion on decoupling economic growth from the emissions of carbon dioxide, *Environment Waikato Technical Report 2007/02*, at http://www.waikatoregion.govt.nz/PageFiles/6131/tr07-02.pdf. 2007.

[7] Imansyah, M. Handry et. al. The Key Sectors in CO2 Emissions in Indonesia: Input Output Analysis in *Jurnal Ilmu Administrasi dan Organisasi,* January 2013, accessed on 23 July 2014 at http://journal.ui.ac.id/index.php/jbb/article/viewFile/1867/1462 .

[8] Tunc, G. Ipek, Serap Turut-Asik and Elif Akbostanci. *CO2 emissions vs CO2 responsibility: an input-output approach for Turkish economy*, accessed on 23 July 2009 at http://www.erc.metu.edu.tr/menu/series06/0604.pdf. 2006.

[9] Alcantara, Vicent and Emilio Padilla. *An Input-Output Analysis of the "Key" Sectors in CO2 Emissions from a Production Perspective: An Application to the Spanish Economy*, accessed on 23 July 2009 at http://www.eacb.uab.es. 2006.

[10] Mukhopadhyay, Kakali. *Sources of CO2 Emissions Changes in India during 1973-74 to 1996-1997: A Structural Decomposition Analysis,* paper at 14th International Conference on Input-Output Techniques, October 10-15, 2002, Quebec University, Montreal Canada.

[11] Mukhopadhyay, Kakali.. *An Input-Output Study of the Relationship Between Information Sector, Energy Use and CO2 Emissions in the Indian Economy during 1973-74 to 1996-97*, paper at 14th International Conference on Input-Output Techniques, October 10-15, 2002, Quebec University, Montreal Canada.

[12] Boden, Tom, Gregg Marland and Robert J. Andres. *National CO2 Emissions from Fossil-Fuel Burning, Cement Manufacture and Gas Flaring: 1751-2006, Indonesia*, Carbon Dioxide Information Analysis Center, accessed on July 23 2009 at http://cdiac.ornl.gov/trends/emis/ido.html. 2009.

[13] Lee, Cheng, Sue J. Lin and Charles Lewis. Devising an Integrated Methodology for Analyzing Energy Use and CO2 Emissions From Taiwan's Petrochemical Industries, *in Journal of Environmental Management* , Vol. 63; 2001: 377-385.

[14] Casler, Stephen D and Adam Rose. Carbon dioxide emissions in the US economy: a structural decomposition analysis, *Environmental and Resource Economics*, April 1998, Volume 11, Issue 3-4; 1998: 349-363.

[15] Matthews, H. Scott, Christopher Weber, , Chris T. Hendrickson. *Estimating Carbon Footprints with Input-Output Models*, paper presented at International Input-Output Meeting on Managing the Environment in Seville (SPAIN), July 9 - 11, 2008. at http://www.upo.es/econ/IIOMME08.

[16] Hondo, Hiroki, Shinsuke Sakai and Shiro Tanno. Sensitivity Analysis of Total CO2 Emissions Intensities Estimated Using Input-Output Table, *Applied Energy*, Vol. 72. 2002: 689-704.

[17] Hikita, Koichi et. al. *Making Input-Output Tables for Environmental Analysis for India: 1993/94 and 1998/1999*, paper presented at the 16th International Input-Output. 2007.

[18] Imori, Denise and Joaquim Jose Martins Guilhoto. *Brazilian productive structure and CO2 emissions*, accessed on 3 March 2013 at http://mpra.ub.uni-muenchen.de/30695/ MPRA Paper No. 30695, posted 4. May 2011 20:45 UTC: 2010.

[19] Grubb, Michael, Lucy Butler and Olga Feldman. *Analysis of the Relationship between Growth in Carbon Dioxide Emissions and Growth in Income*, accessed on 23 July 2009, at http://www/econ.cam.ac.uk/faculty/grubb/publications/GA.pdf.

[20] Okushima, Shinichiro and Makoto Tamura. Multiple calibration decomposition analysis: Energy use and carbon dioxide emissions in the Japanese economy, 1970–1995, *Energy Economics*, Volume 32, Supplement 1, September 2010: S41–S46.

[21] Machado, Giovani Victoria. *Energy Use, CO2 Emissions and Foreign Trade: an IO Approach Applied to the Brazilian Case,*

paper at 13th International Conference on Input-Output Techniques, 21-25 August 2000, Macerata, Italy.
[22] Rasmussen, P.N. *Studies in Intersectorial Relations*, Amsterdam, North-Holland P.C.: 1956.
[23] Hirschman, A.O. (1958). *The Strategy of Economic Development*. New York: Yale University Press: 1958.