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A Structural Analysis of Energy Intensity Change in Malaysia

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ABSTRACT

This research investigates the changes in Malaysia's energy intensity for the 2005-2010 period using structural decomposition analysis. Five contributing factors for energy intensity change namely energy mix, sectoral energy efficiency, production structure, final demand structure and final demand components are analysed. Results demonstrate that energy intensity has decreased but only at a minimal level. The prominent factor responsible for the decline was final demand components mainly due to the lower exports of the country as a result of the 2007/2008 global financial crisis. The production structure factor also contributed to a further decline in energy intensity which can be supported by the stronger dominant role played by services sector which is less energy intensive in addition to the lower contribution of manufacturing sector to gross domestic product. A larger decline in energy intensity was dampened by the positive effects demonstrated by the sectoral energy efficiency and final demand structure factors. The energy mix factor has also contributed to an upsurge in energy intensity but only at a minimal extent. Based on the research findings, several policy implications are highlighted to help Malaysia in achieving its sustainable energy use in the future.

Keywords: Energy Intensity, Energy Efficiency, Structural Decomposition Analysis, Input-output Model, Malaysia
JEL Classifications: C67, O44, Q43

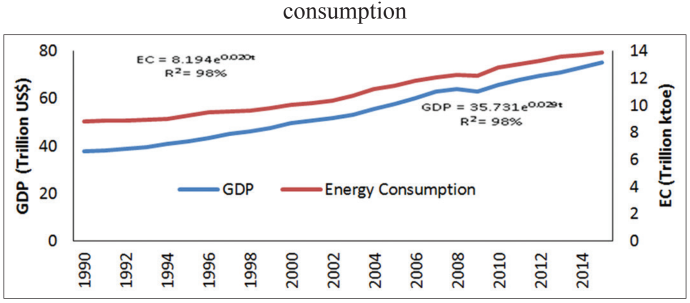
1. INTRODUCTION

Energy is an essential input in production processes and plays a vital role in each country's economic growth (Stern, 2011). Unfortunately, energy-related carbon dioxide (CO_2) are the majority of greenhouse gases (GHG) emissions; mainly from the burning of fossil fuels to produce energy especially electricity which result in rising global temperature (Environmental Protection Agency, 2016). Climate scientists have observed that CO_2 concentrations in the atmosphere have been increasing significantly over the past century, compared with those in the pre-industrial era, which was about 280 parts per million (ppm). The 2014 concentration of CO_2 at 397 ppm was about 40% higher than in the mid-1800s, with an average growth of 2 ppm per year in the last 10 years (International Energy Agency [IEA], 2015a). Due to growing energy demand in all countries, energy consumption is increasing fast especially in those that are developing (Kveselis et al., 2017). Recently, major developing countries such as Brazil, China, India, Mexico, the Philippines, South Africa, Thailand, Turkey and Malaysia have rapidly grown in terms of their energy use and this has resulted in an increase in GHG emissions (Chen et al., 2016). Over the 1990-2015 period it can be observed that the world gross domestic product (GDP) and its energy consumption are moving in the same directions; increasing at the rate of 2.9% and 2.0% per annum, respectively (Figure 1).

Malaysia is the third largest economy and at the same time is the third largest energy consumer in the Southeast Asia (IEA, 2015b). It has been proven that there is a directional causality running from Malaysia's economic development to energy consumption (Azlina and Mustapha, 2012). The country is facing crucial challenge in terms of energy security and reliability of energy supply (Ong et al., 2011). By 2040, fossil fuels will remain dominant in Malaysia's energy mix with its share still exceeding 90% (IEA, 2015b). In 2012, Malaysia was ranked 26th worldwide when it came to CO_2 emission from fuel combustion and it has also been classified as one of the top-10 CO_2 emitters among developing countries (Ertugrul et al., 2016). It is found that Malaysia's economic growth is a major contributor to CO_2 emissions and its energy consumption raises emissions intensity (Shahbaz et al., 2016). Over the 1990-2015 period, Malaysia's GDP and its final energy consumption grow at the rate of 5.23% and 5.19% per annum respectively (Figure 2). Both are generally declining during recession periods due to the Asian financial crisis (1997/1998) and the global financial crisis (2007/2008).

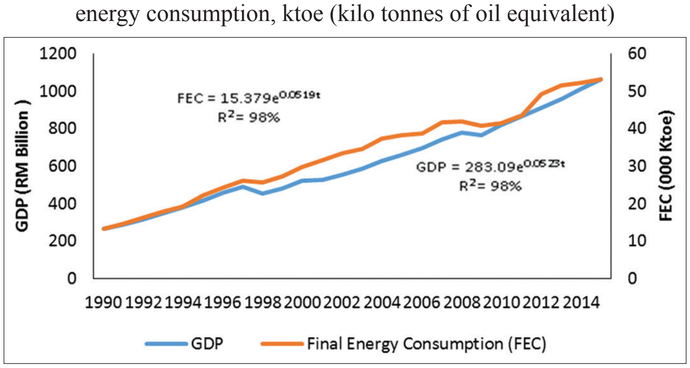
In 2010, Malaysia started to promote energy efficiency (EE) improvement efforts by introducing the National Energy Efficiency Master Plan to stabilize energy consumption against economic growth. Furthermore, Malaysia has taken the initiatives to reduce its GHG emissions intensity of GDP by 45% by 2030 relative to the level in 2005 (United Nations Framework Convention on Climate Change, 2016). This reduction in CO_2 emissions is prior to the Paris declaration ranked 51st among the countries in the projected climate change performance index until 2040 (Rasiah et al., 2016). Unfortunately, in spite of many strategic planning and giving high priority to energy resources management in its development plans, Malaysia has been inconsistently achieved its remarkable performance in energy use when it is found that the growth of its final energy consumption were higher than the growth of GDP in several years. In terms of energy intensity (EI), Malaysia's primary EI and final EI (FEI) were relatively fluctuating. Since the early 2000s, the FEI is found to be generally declining. Unfortunately, it is not a prolonged decline, as it increased again in 2012, attributed mainly to the increase in industrial EI, which indicates that Malaysia's economic growth has been driven mostly by energy intensive industries (Energy Commission, 2014). Previous studies have investigated various aspects of Malaysia's energy issues.

Figure 1: World gross domestic product (2010=100) and energy consumption



Source: World Bank (2016), World Development Indicators (WDI)

Figure 2: Malaysia's real gross domestic product (2010=100) and final energy consumption, ktoe (kilo tonnes of oil equivalent)



Source: Energy Commission (EC) (2016a), Malaysia Energy Information Hub (MEIH)

But, most of the studies were implemented using econometric analyses that investigate the relationships between energy use and economic variables especially economic growth as well as their causalities. Studying merely the relationship between energy use and economic growth is not enough without investigating the causes of the relationship. There is a need for further studies which are more comprehensive to investigate the underlying factors resulted in the changes in the country's energy use.

This study aims to investigate the contributing factors for EI change in Malaysia using structural decomposition analysis (SDA). Compared with other methods in research of energy use, SDA becomes a major research tool to study the energy problem because of its outstanding advantages. SDA studies are found to be very limited in Malaysia. To the best knowledge of the researchers, none of the existing studies has investigated the underlying factors responsible for the changes in Malaysia's economy-wide energy use using SDA. So far, there are only two energy SDA studies available for Malaysia (Chik et al., 2012; Chik and Rahim, 2014). However, they are limited to only investigating factors responsible for changes in household energy use and industrial CO_2 emissions due to energy use respectively. Therefore, in the current paper, the SDA is used to investigate the factors underlying the changes in economy-wide energy use of the country. In addition, it is the first SDA study in Malaysia that is based on full Dietzenbacher and Los (D and L) method which is known for its ideal characteristic. Given the expectations on Malaysia's future energy use and the GHG emission reduction target as stated earlier, hence, conducting energy use research using SDA is crucial so that appropriate policies, strategies and regulations can be enacted.

The rest of the paper is organised as follows. Section 2 reviews the development of decomposition analysis and the state of energy SDA studies in Malaysia. Section 3 presents the data used and its processing. Then, Section 4 explains the methodology of the study. Section 5 elucidates results and provides discussions. Subsequently, conclusion and policy implications are highlighted in Section 6.

2. LITERATURE REVIEW

SDA has been proved to be a useful tool for analysing changes in energy use. The SDA on energy use can be grouped into three methods: Ad hoc, D and L, and Divisia Index Methods (DIMs). There is a strong shift from ad hoc methods to D and L and to DIMs. The number of studies using D and L increased steadily over time while DIMs especially logarithmic mean divisia index (LMDI) started to be adopted by researchers in the last few years. The use of traditional ad hoc SDA methods was the norm in the earlier years (Hoekstra and van den Bergh, 2002). For instance, Chen and Rose (1990) examined energy use changes in Taiwan and Rose and Chen (1991) studied energy demand changes in the USA. Also, Chen and Wu (1994) analysed the change in electricity demand in Taiwan. Han and Lakshmanan (1994) and Okushima and Tamura (2007; 2010; 2011) investigated the changes in Japan energy use. The study by Lin and Polenske (1995) is the cutting-edge SDA study for China's energy use while the earliest energy SDA study for India found to have been implemented by

Mukhopadhyay and Chakraborty (1999). Unfortunately, ad hoc methods give imperfect decomposition, i.e., the results contain a residual term, which complicates results interpretation. Though there were some ad hoc methods without residual terms, they are still not ideal because the decomposition results depend on the sequence of factors in the product. Ideal decomposition guarantees exact decomposition of an aggregate and at the same time fulfills other conditions of the factor reversal test.

Due to the problems in ad hoc SDA method, Dietzenbacher and Los (1998) proposed the use of an average of all factorial n (n!) equivalent exact decomposition forms to achieve ideal decomposition that guarantees exact decomposition of an aggregate and at the same time accomplishes other conditions of the factor reversal test. There are several studies that are found to use full or equivalent D and L method for energy use. For instance, in Vietnam, Tuyet and Ishihara (2006) noted that in almost all economic sectors, the changes of energy-use technology has a greater absolute value than the changes of structure of inter-sector. In the USA, Weber (2009) showed that energy embodied in household consumption and imports were determined mostly by rapidly increasing demand with lesser structural and intensity effects. In China, Cao et al. (2010) concluded that overall decrease in total embodied energy requirements resulted by improved energy-use technology. Also, Liu et al. (2010) suggested that the increasing total exports and increasing exports of energy intensive goods tend to enlarge the energy use. Fan and Xia (2012) summarised that EI was significantly reduced by changes in energy input coefficient and technology coefficient rather than final demand shifts. Zeng et al. (2014) revealed that sectoral EE improvements contribute the most to the EI decline. In Portugal, Guevara and Rodrigues (2016) showed that the main drivers for increased energy use was final demand, and the direct EI; the energy and economic transitions lead to energy use reduction. Regrettably, the D and L method is cumbersome when the number of main factors is large. Due to this problem, several studies are found to apply approximate D and L method for energy use changes. For instance, Jacobsen (2000) showed that a structural change in foreign trade patterns can increase domestic energy demand. Kagawa and Inamura (2001) found that the Japanese total energy requirement has increased mainly because of the changes in the non-energy final demand, while the product-mix changes have opposite effects, that is, energy saving. In Thailand, Supasa et al. (2016) revealed that the final demand effect was the prominent factor in determining energy use reduction whereas the EE effect was not an effective factor in reducing energy use. Besides the full D and L method, SDA based on LMDI is another ideal decomposition method used. It is found that the LMDI method has been adopted in several recent energy SDA studies such as those by Wachsmann et al. (2009) for Brazil and studies by Chai et al. (2009) and Xie (2014) for China. There are also energy use studies using SDA based on other DIMs which include the use of the parametric Divisia methods such as those done by Garbaccio et al. (1999) and Wang et al. (2014) for China.

Internationally, it has been proven that SDA has a strong theoretical foundation for studying the effects of different factors on EI (Wu and Chen, 1990; Peet, 1993; Han and Lakshmanan, 1994; Lin and Polenske, 1995). In Malaysia, it is found that only Chik et al. (2012) and Chik and Rahim (2014) used SDA in their energy studies. Chik et al. (2012) employed SDA model to identify the sources of changes in Malaysian household energy consumption for the period of 1991-2005. They indicated that total household energy consumption has significantly increased mainly due to the increase in private consumption and the increase in energy use in the production sector for consumer goods. Chik and Rahim (2014) utilised SDA to study industrial CO_2 emissions from energy consumption for the 1991-2005 period. The study indicated that export sector was the biggest generator of CO_2 emissions. Due to the gap of the existing studies as discussed in Section 1, further SDA studies on Malaysia's energy use changes are indispensable. An investigation using more factor decompositions is also crucial in order to deeply investigate the root causes of changes in the country's energy use.

3. DATA

Two input-output (I-O) tables for the years 2005 and 2010 published by the Department of Statistics Malaysia (DOSM, 2010; 2015) are used. To conduct energy I-O analysis, the I-O tables need to be combined with energy data from National Energy Balance (NEB). There are 120 and 124 activities (commodities) classification for each table respectively. To make the tables comparable, each table is aggregated to 41 sectors respectively which include five energy sectors and 36 non-energy sectors.[1] The energy sectors are "crude oil and natural gas," "hydropower," "coal," "petrol refinery" and "electricity and gas." The "hydropower" sector is created hypothetically due to its inclusion in "electricity and gas" sector in the original I-O tables. The same practice has been implemented by Lin and Polenske (1995). For "coal" sector, it has also been separated from "other mining" which produces other products such as salt, abrasive material, potassium, barite, peat and asbestos. The separation is done based on unpublished input and output shares of coal and other mining products provided by DOSM. This way of incorporating "hydropower" and "coal" sectors enables us to trace primary and secondary energy requirement correctly and meet the energy conservation condition as required in the hybrid approach of I-O analysis.

This research applies the SDA model as employed by Zeng et al. (2014) with some modification. Instead of separating EI between domestically produced products and imported products as performed in their study, this research treats the imported products the same as the domestic ones. When one uses domestic production tables only, the intermediate inputs reflect only domestic intermediate input structure, which often underestimates total production structure (Kim, 2010). Imported goods cause changes in energy use too when they are used in the production process and used directly by final consumers. Therefore, imports data cannot be neglected. This research combines both the domestic production and imports I-O tables in order to produce a total production table for each period. A total production table is often called as a competitive table because the imported products are treated the same as the domestic products. Miller and Blair (2009) mentioned that if one is interested in the structure of production and how

1 Aggregation details are available with authors upon request.

they have changed over time (i.e., structural analysis), it may be more useful to have competitive imports since such imports are certainly part of production recipes. Among the SDA studies found to use total production tables are Han and Lakshmanan (1994), Alcántara and Roca (1995), Garbaccio et al. (1999), Jacobsen (2000), Munksgaard et al. (2000), Kagawa and Inamura (2001), de Haan (2001), Stage (2002), de Nooij et al. (2003), Kagawa and Inamura (2004), Hoekstra and van den Bergh (2006), Roca and Serrano (2007), Wu et al. (2007), Peters et al. (2007) and Supasa et al. (2016).

Furthermore, this research utilises a commodity-by-commodity type of domestic production and import I-O tables. The tables provide data on a commodity basis, which is best for identifying energy uses (Lin, 1996). This research uses 2005 as the base year. The current price I-O tables of 2005 and 2010 are adjusted for inflation using double deflation method as introduced by Dietzenbacher and Hoen (1999). This research employs hybrid unit approach that was initially put forward by Bullard and Herendeen (1975) which addresses the principal weaknesses in the earlier approaches to energy I-O analysis. The hybrid unit formulation of energy I-O analysis defines energy coefficients that inherently conform to a set of "energy conservation conditions" (Miller and Blair, 2009). To construct the hybrid I-O table, monetary values of all energy rows in the I-O table are changed to physical values in kilo tonnes of oil equivalent (ktoe). The flows of all other non-energy products are reported in value terms (RM = 000). The physical values of energy data were obtained from the NEB for the years 2005 and 2010. Sectoral classification in NEB is too aggregated which only covers six sectors in its final energy use namely; residential, commercial, industrial, transport, agriculture and non-energy use. By their difference in nature, a substantial effort of harmonisation between the two sets of data is required. The final energy use in ktoe is distributed based on sectoral shares from monetary I-O table by assuming different energy prices for the six aggregated sectors respectively.

4. METHODOLOGY

The methodology applied in this study is grounded on the key mathematical equation comprises the Leontief inverse matrix presenting the relationship between total output (x), and final demand (y), as in Equation (1).

$$x = Ax+y =(I-A)^{-1} y = Ly \tag{1}$$

Where x is a vector of total output from each sector, A is a direct input requirement matrix, y is a column vector representing sectoral final demand, I is an identity matrix, $(I-A)^{-1} = L$ is a Leontief inverse matrix demonstrating the production structure.

Aggregate energy use of the production sectors in a given period can be written as follows (Miller and Blair, 2009);

$$e_t = r'x \tag{2}$$

Where e_t is a scalar of energy use for all production sectors, r' is a row vector representing each production sector's EE (i.e., measured by energy usage per unit of total output). Replacing x as defined in Equation (1), hence Equation (2) is extended as in Equation (3);

$$e_t = r'Ly \tag{3}$$

Instead of investigating the changes in energy use, this research examines the changes in EI. Hoekstra and van den Bergh (2002) highlighted that studies that are interested in the relative performance of an economic indicator should use the intensity or elasticity approaches. Therefore, the term e_t in Equation (3) is replaced with;

$$e=\frac{e_t}{g} \tag{4}$$

Where e is EI, g is a scalar representing GDP. Replacing e_t in Equation (3) with e as defined above, thus it is rewritten as in Equation (5).

$$e = r'L\frac{y}{g} \tag{5}$$

Generally, this research follows the SDA method as used in Zeng et al. (2014) which is based on the full (D and L) method. However, some adjustments to the model have been implemented (Note: Adjustment in terms of type of I-O table used has been explained earlier in Section 3). Based on Zeng et al. (2014), the sectoral EE; r', in Equation (5) is further decomposed to comprise an energy mix factor (M), as indicated in Equation (6).

$$r' = \tau M \hat{r} \tag{6}$$

Where τ is a unit row vector conformable for matrix multiplication, M is a matrix representing shares of different energy types (including both domestically produced energy and imported energy) in each sector, $\hat{r}$ is a diagonal matrix with the elements of the r' on its diagonal and all other elements are zeros.

The final demand vector (y), can further be decomposed into two composition components as revealed in Equation (7).

$$y = y^s y^c g \tag{7}$$

There are four final demand components involved in this research: Private consumption (C), government consumption (G), investment (I), and net exports (NX). Hence, y^s is a matrix denotes shares of sectors in each final demand category, y^c is a vector represents shares of each final demand category in GDP and g is a scalar of GDP. Different from Zeng et al. (2014), this research considers private consumption as an exogenous sector. In other words, this research conducts analysis on changes in EI within traditional approach of I-O framework that considers private consumption as part of final demand components. Thus, by incorporating Equations (5-7), the full decomposition of EI; e, can be articulated as in Equation (8).

$$e=\frac{\tau M\hat{r}Ly^{s}y^{c}g}{g} \tag{8}$$

Cancelling out g, the new equation can be written as in Equation (9).

$$e=\tau M\hat{r}Ly^{s}y^{c} \tag{9}$$

Table 1 summarises the variables used in this research.

The change of EI (e), from the basic year (0), to target year (1), can be expressed as in Equation (10). For this research, the basic year is 2005 and the target year is 2010.

$$\Delta e=\tau(M_1\hat{r}_1L_1y_1^{s}y_1^{c}-M_0\hat{r}_0L_0y_0^{s}y_0^{c}) \tag{10}$$

Where $\Delta e = e_1\text{-}e_0 = \tau(M_1\hat{r}_1L_1y_1^{s}y_1^{c}-\tau M_0\hat{r}_0L_0y_0^{s}y_0^{c})$. This study employs the SDA of EI changes that follow the commonly used additive identity splitting methods by adding and subtracting of like terms and rearranging them to the right-hand-side of the equation (Dietzenbacher and Los, 1998). Using additive decomposition, Equation (10) is expanded as in Equation (11).

$$\Delta e=\tau\Delta M\hat{r}Ly^{s}y^{c}+\tau M\Delta\hat{r}Ly^{s}y^{c}+\tau M\hat{r}\Delta Ly^{s}y^{c}+$$
$$\tau M\hat{r}L\Delta y^{s}y^{c}+\tau M\hat{r}Ly^{s}\Delta y^{c} \tag{11}$$

Where $\Delta M = M_1\text{-}M_0$, $\Delta\hat{r}=\hat{r}_1\text{-}\hat{r}_0$, $\Delta L = L_1\text{-}L_0$, $\Delta y^{s}=y_1^{s}\text{-}y_0^{s}$ and $\Delta y^{c}=y_1^{c}-y_0^{c}$. Equation (11) indicates the change in EI (Δe), is decomposed into the changes of individual contributing factors from each of the five variables. Each term in the right-hand-side of the Equation (11) represents how much the change of EI (Δe), is caused by the changes in energy mix (ΔM), sectoral EE($\Delta\hat{r}$), production structure (ΔL), final demand structure (Δy^s), and final demand components (Δy^c), when keeping other factors constant. One can rewrite Equation (11) as in Equation (12).

$$\Delta e=\tau\Delta M\hat{r}_1L_1y_1^{s}y_1^{c}+\tau M_0\Delta\hat{r}L_1y_1^{s}y_1^{c}+\tau M_0\hat{r}_0\Delta Ly_1^{s}y_1^{c}+$$
$$\tau M_0\hat{r}_0L_0\Delta y^{sc}\ y_1^{c}+\tau M_0\hat{r}_0L_0y_0^{s}\Delta y^{c} \tag{12}$$

The change; Δ, runs from left to right and all factors to the right of the changed factor are calculated in the target year (1), values and all the factors to the left of the change factor are calculated in basic year (0), values. This decomposition form is complete, meaning that it has no residual term. However, note that the particular decomposition form presented above is not unique. It is just one of many decompositions, as one can derive a number of alternative decomposition forms using the same method. The derivation of the decomposition equation above arbitrarily assumed that the order of the factors is $M\hat{r}Ly^{s}y^{c}$, but it could just as well have been $LMy^{s}y^{c}\hat{r}$. Following the principles in Equation (12), ΔM appears in the first term and $\Delta\hat{r}$ in the next and so on. Dietzenbacher and Los (1998) showed that in the general n-factors case there is n! different decomposition forms. In other words, the number of possible decomposition forms equals to the permutations of all factors. In this case, there are 5! = 120 (i.e., ${}_5P_5$ = 120) different decomposition forms for this research. No individual decomposition form is theoretically preferred and all alternative decomposition forms are equally valid. This is so called the non-uniqueness problem in SDA (Rose and Casler, 1996). To address the non-uniqueness problem, this research used the full D and L method which takes the average of the decomposition results of all possible decompositions. For this research, the size of the total contribution from each of the five factors to the total change in e is computed as the average of all 120 decompositions. Based on Equation (1), the SDA on EI of Malaysian economy for 2005-2010 period is conducted.[2]

5. RESULTS AND DISCUSSIONS

Table 2 demonstrates the EIs for 2005 and 2010. For the 5 years duration, Malaysia's EI decreased by −4.2%. This result is similar to the I-O analysis findings by Bekhet and Yasmin (2014). They confirmed that there was a reduction in Malaysia's energy consumption during the same period due to the decline in economic activities mainly the export-oriented manufacturing industry. This could be to the 2007/2008 global financial crisis.

Table 3 summarises the contribution of each factor to the decline in EI. First, energy mix (M) is found to be the least influential factor for EI change. It has resulted in a small upsurge in EI at 3.08874E-14% increase. This finding is contradict with Zeng et al. (2014) and Fan and Xia (2012) results for China. Looking at energy sectors performance in Malaysia, the "electricity and gas" sector is found to experience the most significant change in terms of energy mix. "Electricity and gas" sector is well-known

2 The 120 decomposition forms are available with the authors upon request.

Table 1: List of variables and their definitions

Variable	Dimension	Definition
EI (e)	1×1	Energy use per unit of GDP for the whole economy
Energy mix (M)	5×41	Shares of different types of energy use in production sectors. 5 is the number of energy sectors. 41 is the number of production sectors
Sectoral energy efficiency	41×41	Diagonal matrix representing EE in production sectors measured by energy use per unit output
Production structure (L)	41×41	Leontief inverse matrix representing production structure of the economy
Final demand structure (y^s)	41×4	Shares of sectors in each final demand component. 4 is the number of final demand components; C, G, I and NX
Final demand component (y^c)	4×1	Shares of each final demand component in GDP

Table 2: Energy intensity 2005-2010 (ktoe/RM 000')

e	2005	2010	Δe	PercentΔe
EI	0.00023	0.00022	(0.00001)	−4.2

The computation of e for each year is based on Equation (9), the computation for Δe using the average of Equation (12) gives the same result

Table 3: Energy intensity change and the contribution of each factor 2005-2010

No.	Factor	Δe	Percent Δe
1	Energy mix	3.0318E-21	3.08874E-14
2	Sectoral EE	0.00001	117.34
3	Production structure	(0.00001)	(144.59)
4	Final demand structure	0.00002	160.63
5	Final demand components	(0.00002)	(233.38)
	Total	(0.00001)	100

The computation of Δe is based on Equation (12)

for its high energy intensive nature that requires all sorts of energy inputs for power generation. The positive effect of the energy mix factor to the overall EI change can be supported by the higher use of "coal" as input for power generation compensating lower "crude oil and natural gas" and "petrol refinery" use. The share of "hydropower" in "electricity and gas" energy mix was lower too. In terms of non-energy sectors, most are found to experience reductions in the use of "petrol refinery" by compensating it with higher "electricity and gas." Both the "petrol refinery" and "electricity and gas" are of secondary energy types. Therefore, the positive effect of energy mix on overall change in EI can also be supported by non-energy sectors' shift towards more use of "electricity and gas" replacing "petrol refinery" since "electricity and gas" sector itself is highly energy intensive.

Second, sectoral EE ($\hat{r}$) is found to also contribute positively to overall EI change at 117.3% increase. This is in line with the finding in Thailand where EE effect led to an increase in energy use (Supasa et al., 2016). However, this result contradicts with the finding for China which found that sectoral EE contributed most to the overall EI reduction (Zeng et al., 2014). This finding indicates that sectors in Malaysia were found to use more energy for each output that they produced in 2010 compared to in 2005. In other words, the economic sectors in general becoming more energy intensive. Within energy sectors, "crude oil and natural gas" and "electricity and gas" showed EE reductions, while "coal" and "petrol refinery" found to experience EE improvements. In terms of non-energy sectors, there were 17 sectors found to be efficient; led by "transports and transport equipment," "industrial chemical," "communication," "rubber products" and "basic metals." On the other hand, 19 non-energy sectors found to be inefficient during this period. The most inefficient among them were "other agriculture," "rubber plantation," "oil palm plantation," "fishing" and "forestry and logging."

Third, the production structure (L) contributed to −144.59% reduction in EI and appears as the second prominent factor for the decline in overall EI. Its negative effect can be explained by the stronger dominant role played by services sector and the decline in the contribution of manufacturing sector to GDP due to the severe impact of the global financial crisis (2007/2008). In addition, the decline in the mining and quarrying sector's contribution also led to its negative effect. This result is conformed to the study done for Brazil, USA, China and Portugal that also found negative impact of production structure change either on energy consumption or EI at different sub-periods (Chen and Rose, 1990; Chen anbd Wu, 1994; Lin and Polenske, 1995; Garbaccio et al., 1999; Wachsmann et al., 2009; Weber, 2009; Fan and Xia, 2012; Zeng et al., 2014; Guevara and Rodrigues, 2016; Supasa et al., 2016). Unfortunately, a larger negative effect of Malaysia's production structure was dampened by the pro-recovery measures implemented through stimulus packages in 2009 and 2010 that support the growth of agriculture and construction sectors to GDP. In addition, the negative effect shown by Malaysia's production structure factor during 2005-2010 period had been offset by positive effects of other factors resulting in an only minimal reduction in overall EI.

Fourth, the final demand structure factor contributed positively by 160.63% to overall EI change. This result is in line with the findings for India, Japan, China, Thailand and Portugal which also found that the final demand structure contributed positively to the changes in energy use (Mukhopadhyay and Chakraborty, 1999; Kagawa and Inamura, 2001; 2004; Fan and Xia, 2012; Guevara and Rodrigues, 2016; Supasa et al., 2016). However, in USA it is found that it contributed negatively to EI change (OTA, 1990). It is important to further discuss the changes in the structure of each final demand component and elaborate how the changes in the sectoral shares led to the changes in EI. In terms of private consumption, it is clear that there were changes in its sectoral shares demonstrated by the increased demand on the output of 19 sectors that can partly explain the positive effect of final demand structure on EI. It is found that consumers demand more output especially from "wholesales and retail trade," "petrol refinery," "communication" and "amusement and recreation." In terms of government consumption, it is found that the government maintained to demand the output from only five sectors in both years namely: "Business services," "education," "healthcare," "amusement and recreation," and "other services" with the largest portion of its consumption is for the output of "other services" followed by "education" and "healthcare." The government consumption on "other services" was increased, while the demand on other four sectoral output reduced. These structural changes in government consumption are also expected to contribute positively to EI change though at a very minimal level. In terms of investment, 16 sectors experienced positive investment change led by "construction," "business services" and "food," while 18 sectors experienced negative investment change led by "machineries," "wholesale and retail trade" and "crude oil and natural gas." It is important to highlight that the "construction" sector remained as the top three invested sectors in both years. In 2005, the dominant role played by "construction" was dampened by the economic slowdown after the Asian financial crisis (1997/98) and resulted in the sector to only performed as the third important investment direction in that year. However, the stimulus packages implemented by the government in 2009 and 2010 had resulted the sector to recover and become the most important investment direction in 2010. As experienced in China, the overexpansion of investment in construction and heavy industries such as basic metals had created an upsurge in energy use (Xie, 2014; Zeng et al., 2014). Looking at exports, there were positive changes in 17 sectors led by "petrol refinery" and "food." The exports of "machineries" were severely deteriorated, while the export of "electrical, electronics and equipment" maintained its superiority with only a slight decline. As evidenced from China, with expanding exports, the energy embodied in exported goods and services had remarkably increased. Furthermore, the shifting from exporting less energy intensive products to more energy intensive products had also resulted in increased energy requirement (Xie, 2014; Zeng et al., 2014). In Portugal, the final demand component of exports had also found to become among the main contributors to higher energy use (Guevara and Rodrigues, 2016). In terms of imports, it is found that most of Malaysia's imports consisted of intermediate and investment goods mainly due to the rapid growth in construction and manufacturing activities. Reducing their imports means that domestic demand on these products were met by domestic production which lead to higher domestic energy consumption and therefore partially contributed to the positive effect of final demand structure on EI change and vice versa. During the 2005-2010 period, there were lower imports on the products of 13 sectors led by "electrical, electronic and equipment" and "machineries," while 25 sectors experienced higher import led by "basic metals" and "transport and transport equipment."

Fifth, the final demand components factor was the most prominent factor that contributed at -233.38% reduction in EI decline. Overall, the negative effect of final demand components contradicts with the finding of China, Portugal and Thailand which found that it had resulted in an increase in either EI or energy use in different periods (Fan and Xia, 2012; Zeng et al., 2014; Guevara and Rodrigues; 2016; Supasa et al., 2016). Compared to other final demand components, the net exports experienced a negative change with both exports and imports experienced reductions; with larger reduction indicated by exports compared to imports. The significant negative effect of overall final demand component on EI change can be supported by the reduction in exports. Unfortunately, the remarkable negative effect showed by final demand components was offset by the combination effects of other factors which in the end led to only a minor decline in EI.

6. CONCLUSION AND POLICY IMPLICATIONS

This paper investigates the EI change in Malaysia for the 2005-2010 period. It employs SDA that is based on full D and L method. For the 5 years duration, the overall EI has minimally declined mainly due to the change in the final demand components factor which can be explained by the reductions in Malaysia's exports after the 2007/2008 global financial crisis. The change in production structure which indicates the dominant role of services sector and lower manufacturing contributions to GDP has also contributed to EI decline. Unfortunately, further decline in EI was dampened mainly by the positive effects of final demand structure and sectoral EE. The energy mix factor has also contributed positively to EI change but only at a minimal extent.

Based on the research findings, several policy implications are highlighted: First, The energy mix factor is the least important contributor to EI change. Though its positive effect on EI change was very small, however, due to its relatedness with energy diversification policies in Malaysia, therefore, it needs further discussion. Higher share of coal for electricity generation compensating lower shares of "crude oil and natural gas," "petrol refinery" and "hydropower" is expected to mainly cause the positive effect of energy mix on EI change. Higher coal usage has also resulted in "electricity and gas" sector become inefficient, indicated by the positive changes in its EI over the 2005-2010 period. Malaysia plans to use more coal for electricity generation in the future, therefore, it is expected that the positive energy mix and sectoral EE effects will be larger in the future. Furthermore, many non-energy sectors have shifted their energy input from the use of "petrol refinery" to the use of "electricity and gas." This scenario is expected to cause larger positive effect of energy mix on EI change due to energy intensive nature of "electricity and gas" sector which uses all sorts of energy sources in its production process. Therefore, more proactive steps need to be implemented in order to aggressively diversify Malaysia's sectoral energy mix especially renewable energy.

Second, Malaysia has been an important exporter of manufacturing products especially "electrical, electronics and equipment" and "machineries." The "crude oil and natural gas" and "petrol refinery" also become among the important exports. The exports of other energy intensive products such as "basic metals" and "chemicals" were also becoming important. Many studies investigated energy embodied in international trade and found that countries like Brazil and China experienced large embodied energy in their exports (Machado et al., 2001; Liu et al., 2010). Therefore, changing the export structure towards less energy intensive products is important. In terms of imports, Bordigoni et al. (2012) found that embodied energy in the imports of manufactured products represents a significant aspect of the energy situation in European industries with quantities close to the direct energy consumption. Therefore, importing the energy intensive products can lead to lower energy consumption in Malaysia.

Third, Malaysia is on the right track for increasing the share of services sector in GDP which it can help in reducing energy use of the country. However, several industries under services sector had experienced energy inefficiency as indicated by "financial services," "amusement and recreation," and "other services." Therefore, careful steps need to be implemented to ensure EE in the services sector. Furthermore, the accompanying stronger growth of other sectors especially manufacturing will generally result in higher EI assuming business-as-usual. Under the three phases of Industrial Master Plans, Malaysia's production structure was becoming more energy intensive. So, Malaysia is promoting investment for industries under manufacturing sector which some of them are categorised as energy intensive such as basic metals, non-metallic mineral and petrochemical industries. The venture in these heavy industries as well as expanding the productions for meeting the exports demand resulted in an increase in EI. Although there is still scope for reducing EI in heavy industries through more advanced equipment and processes, reducing the share of those industries in GDP is more direct means of addressing future energy challenges. Therefore, Malaysia's production structure has to be rationalised by shifting away from energy intensive to less energy intensive production.

For future research, it is important to investigate the changes in Malaysia's EI for other periods such as the periods of 1991-2000 and 2000-2005. These investigations are important in order to efficiently implement appropriate energy-related policies and therefore achieving sustainable energy in the country.

REFERENCES

Alcántara, V., Roca, J. (1995), Energy and CO_2 emissions in Spain. Energy Economics, 17(3), 221-230.

Azlina, A.A., Mustapha, N.N. (2012), Energy, economic growth and pollutant emissions nexus: The case of Malaysia. Procedia-Social and Behavioural Sciences, 65, 1-7.

Bekhet, H.A., Yasmin, T. (2014), Assessment of the global financial crisis effects on energy consumption and economic growth in Malaysia: An input-output analysis. International Economics, 140, 49-70.

Bordigoni, M., Hita, A., Le Blanc, G. (2012), Role of embodied energy in the European manufacturing industry: Application to short-term impacts of a carbon tax. Energy Policy, 43, 335-350.

Bullard, C.W., Herendeen, R.A. (1975), The energy cost of goods and services. Energy Policy, 3, 268-278.

Cao, S., Xie, G., Zhen, L. (2010), Total embodied energy requirements and its decomposition in China's agricultural sector. Ecological Economics, 69(7), 1396-1404.

Chai, J., Guo, J.E., Wang, S.Y., Lai, K.K. (2009), Why does EI fluctuate in China? Energy Policy, 37(12), 5717-5731.

Chen, C.Y., Rose, A. (1990), A structural decomposition analysis of changes in energy demand in Taiwan: 1971-1984. The Energy Journal, 11(1), 127-146.

Chen, C.Y., Wu, R.H. (1994), Sources of change in industrial electricity use in the Taiwan economy 1976-1986. Energy Economics, 16(2), 115-120.

Chen, P.Y., Chen, S.T., Hsu, C.S., Chen, C.C. (2016), Modeling the global relationships among economic growth, energy consumption and CO_2 emissions. Renewable and Sustainable Energy Reviews, 65, 420-431.

Chik, N.A., Rahim, K.A. (2014), Sources of change in CO_2 emissions from energy consumption by industrial sectors in Malaysia. In: Proceedings for 9th Malaysian National Economic Conference (PERKEM). Conference Conducted in Terengganu, Malaysia. Available from: http://www.ukm.my/fep/perkem/pdf/perkem2014/PERKEM_2014_1D3.pdf. [Last accessed on 2015 May 25].

Chik, N.A., Rahim, K.A., Saari, M.Y., Alias, E.F. (2012), Changes in consumer EI in Malaysia. International Journal of Economics and Management, 6(2), 221-240.

de Haan, M. (2001), A structural decomposition analysis of pollution in the Netherlands. Economic Systems Research, 13, 181-196.

de Nooij, M., van der Kruk, R., van Soest, D. (2003), International comparisons of domestic energy consumption. Energy Economics, 25, 359-373.

Department of Statistics Malaysia. (2010), Input-Output Tables Malaysia 2005. Putrajaya, Malaysia: Malaysia National Printers.

Department of Statistics Malaysia. (2015), Input-Output Tables Malaysia 2010. Putrajaya, Malaysia: Malaysia National Printers.

Dietzenbacher, E., Hoen, A.R. (1999), Double deflation and aggregation. Environment and Planning A, 31(9), 1695-1704.

Dietzenbacher, E., Los, B. (1998), Structural decomposition techniques: Sense and sensitivity. Economic Systems Research, 10, 307-324.

Energy Commission. (2014), National Energy Balance 2012. Available from: http://www.meih.st.gov.my/documents. [Last accessed on 2016 Jul 30].

Energy Commission. (2016a), Malaysia Energy Information Hub. Available from: http://www.meih.st.gov.my/statistics. [Last accessed on 2016 Aug 16].

Energy Commission. (2016b), National Energy Balance 2014. Available from: http://www.meih.st.gov.my. [Last accessed on 2016 Aug 16].

Environmental Protection Agency. (2016), Global Greenhouse Gas Emissions Data. Available from: https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data. [Last accessed on 2016 Aug 25].

Ertugrul, H.M., Cetin, M., Seker, F., Dogan, E. (2016), The impact of trade openness on global carbon dioxide emissions: Evidence from the top ten emitters among developing countries. Ecological Indicators, 67, 543-555.

Fan, Y., Xia, Y. (2012), Exploring energy consumption and demand in China. Energy, 40(1), 23-30.

Garbaccio, R.F., Ho, M.S., Jorgenson, D.W. (1999), Why has the energy-output ratio fallen in China? Energy Journal, 20, 63-91. Available from: http://www.ksg.harvard.edu/m-rcbg/ptep/energy-ratio.pdf. [Last accessed on 2015 Apr 13].

Guevara, Z., Rodrigues, J.F.D. (2016), Structural transitions and energy use: A decomposition analysis of Portugal 1995-2010. Economic Systems Research, 28(2), 202-223.

Han, X., Lakshmanan, T.K. (1994), Structural changes and energy consumption in the Japanese economy 1975-1985: An input-output analysis. Energy Journal, 15, 165-188.

Hoekstra, R., van den Bergh, J.C.J.M. (2002), Structural decomposition analysis of physical flows in the economy. Environmental and Resource Economics, 23, 357-378.

Hoekstra, R., van den Bergh, J.C.J.M. (2006), The impact of structural change on physical flows in the economy: Forecasting and back casting using structural decomposition analysis. Land Economics, 82(4), 582-601.

International Energy Agency. (2015a), Energy and climate change-world energy outlook special report. Available from: https://www.iea.org/publications/freepublications/publication. [Last accessed on 2016 Jul 13].

International Energy Agency. (2015b), Southeast Asia energy outlook 2015-world energy outlook special report. Available from: https://www.iea.org/publications/freepublications/publication/weo2015_southeastasia.pdf. [Last accessed on 2016 Jul 13].

Jacobsen, H.K. (2000), Energy demand, structural change and trade: A decomposition analysis of the Danish manufacturing industry. Economic Systems Research, 12, 319-343.

Kagawa, S., Inamura, H. (2001), A structural decomposition of energy consumption based on a hybrid rectangular input-output framework: Japan's case. Economic Systems Research, 13(4), 339-363.

Kagawa, S., Inamura, H. (2004), A spatial structural decomposition analysis of Chinese and Japanese energy demand: 1985-1990. Economic Systems Research, 16(3), 279-299.

Kim, S.K. (2010), Energy, Emissions and Structural Changes of the Korean Economy: Implications for a Low-Carbon Economy (PhD Thesis). Rensselaer Polytechnic Institute. Available from: http://www.digitool.rpi.edu. [Last accessed on 2014 Aug 20].

Kveselis, V., Dzenajavičienė, E.F., Masaitis, S. (2017), Analysis of energy development sustainability: The example of the Lithuanian district heating sector. Energy Policy, 100, 227-236.

Lin, X. (1996), China's Energy Strategy: Economic Structure, Technological Choices, and Energy Consumption. Westport, USA: Greenwood Publishing Group.

Lin, X., Polenske, K.R. (1995), Input-output anatomy of China's energy use changes in the 1980s. Economic Systems Research, 7(1), 67-84.

Liu, H., Xi, Y., Guo, J.E., Li, X. (2010), Energy embodied in the international trade of China: An energy input-output analysis. Energy Policy, 38(8), 3957-3964.

Machado, G., Schaeffer, R., Worrell, E. (2001), Energy and carbon embodied in the international trade of Brazil: An input-output approach. Ecological Economics, 39(3), 409-424.

Miller, R.E., Blair, P.D. (2009), Input-output analysis: Foundations and extensions. Cambridge, UK: Cambridge University Press.

Mukhopadhyay, K., Chakraborty, D. (1999), India's energy consumption changes during 1973/74 to 1991/92. Economic Systems Research, 11, 423-438.

Munksgaard, J., Pedersen, K.A., Wier, M. (2000), Impact of household consumption on CO_2 emissions. Energy Economics, 22, 423-440.

Office of Technology Assessment (OTA). (1990), Energy use and the U.S. Economy (OTA-BP-E-57). Washington DC, USA: US Government Printing Office. Available from: http://www.ota.fas.org/reports/9016.pdf. [Last accessed on 2016 Jun 16].

Okushima, S., Tamura, M. (2007), Multiple calibration decomposition analysis: Energy use and carbon dioxide emissions in the Japanese economy, 1970-1995. Energy Policy, 35(10), 5156-5170.

Okushima, S., Tamura, M. (2010), What causes the change in energy demand in the economy? The role of technological change. Energy Economics, 32(1), 41-46.

Okushima, S., Tamura, M. (2011), Identifying the sources of energy use change: Multiple calibration decomposition analysis and structural decomposition analysis. Structural Change and Economic Dynamics, 22(4), 313-326.

Ong, H.C., Mahlia, T.M.I., Masjuki, H.H. (2011), A review on energy scenario and sustainable energy in Malaysia. Renewable and Sustainable Energy Reviews, 15(1), 639-647.

Peet, N.J. (1993), Input-output methods of energy analysis. International Journal of Global Energy Issues, 5(1), 10-18.

Peters, G.P., Weber, C.L., Guan, D., Hubacek, K. (2007), China's growing CO_2 emissions a race between increasing consumption and efficiency gains. Environmental Science and Technology, 41(17), 5939-5944.

Rasiah, R., Al-Amin, A.Q., Ahmed, A., Leal-Filho, W., Calvo, E. (2016), Climate mitigation roadmap: Assessing low carbon scenarios for Malaysia. Journal of Cleaner Production, 133, 272-283.

Roca, J., Serrano, M. (2007), Income growth and atmospheric pollution in Spain: An input-output approach. Ecological Economics, 63(1), 230-242.

Rose, A., Casler, S. (1996), Input-output structural decomposition analysis: A critical appraisal. Economic System Research, 8, 33-62.

Rose, A., Chen, C.Y. (1991), Sources of change in energy use in the US economy 1972-1982. Resources and Energy, 13, 1-21.

Shahbaz, M., Loganathan, N., Muzaffar, A.T., Ahmed, K., Jabran, M.A. (2016), How urbanization affects CO_2 emissions in Malaysia? The application of STIRPAT model. Renewable and Sustainable Energy Reviews, 57, 83-93.

Stage, J. (2002), Structural shifts in Namibian energy use: An input-output approach. South African Journal of Economics, 70(6), 1103-1125.

Stern, D.I. (2011), The role of energy in economic growth. Ecological Economics Reviews, 1219, 26-51.

Supasa, T., Hsiau, S.S., Lin, S.M., Wongsapai, W., Wu, J.C. (2016), Has energy conservation been an effective policy for Thailand? An input-output structural decomposition analysis from 1995 to 2010. Energy Policy, 98, 210-220.

Tuyet, N.T.A., Ishihara, K.N. (2006), Analysis of changing hidden energy flow in Vietnam. Energy Policy, 34(14), 1883-1888.

United Nations Framework Convention on Climate Change. (2016), Intended Nationally Determined Contribution of the Government of Malaysia. Available from: http://www.4.unfccc.int. [Last accessed on 2016 Jul 14].

Wachsmann, U., Wood, R., Lenzen, M., Schaeffer, R. (2009), Structural decomposition of energy use in Brazil from 1970 to 1996. Applied Energy, 86, 578-587.

Wang, C., Liao, H., Pan, S.Y., Zhao, L.T., Wei, Y.M. (2014), The fluctuations of China's EI: Biased technical change. Applied Energy, 135, 407-414.

Weber, C.L. (2009), Measuring structural change and energy use: Decomposition of the US economy from 1997 to 2002. Energy Policy, 37(4), 1561-1570.

World Bank. (2016), World Development Indicator. Available from: http://www.databank.worldbank.org/data. [Last accessed on 2016 Jul 17].

Wu, J.H., Chen, Y.Y., Huang, Y.H. (2007), Trade pattern change impact on industrial CO_2 emissions in Taiwan. Energy Policy, 35(11), 5436-5446.

Wu, R.H., Chen, C.Y. (1990), On the application of input-output analysis to energy issues. Energy Economics, 12(1), 71-76.

Xie, S.C. (2014), The driving forces of China's energy use from 1992 to 2010: An empirical study of input-output and structural decomposition analysis. Energy Policy, 73, 401-415.

Zeng, L., Xu, M., Liang, S., Zeng, S., Zhang, T. (2014), Revisiting drivers of EI in China during 1997-2007: A structural decomposition analysis. Energy Policy, 67, 640-647.