A Decomposition of Changes in the Energy Consumption of the Indonesian Manufacturing Sector during 1990-2008

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Abstract: Manufacturing sector is important and central to the economy. The growth of manufacturing machinery output, and technological changes in that machinery, are the main drivers of economic growth. In 1997, the Asian financial crisis hitall economic activities in Indonesia seriously. During period 1997-1998 the growths of the manufacturing sector Gross Domestic Product (GDP) and energy consumption were-13.1% and -0.79% respectively. An Index Decomposition Analysis (IDA) has been implemented to study the changes in energy consumption. Three factors contribute to the changes in energy consumption: economic activity or GDP, structure, and energy intensity effects. The Logarithmic Mean Divisia Index I method was selected due to its ease of use and ease of interpretation. The investigation was conducted on three time series periods: before (1990-1997), during (1997-2004), and after the Asian financial crisis (2004-2008). Results of this study show that the economic activity (GDP) effect was the major factor contributing to the change in manufacturing energy consumption. During the crisis in 1998, the energy consumption decreased due to the economic activity collapse. The second largest effect was the structure effect. The significant structure change happened at the beginning of the crisis from 1997 to 1999 where the food, water and tobacco subsector increased rapidly. However, in the same period the transport equipment, machinery and apparatus subsector decreased. At the start of the recovery period in 2004, the transport equipment, machinery and apparatus subsector surpassed the food, water and tobacco subsector and became the largest factor. The smallest factor contributing to the changes in the manufacturing sector energy consumption was the energy intensity effect. It was found that the energy efficiencies of the cement and mineral excavation subsector, the iron, metal, and steel subsector, and the wood product and forestry subsector after the crisis (2004-2008) were lower than before the crisis (1990-1997).

Keywords: Decomposition, LMDI I, Energy consumption, Indonesia.

1. Introduction

Starting in the period 1990-1997, the gross domestic product (GDP) of Indonesia grew with average rate 6.53%, unemployment average rate 4.19% and the manufacturing sector grew with average rate 13.65%. In the same period, the manufacturing sector was considered as the highest contributor with average share 19.14% [1-5]. In 1998, the Asian financial crisis affected Indonesian economy and the gross domestic product (GDP) of Indonesia fell drastically with growth rate -13.13% and unemployment rate 5.4%. In the same year, the manufacturing sector also fell with growth rate -13.10% and the manufacturing sector share was 22.38% [6]. In the period 2004-2008 after the crisis, the gross domestic product (GDP) of Indonesia returned to equilibrium and grew smoothly with average growth rate5.40%, unemployment average growth 9.78% while the manufacturing sector grew at average rate 5.57% and the manufacturing sector average share in the GDP was 25.05% [8-10].

Since the manufacturing sector is the biggest consumer of energy and its pattern of energy consumption has a great impact on the Indonesian economy, it is important to understand the energy consumption pattern of the manufacturing sector, from the past to the current situation. There are several factors which influence the change of energy consumption. These factors are identified by factor decomposition. In particular, the factors that have the main contributions are: economic changes (GDP), structural changes and sectorial energy intensity changes [11]. Economic changes (GDP) are measured in terms of levels of aggregate industrial output activity or GDP. Structural changes are measured by the shares or components of the economic or manufacturing sector activity. Sectorial energy intensity changes are given by the quantity of energy consumption needed to achieve a given level of output for each industrial sector. The changes in energy intensity occur in the opposite direction to energy efficiency, so that as energy intensity drops, energy efficiency increases. In 1995, B.W. Ang [12] conducted an analysis by the decomposition method of industrial energy demandand concluded that the application of the decomposition method helps to evaluate the effect of the factors influencing energy consumption.

It is important to investigate manufacturing sector with focus on 3 (three) time periods; before the Asian financial crisis (1990-1997), during the Asian financial crisis (1997-2004), and after the Asian financial crisis (2004-2008). The study elaborates the economic changes, structural changes, and energy intensity changes in manufacturing sector over 3 (three) time periods to improve the Indonesian economy related to the change in energy consumption in the future.

The objective of the current study is to investigate the change in energy consumption in the Indonesian manufacturing sector before, during and after the Asian financial crisis from 1990 to 2008. The Logarithmic Mean Divisia Index I (LMDI I) with additive approach will be used. The changes in energy consumption will be decomposed into three main factors: gross domestic product (GDP) or economic activity in the manufacturing sector changes, structural changes, and sectoral energy intensity changes [13]. The study focuses only on the manufacturing sector, as it is the biggest energy consumption sector and has the largest GDP share.

The outline of this paper consists of 5sections. Section 1 is introduction. Section 2 is analysis of the Indonesian industrial growth and energy demand. Section 3 is reviewing of concepts, data sources and method of Index Decomposition Analysis (IDA). Section 4 is results and discussion. Section 5 is conclusions and recommendations of this study.

2. Analysis of the Indonesian Industrial Growth and Energy Demand

2.1 GDP of the Manufacturing Sector

Before the crisis, the GDP of the manufacturing sector increased smoothly from 140,801.30 billion rupiah (16.76 billion USD, USD price at 2000) in 1990 to 339,920.70 billion rupiah

(40.047 billion USD, USD price at 2000) in 1997 (shown in Figure 1). The highest GDP growth of the manufacturing sector happened in 1993, at 22.72% and the lowest one happened in 1997 at 6.10%. Figure 2 shows the annual GDP growth of the manufacturing sector and its subsector. The main contribution was from the food, beverages and tobacco subsector, with shares 38.45% in 1990 and 50.47% in 1997. The second largest contributor was the fertilizers, chemical, and rubber products subsector, with shares14.95% in 1990 and 12.28% in 1997. Figure 3 below shows the GDP shares the manufacturing sector into its subsector.

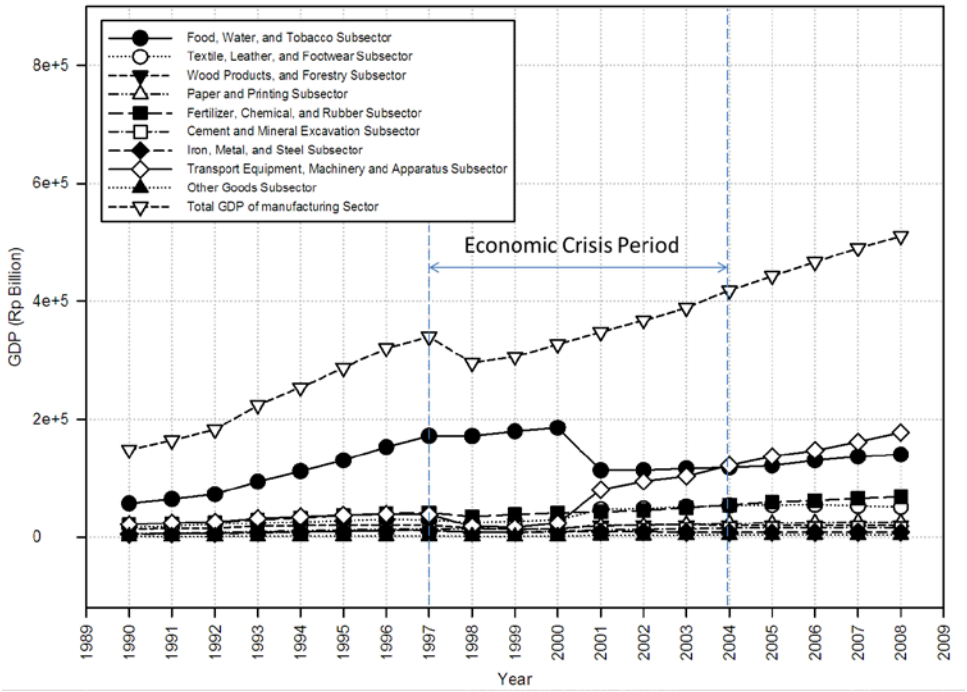

Figure 1. Total GDP of the manufacturing sector and its subsectors from 1990 to 2008.

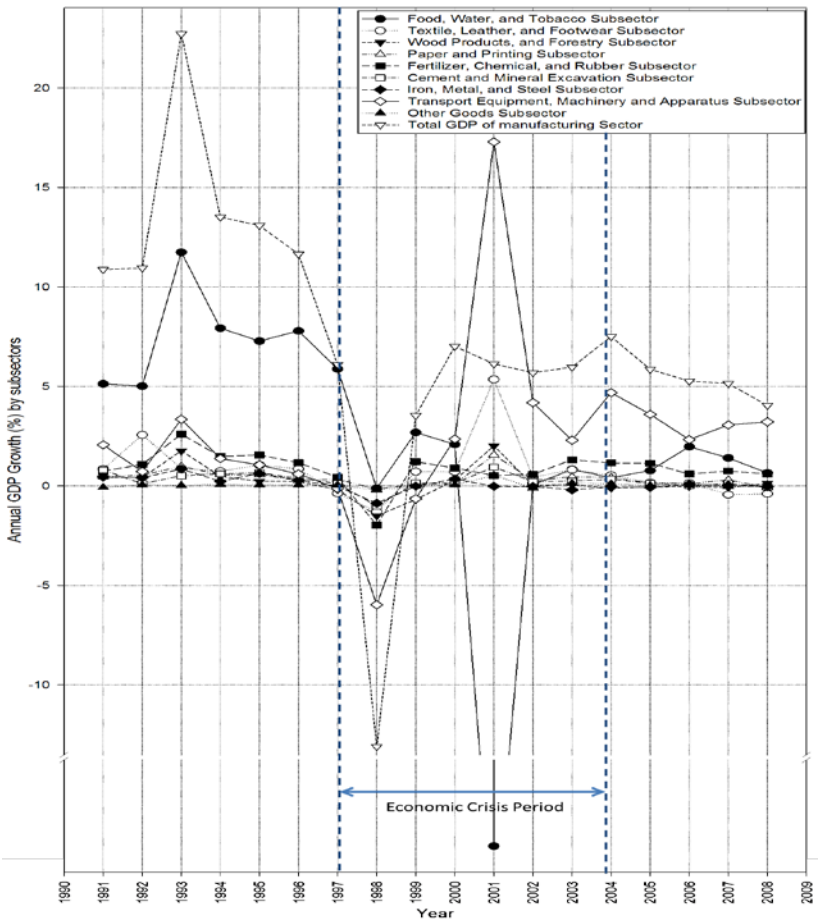

Figure 2. Annual GDP growth of the manufacturing sector and its subsectors from 1990 to 2008.

During the Asian financial crisis period (1998-2004), the total GDP of the manufacturing sector fell to the lowest point, 295,919.38 billion rupiah (35.23 billion USD, USD price at 2000) in 1998. However, it gradually recovered after the worst year in 1998 for the remainder of the economic crisis period. Likewise, in 2003 the overall GDP of the manufacturing sector recovered to 389,145.80 billion rupiah (46.33 billion USD, USD price at 2000). In 2001, the food, water, and tobacco subsector for the first time fell with a negative growth at -38.95% because production tobacco as the biggest contributor to this subsector was declining [14]. However, after that it steadily increased until 2008. In the same year (2001), the transport equipment, machinery and apparatus subsector rapidly grew by 237.67% and then slowly increased until 2004. The higher GDP growth of manufacturing sector during crisis happened in 2004 at 7.5% and the lowest one happened in 1998 at -13.09%. The biggest share during crisis gave by the food, water, and tobacco subsector with 58.57% in 1999 and the smallest contributed from other goods subsector with 0.4% in 1999.

After the Asian financial crisis period (2004-2008), the total GDP of the manufacturing sector moved up smoothly with average growth 5.08%. It started from 418,368.50 billion rupiah (49.81 billion USD, USD price at 2000) in 2004 and grew to 510,101.70 billion rupiah (60.73 billion USD, USD price at 2000) in 2008. In this period, the GDP of the subsector of transport equipment, machinery and apparatus surpassed that of the subsector of food, water and tobacco; its value changed from 121,683.30 billion rupiah (14.49 billion USD,USD price at 2000) in 2004 to 177,961.6 billion rupiah (21.19 billion USD,USD price at 2000)in 2008. The highest GDP growth of manufacturing sector reached at 7.51% in 2004, and the lowest one came to 4.04% in 2008. The biggest share of manufacturing sector contributed by transport equipment, machinery and apparatus subsector at 34.8% in 2008 and the smallest one contributed by other goods subsector at 0.74% in 2008.

2.2 Energy Consumption

In the period before the crisis, during 1990-1997 the total energy consumption of the manufacturing sector grew smoothly with average rate at 6.42% from 15,559.86 ktoe to 24,007.26 ktoe (see Figure 4). The highest energy consumption subsector was the cement and mineral excavation subsector with an average share of 24.8% in the total energy consumption in the manufacturing sector. Then the second and third largest energy consumption subsectors were the textile, leather, and footwear subsector, and the food, water, and tobacco subsector with 15.11% and 14.7% shares, respectively.

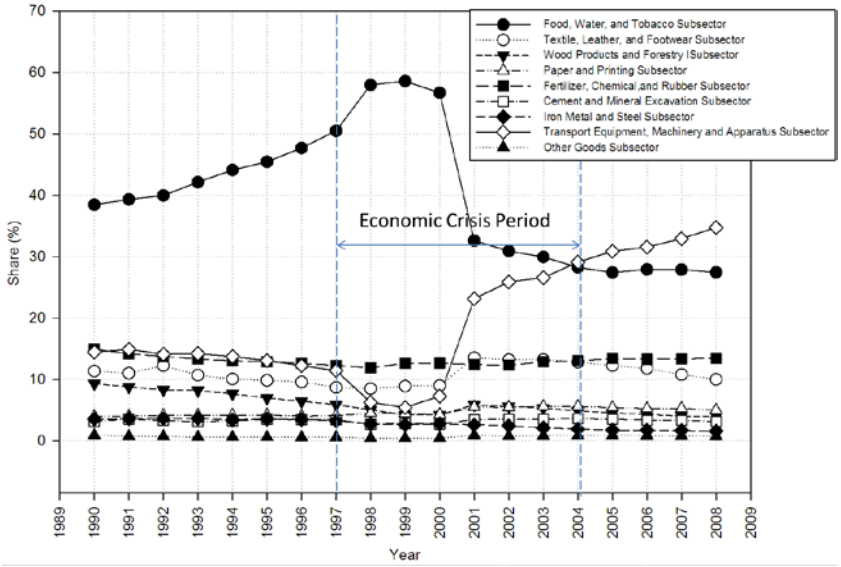

Figure 3. GDP Share of subsectors from 1990 to 2008.

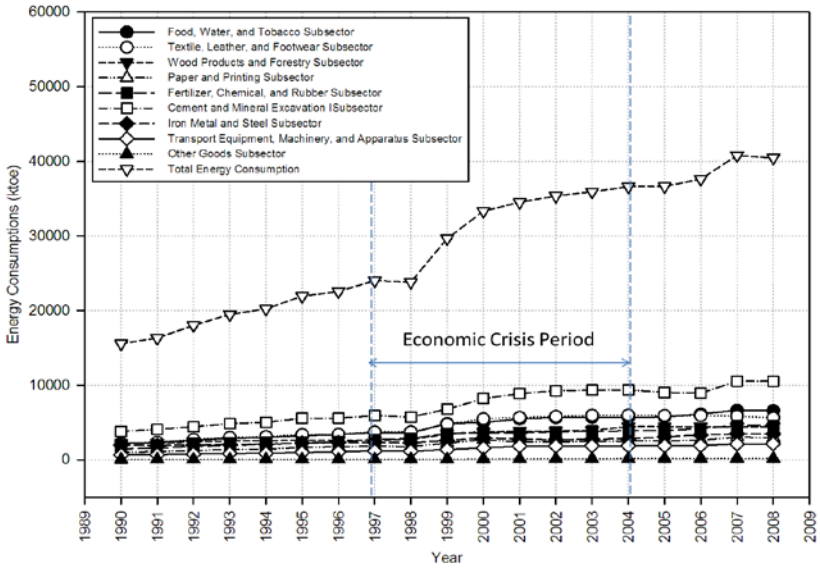

Figure 4. The total energy consumption of the manufacturing sector and its subsectors from 1990 to 2008.

During the recession period in 1998-2003, the total energy consumption of the manufacturing sector dropped to the lowest growth rate at -0.79% in 1998. The lowest growth rate occurred in the cement and mineral excavation subsector at -3.16%. However, the growth rates of energy consumption in the textile, leather and footwear subsector, the wood products and forestry subsector, and the fertilizer, chemical and rubber subsector were slightly down at 0.25%, 5.16% and 4.06% respectively. At the end of the crisis period in 2003, the total energy consumption of the manufacturing sector reached 35,938.49 ktoe.

Starting in 2004, the total energy consumption of the manufacturing sector increased and fluctuated from 36,627.97 ktoe to 40,482.71 in 2008. At the end of 2008, the total energy consumption of the manufacturing sector was slightly down from the previous year, with a rate of -0.79%. Figure 3 shows the total energy consumption of the manufacturing sector and its subsector trend from 1990 to 2008.

3. Review of concepts, data sources and method of Index Decomposition Analysis (IDA)

Studies on the decomposition of industry energy consumption have been widely conducted in several countries [15]. A simple and easy way to understand numerical example was introduced by Laspeyres. Later on, this method was improved by Ang [16] to give more accurate analysis. He introduced the logarithmic mean divisia index (LMDI) approach as the practical guide for the case study of decomposition analysis. He used Canadian industry data from the years 1990 and 2000 to show the index decomposition analysis (IDA) identity calculation and its result [17]. G.P. Hammond, and J.B.Norman, [18] adopted the logarithmic mean divisia index I (LMDI I) method to study the energy consumption in the manufacturing sector over the period 1990-2007. They divided the manufacturing sector into two main groups by energy consumption, that were called energy intensive (EI) and non-energy intensive (NEI) subsectors, to better understand the improvement in energy efficiency. They found that neither energy price nor production growth appears to be strongly correlated with the improvement in efficiency over the period 1990-2007. A recent study was conducted in the U.S.A.by Ali Hasanbeigi et al. [19] on energy consumption in California by using the logarithmic mean divisia index I (LMDI I) method. The study was part of a larger study, the "California Energy Balance Update and Decomposition Analysis for the Industry and Building Sectors," performed at Lawrence Berkeley National Laboratory for the California Energy Commission. The decomposition analysis result show that the observed reductions of energy use in the Californian industry since 2000 was the result of two main factors: the intensity effect and the structural effect. The intensity effect started pushing the final energy use downward in 2000 and has since amplified. The second significant contribution is the structural effect. It caused a decrease of the energy-intensive "Oil and Gas extraction" subsector's share of total industry value added, from 15% in 1997 to 5% in 2008, and an increased of the non-energy intensive "Electric and electronic equipment manufacturing" sector's share of value added, from 7% in 1997 to 30% in 2008, both contributing to a decreasing in the energy intensity in the industry sector.

The manufacturing sector classification used here is based on the code of klasifikasi lapangan usaha Indonesia (KLUI) 1990, following the international standard industrial classification (ISIC)of all economic activities revision 2, 1968 (see Table 1). Energy consumption of the manufacturing sector during period 1990-2008 was obtained from the data and information center at the ministry of energy and mineral resources (MEMR) of the republic Indonesia [20-21]. The original energy units of the data are all converted to tons of oil equivalent (toe) for standardization. The unit conversion factors are listed in [22]. The gross domestic products for the manufacturing sector during period 1990-2008 were obtained from annual reports published by the office of Statistics Indonesia. The GDPs used were adjusted to GDP price in the year 2000.

Table 1.KLUI = Klasifikasi Lapangan Usaha Indonesia 1990 / ISIC (International Standard Industrial Classification) revised 2.

Code	Industrial Classifications
31	Food, Water, and Tobacco
32	Textile, Leather, and Footwear
33	Wood Products and Forestry
34	Paper and Printing
35	Fertilizer, Chemical, and Rubber
36	Cement and Mineral Excavation
37	Iron, Metal, and Steel
38	Transport Equipment Machinery, and Apparatus
39	Other Goods

The method developed by Ang as mentioned above, has become more popular and is recommended because the decomposition result gives no residual term. Therefore, it is easy to use and the result is easy to interpret [23]. Ang did not recommend the conventional Laspeyres Index method that was used by energy researchers in the early 1980s, because this method often gives a large residual, the size of which can be several times larger than the estimated effects. The details of this method are described in a practical guide provided by Ang [24] as follows:

Let V be the total energy consumption in a given sector. This is assumed to be an aggregate $V = \sum_{i=1}^{N} V_i$ of the energy consumptions V_i in N subsectors. We also assume that there are n variables $x_1,\ldots,x_n$ whose values are factors in the subsector energy consumptions as follows:

$V_i = x_{1i}x_{2i}\ldots x_{ni}$, i = 1 to N, and that from period 0 to period T these change from

$V_i^0 = x_{1i}^0 x_{2i}^0 \ldots x_{ni}^0$ to $V_i^T = x_{1i}^T x_{2i}^T \ldots x_{ni}^T$. Ang showed that the total change

$\Delta V = \sum_{i=1}^{N}(V_i^T - V_i^0)$ can be decomposed additively as follows

$$\Delta V = \Delta V_{x_1} + \Delta V_{x_2} + \cdots + \Delta V_{x_n}, \quad (1)$$

Where $\Delta V_{x_k} = \sum_{i=1}^{N} L(V_i^T, V_i^0) ln\left(\frac{x_{ki}^T}{x_{ki}^0}\right)$, (2)

$$L(a,b) = \frac{a-b}{\ln a - \ln b} \quad for\ a \neq b, \quad (3)$$

$$L(a,b) = a \quad for\ a = b. \quad (4)$$

The change in total energy consumption (ΔE_{tot}) over a time period (0 to T), is a sum of the changes due to changes in GDP or economic activity (ΔE_{act}), changes in structure (ΔE_{str}) and changes in energy intensity (ΔE_{int}):

$$\Delta E_{tot} = E^T - E^0 = \Delta E_{act} + \Delta E_{str} + \Delta E_{int}, \quad (5)$$

For subsectors i of manufacturing sector, the index decomposition analysis (IDA) is

$$E = \sum_{i=1}^{N} E_i = \sum_{i=1}^{N} Q \frac{Q_i}{Q} \frac{E_i}{Q_i} = \sum_{i=1}^{N} Q S_i I_i, \quad (6)$$

where Q (=$\sum_{i=1}^{N} Q_i$) is the total manufacturing sector activity level, S_i (=$\frac{Q_i}{Q}$) and I_i (=$\frac{E_i}{Q_i}$)are respectively the activity share and energy intensity of subsector i.

The factor contribution changes in (5) are calculated as,

$$\Delta E_{act} = \sum_i L(E_i^T, E_i^0) ln \frac{Q^T}{Q^0}, \quad (7)$$

$$\Delta E_{str} = \sum_i L(E_i^T, E_i^0) ln \frac{S_i^T}{S_i^0}, \quad (8)$$

$$\Delta E_{int} = \sum_i L(E_i^T, E_i^0) ln \frac{I_i^T}{I_i^0}, \quad (9)$$

where,

$$L(E_i^T, E_i^0) = \frac{E_i^T - E_i^0}{lnE_i^T - lnE_i^0}. \quad (10)$$

4. Results and Discussion

4.1 Decomposition Analysis

4.1.1 Aggregate decomposition analysis of total energy consumption of manufacturing sector in Indonesia from 1990 to 2008

Figure 5 presents the changes in total energy consumption of the manufacturing sector of a current year over the previous year (ΔE_{tot}), and the decomposition of these changes due to the effects of the economic activity or GDP change of manufacturing sector (ΔE_{act}), the structure change (ΔE_{str}), and the intensity change (ΔE_{int}). Aggregate decomposition analysis showed that the major contribution to the total effect was given by the GDP or economic activity change and the second contributor was from the structure change and the smallest contribution was given by the energy intensity change. Before the Asian financial crisis, during 1990-1997, the total energy consumption changes (ΔE_{tot}) were always positive and fluctuated. However, during the first year of the crisis in 1998, the total energy consumption change (ΔE_{tot}) was negative. Then it sharply increased in the following year in 1999, and decreased again gradually until the end of the crisis period in 2004. After 2005, the total energy consumption changes (ΔE_{tot}) climbed year by year until 2007, and fell again in 2008.

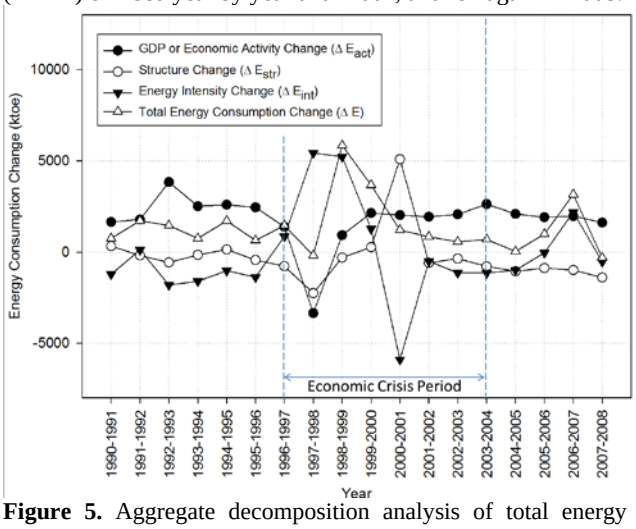

Figure 5. Aggregate decomposition analysis of total energy consumption of the manufacturing sector in Indonesia from 1990 to 2008.

4.1.2 Change in energy consumption due to economic activity effect (ΔE_{act})

Figure 5 presents the relationship between the change in energy consumption due to the economic activity effect (ΔE_{act}), as affected by GDP Change (Q^T-Q^0). Before the crisis period in 1990-1997, the magnitudes of the GDP change and the change in energy consumption due to economic activity (ΔE_{act}) in each year both had positive values and the same trend. At the beginning of the crisis in 1998, the GDP change in that year became negative and made the change in energy consumption due to economic activity (ΔE_{act}) negative also (see point 1 in Figure 6). The GDP change in the transport equipment, machinery and apparatus subsector was the largest contributor with -20,315.46 billion rupiah (-2.42 billion USD, USD price at 2000) and the largest change in the energy consumption due to economic activity (ΔE_{act}) was contributed by the cement and mineral excavation subsector with -817.49 toe. During the period of economic crisis, in particular from 2000 to 2003 (point 2 to point 3 in Figure 5), the change in energy consumption due to economic activity (ΔE_{act}) gradually slowed. This was similar to the decline in the change in economic activities, which it followed in the same trend, except for the final year of the period in 2003 (point 3) before the crisis ended in 2004 (point 4) where the change in economic activity became slightly positive. In 2003, the total GDP growth rate of the manufacturing sector was just slightly increased from 5.69% to 5.97%, by the contribution of the transport equipment, machinery, and apparatus subsector. However, the energy intensity (ktoe/billion rupiah) of this subsector is the lowest. As a result, its impact on the change in energy consumption due economic activity (ΔE_{act}) was insignificant. Suddenly in 2007 (point5), there was a high increase in the change in energy consumption due to economic activity (ΔE_{act}). This is due to a substantial GDP change contributed by the high energy intensity subsectors, i.e. the cement and mineral excavation subsector and the iron, metal and steel subsector, which suddenly increased from -1.56% and 4.03% in 2006 to 13.88% and 1.94% in 2007.

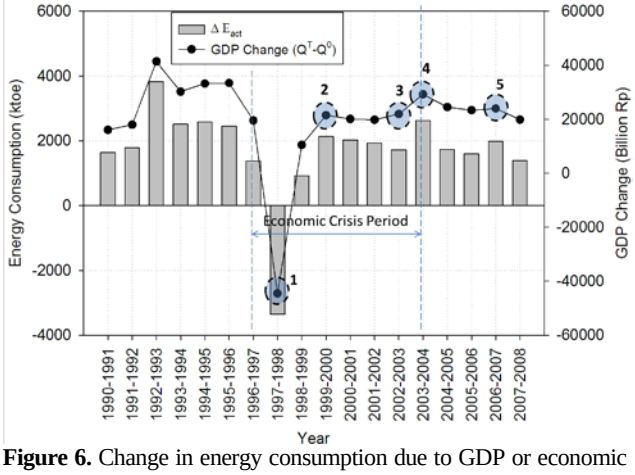

Figure 6. Change in energy consumption due to GDP or economic activity (ΔE_{act}) versus GDP Change (Q^T-Q^0).

Generally, one can see that there were substantial changes in the energy consumption due to economic activity (ΔE_{act}) after the crisis year in 1998. Even though the yearly absolute changes in energy consumption were always positive after the year 1998, the trend of growth rate in energy consumption was gradually decreasing, except in the years 2004 and 2007 where the shares of the GDP growth were largely contributed by the high energy intensity of the cement and mineral excavation subsector, and the iron, metal, and steel subsector.

4.1.3 Change in energy consumption due to energy intensity effect (ΔE_{int}).

From Figure 7, one can see that the highest and the second highest energy intensity subsector are the cement and mineral excavation subsector and the iron, metal and steel subsector respectively. This remained true for the entire period of this study. However, there was a substantial change of the third highest energy intensity subsector, the paper and printing subsector and the wood product and forestry subsector, before and after the worse crisis year in 1997. Before 1997, the paper and printing subsector was the third highest energy intensity subsector. But after this year, the wood product and forestry subsector had the third highest energy intensity. This implies that there has been a substantial improvement in energy efficiency in the paper and printing subsector.

As we mentioned earlier, the cement and mineral excavation subsector and the iron, metal, and steel subsector have

the highest energy intensity among all. As a result, these two subsectors play the key role influencing the changes of the profile of the change in energy consumption due to the energy intensity effect (ΔE_{int}) for the manufacturing sector. Before the crisis year in 1997, the changes in energy consumption due to the energy intensity effect (ΔE_{int}) fell every year until the crisis year. This followed the energy intensity pattern of the cement and mineral excavation subsector. However, as soon as the crisis began in 1997, the changes in energy consumption due to the energy intensity effect (ΔE_{int}) suddenly jumped up and became positive changes (i.e. increased in energy intensity). This is because of declining energy efficiency due to under production in the cement and mineral excavation subsector as well as other subsectors. After that, starting from year 2001, the energy intensity of the cement and mineral excavation subsector gradually improved, after its production hit the bottom in the previous year (2000). Then the improvement in production volume of this subsector helped to reduce its energy intensity. As a result, it also helped by reducing energy consumption of the manufacturing sector as a whole, until the end of the economic crisis.

Generally, there were substantial pattern changes in energy intensity before the crisis period (1990-1997), during the crisis period (1997-2004) and after the crisis period (2004-2008). Before the crisis period, the highest and second highest energy intensity subsectors (the cement and mineral excavation subsector and the iron, metal, and steel subsector) tended to decrease. After that, during the crisis period (1997-2004), the highest and second highest energy intensity subsectors (the cement and mineral excavation subsector and the iron, metal and steel subsector) climbed due to low production under their capacity. After the crisis ended, from 2006 to 2008, particularly in year 2007, the highest and second highest energy intensity subsectors (the cement and mineral excavation subsector and iron, metal, and steel subsector) increased insignificantly. However, at the end of the study in 2008, the change of energy intensity of both the cement and mineral excavation subsector and also the iron, metal and steel subsector became almost stagnant as compared to the previous year (2007), while the energy intensity of the other subsectors were slightly improved. So the overall effects caused by the changes in energy consumption due to energy intensity effect (ΔE_{int}) became negative again in this year.

4.1.4 Change in energy consumption due to structure effect (ΔE_{str})

Figure 8 shows the relationship between the change in energy consumption due to the structure effect (ΔE_{str}) and the economic structure shares. The changes in energy consumption due to the structure effect (ΔE_{str}) are influenced by interrelationship between changes in structure share of each subsector and its corresponding individual energy intensity of that subsector.

During the entire period of this study from 1990 to 2008, the largest and the second largest shares of economy in Indonesia were the food, water, and tobacco subsector, and the transport equipment, machinery, and apparatus subsector. However, these two subsectors possessed the low and the lowest energy intensity. Moreover, changes in the percentage shares of both subsectors seemed to substitute each other; when the share of the food, water, and tobacco subsector increased the share of the transport equipment, machinery, and apparatus subsector decreased and vice versa. As a result, the effect of the structural changes to energy consumption seemed to cancel out. This left the net change of energy consumption due to the structural effects dependent on the other subsectors, particularly on the high energy intensity subsectors.

During the pre-crisis period from 1990 to 1997, the shares of the wood products and forestry subsector, the textile, leather, and footwear subsector, and the fertilizer, chemical and rubber subsector shrunk year by year (except that shares of the textile, leather, and footwear subsector increased slightly in 1992). The shares resulted in net negative changes in energy consumption due to structural effect (ΔE_{str}) every year, except in 1991 and 1995. In 1991 and 1995, the share of the cement and mineral excavation subsector significantly increased being 0.42% and 0.20% from the previous years, respectively. Even though, these subsector shares were small, their energy intensities were the highest at 0.70 ktoe/billion rupiah and 0.56 ktoe/billion rupiah respectively. Consequently, any moderate change of the share of the cement and mineral excavation subsector can have a large effect on energy intensity.

During the crisis period, particularly in 1998, the changes in energy consumption due to the structural effect (ΔE_{str}) was obviously pronounced and became lowest. Again this was affected by a significant change in the cement and mineral excavation subsector. In this year the cement and mineral excavation subsector contributed the largest change in energy consumption of -1,239.79 ktoe (see Table 2).

In 2001, after the economic crisis hit the bottom, most of subsectors recovered and gained more share at the expense of the share of the food, water and tobacco subsector. From Table 2, one can see that the changes in energy consumption of all subsectors significantly became positive (except the food, water and tobacco subsector). The largest contributor was from the cement and mineral excavation subsector.

Table 2. Changes in energy consumption due to structural effect (ΔE_{str}) by subsector from 1990 to 2008.

	31	32	33	34	35	36	37	38	39	
Period	Food, Water, and Tobacco	Textile, Leather, and Footwear	Wood Products and Forestry	Paper and Printing	Fertilizer, Chemical, and Rubber	Cement and Mineral Excavation	Iron, Metal, and Steel	Transport Equipment Machinery, and Apparatus	Other Goods	Total
1990-1991	49.93	-71.03	-128.96	7.72	-83.18	497.23	36.50	20.46	-6.68	321.99
1991-1992	40.16	268.23	-131.51	28.63	-50.41	-313-01	11.38	-41.60	-1.15	-189.29
1992-1993	146.11	-386.54	-28.29	13.32	-58.06	-275.00	14.72	7.20	-7.70	-574.24
1993-1994	134.52	-181.43	-175.24	5.17	-43.15	260.93	-131.96	-29.65	-0,52	-161.33
1994-1995	92.75	-76.63	-240.59	5.91	-22.09	320.24	103.95	-45.38	-1.68	136.50
1995-1996	159.15	-90.52	-203.14	-74.98	-55.33	-33.49	-74.59	-66.68	-0.92	-440.49
1996-1997	200.76	-351.21	-229.09	37.42	-65.15	-142.45	-150.35	-79.07	0.44	-778.71
1997-1998	499.15	-76.72	-407.67	177.54	-94.33	-1,239.79	-398.46	-701.39	-17.10	-2,258.78
1998-1999	44.54	198.58	-552.49	-24.22	199.47	100.35	-89.61	-179.10	-3.08	-305.55
1999-2000	-161.87	48.26	-4.70	-104.72	4.21	-109.70	151.29	435.04	3.92	261.72
2000-2001	-2,900.03	2,277.41	1,257.00	635.80	-69.23	2,028.56	-184.43	1,969.00	69.80	5,083.89
2001-2002	-297.62	-135.07	-189.26	-9.78	-33.87	73.62	-185.99	203.07	-19.54	-594.45
2002-2003	-178.59	0.00	-179.45	55.28	165.76	94.37	-384.57	50.09	3.54	-373.57
2003-2004	-332.41	-194.28	-389.78	2.25	53.32	174.23	-275.50	167.96	6.64	-787.57
2004-2005	-170.32	0.00	-293.90	-84.05	104.78	-180.26	-277.79	112.02	-4.84	-794.37
2005-2006	108.42	0.00	-256.81	-79.21	-30.55	-414.32	-16.46	40.58	-2.55	-650.90
2006-2007	-6.04	-515.78	-300.01	17.21	22.29	-163.27	-113.61	86.02	-13.30	-986.49
2007-2008	-109.42	0.00	-25.46	-163.41	18.16	-575.53	-208.83	115.12	-8.62	-958.01

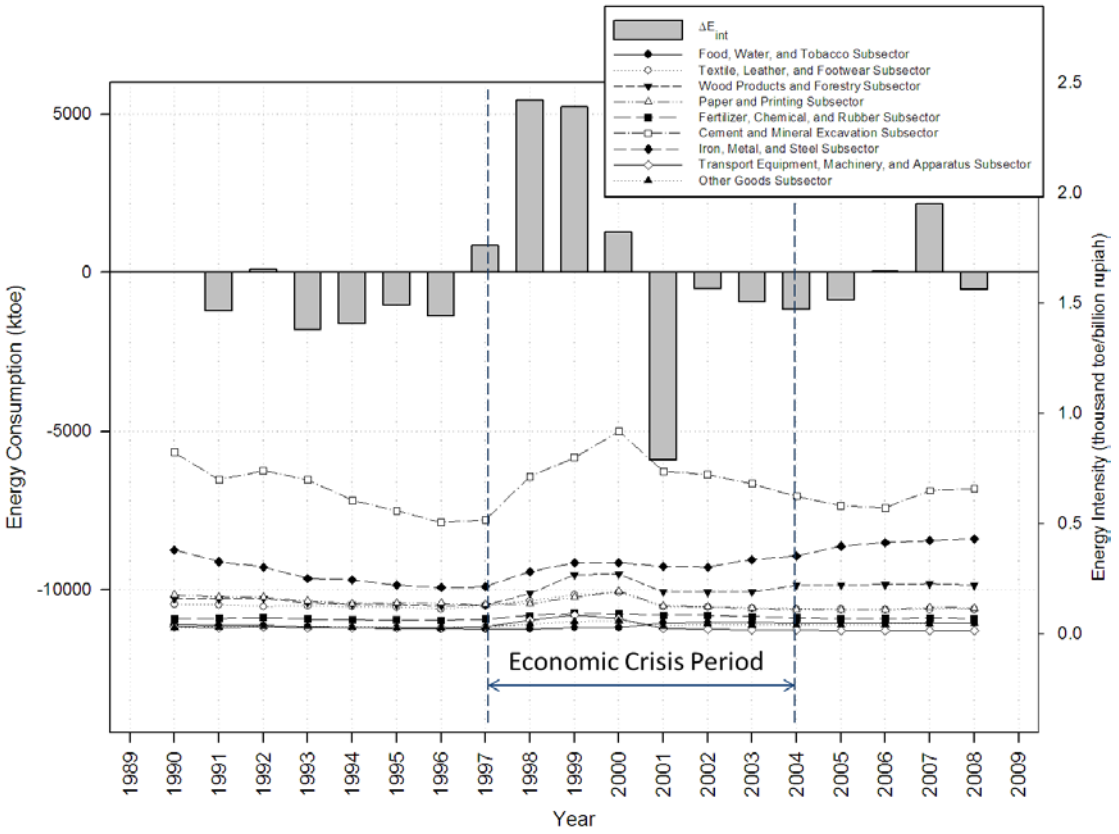

Figure 7. Sectoralenergy intensity vs change in energy consumption due to energy intensity effect (ΔE_{int}).

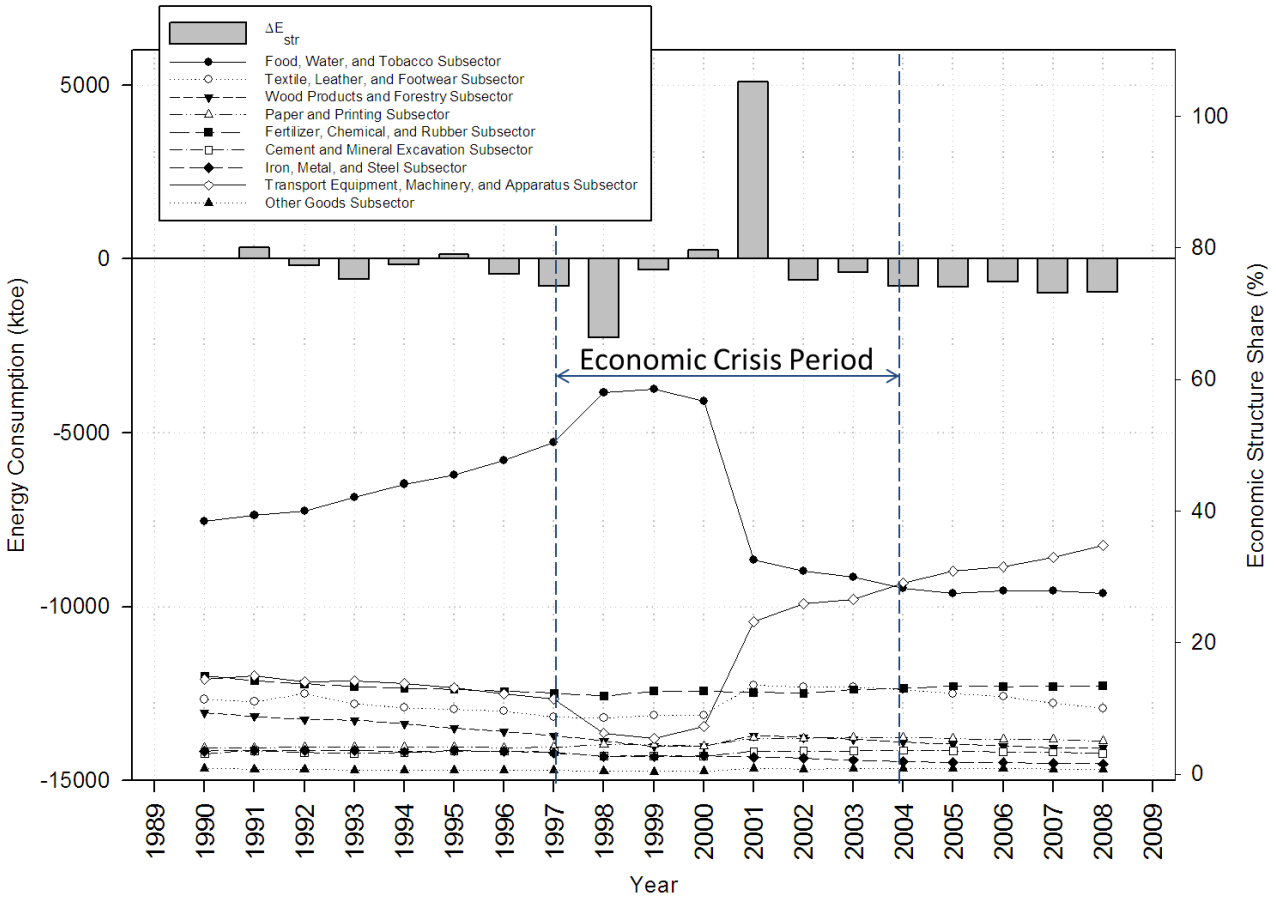

Figure 8. Economic structure share vs change in energy consumption due to structural Effect (ΔE_{str}).

After the post crisis period, from 2004 to 2008, the net changes in energy consumption due to the structural effect were consistently negative every year. The senegative effects were mainly contributed by the second and third highest energy intensities (from the iron, metal and steel subsector, and the wood product and forestry subsector), which contributed decreases in energy consumption every year. In addition, this reduction of energy consumption was dominated by the reduction of energy consumption in the cement and mineral excavation subsector from 2006 until 2008 (see Table 2).

4.2 Policy implication

From our study, it is obvious that a high energy intensity subsector like the cement and mineral excavation subsector is a key driver of changes in energy consumption, even though its share in the Indonesia economy is relative small. Any deviation in energy intensity can strongly influence the total energy consumption in the manufacturing sector. Thus, any improvements in energy efficiency improvement in the high energy intensity subsectors are very important. The Indonesian government should pay attention to these subsectors.

Even though this study was conducted for the Indonesian economy, we expect this fact will apply to other developing countries as well.

5. Conclusions and Recommendations

This study shows that before, during and after the Asian financial crisis, the economic activity effect plays the most important role in the manufacturing sector. The highest GDP before and during the crisis (1990-2003) was earned from the food, water, and tobacco subsector. However, after the crisis period in 2004-2008, contribution of the transport equipment, machinery, and apparatus subsector exceeded that of the food, water, and tobacco subsector and became the highest contribution to the GDP.

The second important role in the manufacturing sector is structure effect. Before the crisis period in 1990-1997, the food, water, and tobacco subsector contributed the largest share to the economy. During the crisis period, its share was even greater; this reflected to its importance to Indonesia's economy. However, after the crisis period from 2004 to 2008, it became the second largest economic subsector as it was replaced by the transport equipment, machinery, and apparatus subsector.

The high energy intensity subsectors, such the cement and mineral excavation subsector and the iron, metal, and steel subsector, can strongly affect the total energy consumption in the manufacturing sector, even though their shares are small. However, they play a vital role in the energy intensity of the country. Priority in energy saving improvement should be focused on these subsectors.

Finally, we have found that decomposition analysis of the total primary energy consumption into economic activity, structure and intensity effects in the manufacturing sector in Indonesia during the period 1990-2008 is a useful tool for a better understanding of changes in energy consumption and provides in-depth analysis to investigate possible areas for improvements.

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References

[1] Statistics Indonesia, *Statistical Year Book of Indonesia 1990* (1990).
[2] Statistics Indonesia, *Statistical Year Book of Indonesia 1992* (1992).
[3] Statistics Indonesia, *Statistical Year Book of Indonesia 1994* (1994).
[4] Statistics Indonesia, *Statistical Year Book of Indonesia 1996* (1996).
[5] Statistics Indonesia, *Statistical Year Book of Indonesia 1998* (1998).
[6] Statistics Indonesia, *Statistical Year Book of Indonesia 2000* (2000).
[7] Statistics Indonesia, *Statistical Year Book of Indonesia 2002* (2002).
[8] Statistics Indonesia, *Statistical Year Book of Indonesia 2004* (2004).
[9] Statistics Indonesia, *Statistical Year Book of Indonesia 2006* (2006).
[10] Statistics Indonesia, *Statistical Year Book of Indonesia 2008* (2008).
[11] Reitler W, Rudolph M, Schaefer M, Analysis of the factors influencing energy consumption in industry: a revised method, *Energy Economics* 9 (1987) 145-148.
[12] Ang BW, Decomposition methodology in industrial energy demand analysis,*Energy International Journal* 20 (1995)1081-1095.
[13] Ang BW, Zhang FQ, Choi KH,Factorizing changes in energy and environmental indicators through decomposition, *Energy* 23/6 (1998)489-495.
[14] Dwi Mega Sari, *Forecasting the price and production of tobacco in Indonesia*(2008) Bogor Agriculture Institute, Bogor.
[15] Ang BW, Zhang FQ, A survey of index decomposition analysis in energy and environmental studies,*Energy* 25/12 (2000) 1149-1176.
[16] Ang BW, Liu FL, Chew EP,Perfect decompostion techniques in energy and environmental analysis, *Energy Policy* 31 (2003)1561-1566.
[17] Ang BW, The LMDI approach to decomposition analysis: a practical guide,*Energy Policy* 33 (2005)867-871.
[18] Hammond GP, Norman JB,Decomposing Changes in the Energy Demand of UK Manufacturing, *ECOS2010 2010* (2010) Lausanne, Switzerland.
[19] Hasanbeigi A, de la Rue du Can S, Sathaye J,Analysis and decomposition of the energy intensity of California industries,*Energy Policy* 46 (2012)234-245.
[20] Ministry of Energy and Mineral Resources (MEMR), *Handbook of Energy and Economics Statistics of Indonesia 2005*(2005).
[21] Ministry of Energy and Mineral Resources (MEMR), *Handbook of Energy and Economics Statistics of Indonesia 2009* (2009).
[22] Ministry of Energy and Mineral Resources (MEMR), *Neraca Energi 1990-1994* (1994).
[23] Ang BW, Decompostion analysis for Policymaking in Energy: which is the preferred method?, *Energy Policy* 32/9 (2004) 1131-1139.
[24] Ang BW, The LMDI aproach to decomposition analysis: A practical guide, *Energy Policy* 33/7 (2005) 867-871.