Abdullah, Azlina; Hussain Ali Bekhet

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Investigating the Driving Forces of Energy Intensity Change in Malaysia 1991-2010: A Structural Decomposition Analysis

Azlina Abdullah[1]*, Hussain Ali Bekhet[2]

[1]College of Business Management and Accounting, Universiti Tenaga Nasional, 26700, Muadzam Shah, Pahang, Malaysia, [2]College of Graduate Studies, Universiti Tenaga Nasional, 43000, Kajang, Selangor, Malaysia. *Email: azlina@uniten.edu.my

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ABSTRACT

This research investigates the changes in Malaysia's energy intensity from 1991 to 2010 using structural decomposition analysis. Energy mix, sectoral energy efficiency, production structure, final demand structure, and final demand components factors are analysed. Results show that energy intensity has increased, and the responsible factors of this change were production structure, final demand structure, and sectoral energy efficiency. Further, this increase was offset by the negative effect of the change in final demand components owing to smaller positive net exports (due to a larger increase in imports compared with the increase in exports) plus with lower investment in 2010 compared with 1991. In addition, energy mix change also has contributed to energy intensity decline but at a minimal extent. The prominent effect of the production structure factor can be explained by the industrialisation occurring in the country. The economic plans, which, among others, promote several energy intensive industries, had dampened energy efficiency initiatives. Policy suggestions are proposed to reduce the energy intensity of Malaysia.

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

1. INTRODUCTION

The role of each country's energy sector is becoming increasingly important. Energy use has indisputably enhanced the material well-being of the world's population. As an input in a production process, energy plays a vibrant role in economic growth, and future limitations on its use would limit economic growth (Stern, 2011). The world of energy is rapidly changing and the global perspective on energy has experienced astonishing changes since the oil crisis of the 1970s. A vast number of empirical studies has been conducted to investigate the association between energy use and economic growth (Apergis and Danuletiu, 2014). As for the causal relationships between the two variables, it can be classified into no causality, uni-directional causality in either direction, and bidirectional causality (Ozturk and Acaravic, 2010). Chen et al. (2016) found that, in developed and developing countries, a higher gross domestic product (GDP) gives rise to energy use. Regrettably, there are two major challenges of energy use: Peak oil and climate change. However, the world does not show a clear indication of peak oil as the time frame for that peak is always disputed due to discoveries of new oil field and new technologies that have increased world oil production. Furthermore, the extraction of shale oil has grown dramatically, not only in USA but also estimated to be abundant in other countries (Mănescu and Nuño, 2015). Though we have successfully delayed peak production, a permanent drop in total production seems inevitable. Moreover, human activities emit large amounts of greenhouse gases (GHG) into the atmosphere, which result in rising global temperature. Energy-related carbon dioxide (CO_2) are the majority of GHG emissions, mainly from the burning of fossil fuels to produce energy by power sector and emissions from industrial sector (Environmental Protection Agency, 2016).

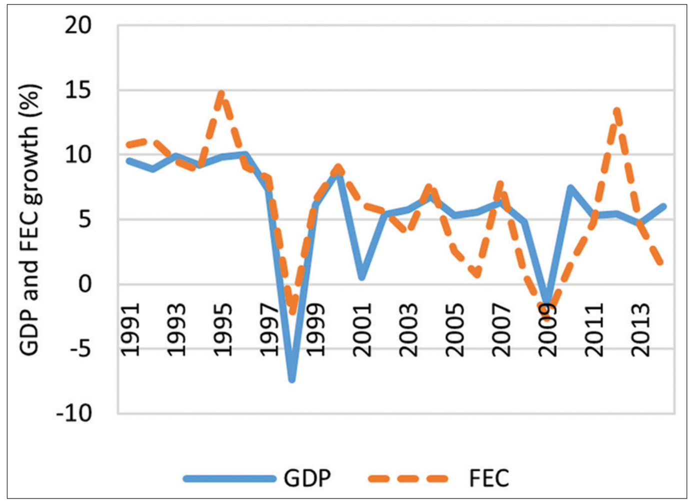
Recently, major developing countries including Malaysia have grown in terms of their GHG emissions due to rapid increase in energy use (Chen et al., 2016). Malaysia has always seen its energy sector primarily as a strategic resource and an essential input to the economy. Its energy sector constitutes about one-fifth of the GDP (Solarin and Shahbaz, 2015). Malaysia is the third largest economy in Southeast Asia and it is the third leading energy consumer in the region (International Energy Agency [IEA], 2015). Since 1988, Malaysia's energy demand is growing faster than the ability of indigenous production to keep apace (Hashim, 2010). This scenario indicates that the country is facing a crucial challenge in terms of energy security and reliability of energy supply (Ong et al., 2011). It is forecasted that Malaysia will become a net energy importer starting from 2017 (assuming business-as-usual) or 2019 (assuming energy efficiency and conservation measures and development of renewable energy [RE] power projects) (Khor and Lalchand, 2014). By 2040, fossil fuels will remain dominant in Malaysia's energy mix with its share still exceeding 90% (IEA, 2015). Globally, Malaysia was ranked 26th in 2012 when it came to CO_2 emission from fuel combustion. It also has been categorised as one of the top-10 CO_2 emitters among developing countries (Ertugrul et al., 2016). It contributed to 0.62% of global emissions each year, and the surface mean temperature of the country went up by 0.14° to 0.25°C every 10 years (Lee, 2015). It has been demonstrated that Malaysia's economic growth is a major contributor to CO_2 emissions, and its energy use has elevated emissions intensity (Shahbaz et al., 2016). It also has been proven that there is a relationship between Malaysia's industrial productivity with its CO_2 emission level (Rahman et al., 2017). Fortunately, 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).

The concerns on energy efficiency initiatives are relatively new in Malaysia. The country has begun to promote energy efficiency improvement efforts by introducing the National Energy Efficiency Master Plan (NEEMP) in 2010. Regardless of strategic planning and giving high priority to energy resources management in its development plans since 1979, unfortunately, Malaysia has inconsistently achieved a remarkable performance in energy use. Figure 1 indicates that the growth of final energy consumption (FEC) was higher than the growth of GDP in several years (i.e., 1995, 1998, 2001, 2004, 2007, and 2012).

Furthermore, Figure 2 shows that the final energy intensity (FEI) is also fluctuating over time. Though it indicates an outstanding performance in 2011 and 2012; disappointingly, it rose again in 2013 and 2014.

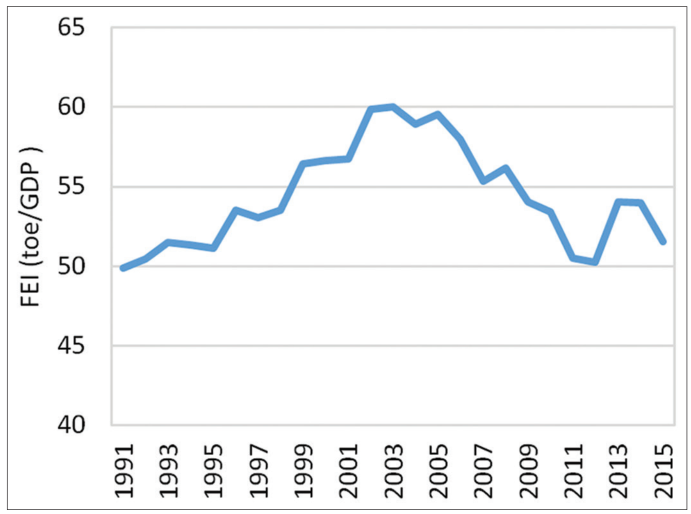
Earlier studies have explored numerous aspects of Malaysia's energy issues primarily using econometric analyses that examine the relationships between energy use and economic variables, particularly economic growth as well as their causalities. Investigating only the relationship between energy use and economic growth is insufficient without exploring the foundations of the relationship. Therefore, it is essential to conduct more advance studies for exploring the fundamental factors that resulted in changes in the country's energy use. This study aims to examine the contributing factors for energy intensity change in

Figure 1: Growth rates of gross domestic product and final energy consumption



Source: Energy Commission (EC), 2016a

Figure 2: Final energy intensity



Source: EC, 2016a

Malaysia using structural decomposition analysis (SDA) which is based on input–output (I-O) tables that can reflect clearly the relationship between production and energy use of each sector in a national economy. Compared with other methods in the research of energy use, it becomes a major research tool in which to study energy problems because of its outstanding advantages. SDA studies are limited in Malaysia especially those that investigate the factors responsible for the changes in economy-wide energy use. Earliest energy SDA studies by Chik et al. (2012) and Chik and Rahim (2014) investigate factors responsible for changes in household energy use and industrial CO_2 emissions due to energy use, respectively. In the current paper, the SDA is used to investigate the factors underlying the changes in energy use of the whole economic sectors of the country. In addition, it is an energy SDA study that is based on full Dietzenbacher and Los (D&L) method which is well known for its ideal characteristic. Bekhet and Abdullah (2017, 2018) has implemented the same approach in order to investigate the factors for energy intensity changes in Malaysia but for the period of 2005-2010 and three subperiods between 1991 and 2010 (1991-2000, 2000-2005 and 2005-2010) respectively. In this study, the whole period of 1991-2010 is investigated for complementing the previous two studies. Most of the sectors investigated are under the four broad focus areas in the 11th Malaysia Plan (2016-2020), which aimed to be migrated toward high value-added and knowledge-intensive economic activities, namely: Services, manufacturing, agriculture, and construction (Economic Planning Unit, 2015). Hence, this research contributes toward studying energy use changes in their subsectors, which are more appropriate in the policymaking process. Given the expectations for Malaysia's future energy use and the GHG emission reduction target as stated earlier, hence, conducting energy use study using SDA is crucial so that appropriate policies, strategies, and regulations can be enacted. Furthermore, this study can serve as a representative case for understanding the energy consumption changes in small developing countries and countries in Southeast Asia.

The rest of the paper is structured as follows. Section 2 reviews the development of the global energy SDA studies and its development in Malaysia's context. Section 3 explains the data used and its processing. Subsequently, Section 4 clarifies the methodology of the study. Section 5 presents the research findings and provides discussions. Then, Section 6 delivers the conclusion and policy implications of the study.

2. LITERATURE REVIEW

The oil crises in the 1970s motivated many researchers to conduct energy demand analyses in an effort to find ways to increase efficiency of energy use. It has been noted that an economy requires different energy input levels in different development phases. Thus, it is useful to assess the driving forces that underlie the changes. Decomposition analysis has been extensively employed to investigate the driving forces of energy use changes. Shift-share analysis (SSA), index decomposition analysis (IDA), and SDA are used to gauge the effects of the driving forces on energy use changes. But IDA and SDA are the two widely used techniques. Both have been established independently and applied extensively in energy studies. Traditionally, IDA is employed to examine past development analysis of changes of an aggregate. The growth of IDA literature has been exponential due to its fewer data requirements. Dietzenbacher and Los (1998) confirmed that the methodology of SDA is nearly similar to that of SSA. However, typical SDA studies has the ability to provide more detailed factors, such as a Leontief effect (or technical effect) and final demand effect by both sector and demand sources. Furthermore, SDA is better due to its ability to measure indirect demand effects, which are not possible in SSA and IDA. It is also a pragmatic alternative to the time-series econometric estimation due to its requirement of only two I-O tables: One for the initial year and the other for the terminal year of the analysis.

SDA has been proven to be a useful tool for examining changes in energy use. It can be divided into three groups of methods; ad hoc, Dietzenbacher and Los (D&L), and Divisia index methods (DIMs). There is a strong shift from ad hoc methods to D&L and to DIMs, particularly the logarithmic mean Divisia index (LMDI). In the earlier years, many studies were reported using ad hoc SDA (Hoekstra and van den Bergh, 2002). However, the number of studies using D&L have increased steadily over time, while LMDI started to be adopted by researchers in the last few years. Among the earliest ad hoc SDA studies on energy use are Chen and Rose (1990) which examined energy use changes in Taiwan, and Rose and Chen (1991) which studied energy demand changes in the USA. Also, Chen and Wu (1994) analysed the change in electricity demand in Taiwan. Han and Lakshmanan (1994), Okushima and Tamura (2007; 2010; and 2011) investigated changes in Japan's energy use. Furthermore, Lin and Polenske (1995) and Mukhopadhyay and Chakraborty (1999) studied the changes in energy use for China and India respectively. Regrettably, ad hoc methods generally give imperfect decomposition mainly due to its results that contain a residual term, which complicates results interpretation.

Dietzenbacher and Los (1998) suggested the use of an average of all $n!$ equivalent exact decomposition forms to achieve ideal decomposition that guarantees exact decomposition of an aggregate and, at the same time, satisfies other conditions of the factor reversal test. Due to the burdensome of D&L method when the number of factors is large, several studies are found to use an approximate D&L method for energy use changes. Jacobsen (2000) demonstrated that a structural change in foreign trade patterns can intensify domestic energy demand. Kagawa and Inamura (2001) showed that Japan's total energy requirement has increased largely because of changes in the nonenergy final demand, while the product-mix changes have contrary effects, that is, energy savings. For Thailand, Supasa et al. (2016) discovered that the final demand effect was the strongest factor in determining the decline in energy use, whereas the energy efficiency effect was not an effective factor in reducing energy use. Several studies employed a full or equivalent D&L method for energy use. For Vietnam, Tuyet and Ishihara (2006) showed that, in nearly all economic sectors, the changes of energy-use technology had a greater absolute value than the changes of structure of inter-sectors. In the USA, Weber (2009) revealed that the energy embodied in household consumption and imports was determined mainly by rapidly increasing demand with the lesser structural and intensity effects. For China, Cao et al. (2010) found that overall decrease in total embodied energy requirements resulted in a better energy-use technology. Furthermore, Liu et al. (2010) demonstrated that escalating total exports and growing exports of energy-intensive goods tend to increase energy use. Fan and Xia (2012) summarised that energy intensity was significantly reduced by changes in energy input coefficients and technology coefficients rather than by final demand shifts. Zeng et al. (2014) showed that sectoral energy efficiency improvements contributed the most to the energy intensity decline. For Portugal, Guevara and Rodrigues (2016) found that the main drivers for increased energy use was final demand and direct energy intensity. The energy and economic transitions lead to energy use decline.

Other than the full D&L method, SDA grounded on LMDI is another ideal decomposition method. It has been discovered that the LMDI method has been adopted in some recent SDA studies. For Brazil, Wachsmann et al. (2009) studied the sources of changes in energy use of industries and households. The growth of energy use was mainly due to the changes in affluence, population, and inter-sectoral dependencies, while changes in direct energy intensity and per capita residential energy use had a retarding impact on energy use. For China, Chai et al. (2009) found that the fluctuation of energy intensity is mostly due to technology advances and the corresponding change in industrial structure. Xie (2014) revealed that energy use is investment-led demand. There also are energy use studies using SDA based on other DIMs that include the use of the parametric Divisia methods. For example, Garbaccio et al. (1999) concluded that technical change within sectors accounted for most of the fall in the energy-output ratio, and structural change actually increased the use of energy. Increase in the imports of some energy-intensive products also contributed to the decline in energy intensity. For China, Wang et al. (2014) discovered that energy intensity of coal and electricity increased, and the changes were mainly attributed to structural changes. As for crude oil and refined oil, the energy intensity reduced. The changes were mostly attributed to the changes in the production technology.

Globally, it has been verified that SDA has a robust theoretical foundation for investigating the effects of different factors on energy intensity (Wu and Chen, 1990; Peet, 1993; Han and Lakshmanan, 1994; Lin and Polenske, 1995). For Malaysia, the earliest energy SDA studies are Chik et al. (2012) and Chik and Rahim (2014). Chik et al. (2012) demonstrated that for the 1991-2005 period, 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. On the other hand, Chik and Rahim (2014) found that the export sector was the biggest contributor of industrial CO_2 emissions due to its energy consumption for the 1991-2005 period. Recently, Bekhet and Abdullah (2017) initiated the effort on investigating the factors contributing to energy intensity change in Malaysian economy for the 2005-2010 period using SDA that is based on full D&L method. Five contributing factors for energy intensity change namely energy mix, sectoral energy efficiency, production structure, final demand structure and final demand components were analysed. Results show 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 GDP. 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. Bekhet and Abdullah (2018) extended the period of investigation by covering three periods of 1991-2000, 2000-2005 and 2005-2010. The results indicate that the energy intensity has increased sharply during the 1991-2000 period, decreased in the 2000-2005 period and decreased again in the 2005-2010 period but only at a minimal level. The final demand structure factor was the most prominent factor resulted in the changes of energy intensities during the 1991-2000 and 2000-2005 periods. On the other hand, the final demand components factor showed its dominant role over the other factors for the decline in energy intensity during the 2005-2010 period. Several policy implications are discussed based on the findings of both studies.

3. DATA

This study employs two I-O tables for the years 1991 and 2010 published by the Department of Statistics Malaysia (DOSM, 2002; 2015). There are 92 and 124 activities (commodities) classification for each table respectively. Each table is aggregated to 41 sectors, which include five energy sectors and 36 nonenergy 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 as implemented by Lin and Polenske (1995) due to its inclusion in the electricity and gas sector in the original I-O tables. Due the importance of coal in Malaysia's energy mix, the coal sector has also been separated from other mining based on unpublished information provided by DOSM. This way of incorporating hydropower and coal sectors enables us to meet the energy conservation condition as required in the hybrid approach of I-O analysis.

This study employs the SDA model that is based on Zeng et al. (2014) with some modifications. Instead of splitting energy intensity into domestically produced products and imported products, this study treats the imported products the same as the domestic ones. According to Kim (2010), when one uses domestic production tables only, the intermediate inputs reflect only domestic intermediate input structure, which often underestimates total production structure. Therefore, this study combines both the domestic production and import I-O tables in order to produce a total production table for each period. The table is often called a competitive table because the imported products are treated the same as the domestic products. Miller and Blair (2009) stated that, if one is concerned on the structure of production and how they have changed over time (i.e., structural analysis), it may be more valuable to have competitive imports because such imports are surely part of production recipes. Among the SDA studies that employed total production tables are those from 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 I-O tables, which is best for identifying energy uses (Lin, 1996). The current price I-O tables are adjusted for inflation using the double deflation method, as introduced by Dietzenbacher and Hoen (1999) and the year 2005 is used as the base year. This research employs a hybrid units approach as initially introduced by Bullard and Herendeen (1975). The physical values of energy data were obtained from the national energy balance (NEB) for the years 1991 and 2010. Sectoral classification in NEB is too aggregated, and therefore requires a substantial effort for harmonising it with data from I-O tables.

1 Aggregation details are available with authors upon request.

4. METHODOLOGY

The energy I-O analysis methodology employed in this study is based on the key mathematical equation contains the Leontief inverse matrix presenting the relationship between total output (x), and final demand (f), as in Equation (1):

$$x = Ax+f=(I-A)^{-1}f=Nf \quad (1)$$

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

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

$$e_t = r'x \quad (2)$$

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

$$e_t = r'Nf \quad (3)$$

Instead of studying the changes in energy use, this study investigates the changes in energy intensity. Hoekstra and van den Bergh (2002) stated that studies that are concerned on the relative performance of an economic indicator should use the intensity or elasticity approaches. Thus, the term e_t in Equation (3) is substituted with

$$e = \frac{e_t}{g} \quad (4)$$

Where, e = energy intensity and g = a scalar representing GDP. Substituting e_t in Equation (3) with e as defined above, it is rewritten as in Equation (5).

$$e = r'N\frac{f}{g} \quad (5)$$

Based on Zeng et al. (2014), the sectoral energy efficiency (r') in Equation (5) is further decomposed to include an energy mix factor (M), as indicated in Equation (6):

$$r' = \tau M\hat{r} \quad (6)$$

Where, τ = a unit row vector conformable for matrix multiplication; M = a matrix demonstrating shares of different energy types in each sector; $\hat{r}$ = a diagonal matrix with the elements of the r' on its diagonal and all other elements are zeros.

The final demand components involved in this study are private consumption (C), government consumption (G), investment (I), and net exports (NX). The final demand vector (f) can further be decomposed into two components as indicated in Equation (7).

$$6f=f^s f^c g \quad (7)$$

Where, f^s = a matrix that denotes shares of sectors in each final demand category; f^c =a vector that signifies shares of each final demand category in GDP and g = a scalar of GDP.

Different from Zeng et al. (2014), this study considers private consumption as an exogenous sector. In other words, this study conducts investigations on changes in energy intensity within the traditional approach of I-O framework, which includes private consumption as part of the final demand components. Thus, by integrating Equations (5), (6), and (7), the full decomposition of energy intensity (e) can be expressed as in Equation (8).

$$e = \frac{\tau M\hat{r}Nf^s f^c \text{g}}{\text{g}} \quad (8)$$

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

$$e = \tau M\hat{r}Nf^s f^c \quad (9)$$

Table 1 summarises the variables used in this research.

The change of energy intensity (e), from the basic year (0), to target year (1), can be articulated as in Equation (10). For this study, the basic year is 1991 and the target year is 2010.

$$\Delta e = \tau(M_1\hat{r}_1N_1f_1^s f_1^c - M_0\hat{r}_0N_0f_0^s f_0^c) \quad (10)$$

Where $\Delta e = e_1 - e_0 = \tau M_1\hat{r}_1N_1f_1^s f_1^c - \tau M_0\hat{r}_0N_0f_0^s f_0^c$. This study uses the SDA of energy intensity changes that follow the commonly used additive identity splitting methods by adding and subtracting of like terms and reordering them to the right-hand-side of the equation (Dietzenbacher and Los, 1998). Using additive decomposition, Equation (10) is extended as in Equation (11).

$$\Delta e = \tau\Delta M\hat{r}Nf^s f^c + \tau M\Delta\hat{r}Nf^s f^c + \tau M\hat{r}\Delta Nf^s f^c + \tau M\hat{r}N\Delta f^s f^c + \tau M\hat{r}Nf^s\Delta f^c \quad (11)$$

Where, $\Delta M = M_1 - M_0$

$$\Delta\hat{r} = \hat{r}_1 - \hat{r}_0$$

$\Delta Mere_1 - N_0$

$$\Delta f^s = f_1^s - f_0^s$$

$$\Delta f^c = f_1^c - f_0^c$$

Equation (11) shows the change in energy intensity (Δe) is decomposed into the changes of individual contributing factors from each of the five variables. Each term on the right-hand-side of the Equation (11) signifies how much the change of energy intensity (Δe), is due to the changes in energy mix (ΔM), sectoral energy efficiency $\Delta\hat{r}$, production structure (ΔN), final demand structure (Δf^{sc}, and final demand components (Δf^c), when keeping

Table 1: List of variables and their definitions

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

GDP: Gross domestic product

other factors constant. One can rewrite Equation (11) as in Equation (12).

$$\Delta e = \tau \Delta M \hat{r}_1 N_1 f_1^s f_1^c + \tau M_0 \Delta \hat{r} N_1 f_1^s f_1^c + \tau M_0 \hat{r}_0 \Delta N f_1^s f_1^c + \tau M_0 \hat{r}_0 N \Delta f - f_1^c + \tau M_0 \hat{r}_0 N_0 f_0^s \Delta f^c \quad (12)$$

The change (Δ) goes from left to right and all factors to the right of the changed factor are counted in the target year (1) values and all the factors to the left of the change factor are counted in basic year (0), values. This decomposition form is complete, i.e., it has no residual term. Nevertheless, the decomposition form showed above is not unique. It is just one of many decompositions, as one can develop a number of alternative decomposition forms using the similar method. The derivation of the decomposition equation above arbitrarily assumed that the order of the factors is $M\hat{r}Nf^s f^c$, but it could just as well have been $NMf^s f^c \hat{r}$. 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) revealed that in the general *n*-factors case, there is *n!* different decomposition forms. In other words, the number of potential 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 study. No individual decomposition form is theoretically favoured and all alternative decomposition forms are equivalently valid. This is a so-called the non-uniqueness problem in SDA (Rose and Casler, 1996). To address the non-uniqueness problem, this study employed the full D&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 calculated as the average of all 120 decompositions. Based on the full D&L method, Section 5 demonstrates the results for energy intensity change in Malaysia for the 1991-2010 period and provides discussion.

5. RESULTS AND DISCUSSIONS

Table 2 illustrates the energy intensities for 1991 and 2010. For the 19 years duration, Malaysia's energy intensity increased by 22.13%. The results can be supported by the implementation of the three phases of Malaysia's Industrial Master Plan (IMP) (i.e., IMP1: 1986-1995; IMP2: 1996-2005; IMP3: 2006-2020) which involves the period of the analysis (1991-2010).

Table 3 demonstrates the contribution of each factor to the increase in energy intensity. First, the energy mix (*M*) is found to be the least influential factor for energy intensity change. It has resulted in a decline in energy intensity but at a very minimal level with only −1.84E−14% decline. This finding is in line with Zeng et al. (2014), and Fan and Xia (2012) results for China. In Malaysia, the electricity and gas is the most energy intensive sector. This is because of its requirements of all sorts of energy inputs for power generation. The reduction in the use of petrol refinery products in its energy mix did not give a significant negative effect on Malaysia's energy intensity due to higher use of crude oil and natural gas, and coal compensating lower petrol refinery input for power generation. The share of hydropower in electricity and gas energy mix also was reduced. Most of the nonenergy sectors found to experience reductions in the use of petrol refinery products by compensating them with electricity and gas for their production processes. Petrol refinery and electricity and gas are secondary energy types. Therefore, the shift toward increased use of electricity and gas replacing the use of petrol refinery products has not resulted in significant negative changes in energy intensity because electricity and gas sector itself is highly energy intensive.

Table 2: Energy intensity 1991-2010 (ktoe/GDP)

	1991	2010	Δ*e*	% Δ*e*
Energy intensity	1.83E-04	2.24E-04	4.06E-05	22.13

(1) The computation of *e* for each year is based on Equation (9). (2) The computation for Δ*e* using the average of all 120 decompositions gives the same result

Table 3: Energy intensity change and the contribution of each factor 1991-2010

No.	Factor	Δ*e*	%Δ*e*
1	Energy mix	−7.4552E-21	−1.84E-14
2	Sectoral energy efficiency	5.38679E-06	13.3
3	Production structure	4.2226E-05	104.0
4	Final demand structure	1.21468E-05	29.9
5	Final demand components	−1.91685E-05	−47.2
	Total	4.05911E-05	100

Second, the sectoral energy efficiency $(\hat{r})$ is found to be the third largest factor, contributed to 13.3% increase in energy intensity (Table 3). This finding is in line with a study for Thailand, where the energy efficiency effect contributed to an increase in energy use too (Supasa et al., 2016). However, the result is different from the finding for China which found that sectoral energy efficiency improvements contributed most to overall energy intensity decline (Zeng et al., 2014). This finding designates that sectors in Malaysia use more energy for each output they produced in 2010 compared with that of 1991. Within energy sectors, crude oil and natural gas sector was found to experience the largest efficiency reduction while electricity and gas sector indicated minimal efficiency reduction. Coal and petrol refinery sectors experienced energy efficiency improvements. Within nonenergy sectors, 19 indicated improvements in energy efficiency; led by other mining, followed by basic metals, wholesale and retail trade, and rubber products. Seventeen sectors experienced energy efficiency reduction led by forestry and logging, followed by textiles and leather, fisheries, real estate and dwelling, oil palm plantation, and other agriculture. These energy efficiency reductions have contributed to a positive effect of sectoral energy efficiency on energy intensity during 1991-2010 period.

Third, the production structure (*N*) contributed to a 104% increase in energy intensity and appears as the most prominent factor for the upsurge for the 19 years duration (Table 3). Unfortunately, there are limited energy SDA studies with the time frame of more than 10 years. Most studies divided their analysis into subperiods. For Brazil, Wachsmann et al. (2009) revealed that the production structure for 26 years (1970-1996) was among the main factors for the increase in energy use, i.e., not energy intensity. Conversely, for the USA (13 years; 1972-1986) and Japan (15 years; 1970-1985), the authors revealed that production structure was the most responsible factor for energy use decline (OTA, 1990; Okushima and Tamura, 2010). In Malaysia, the production structure factor is the main driver in increasing Malaysia's energy intensity, which can be explained by Malaysia's manufacturing sector being more capital intensive, with an increasing number of heavy industries guided by its three phases of the IMPs. In addition, the mining and quarrying and services sectors' contribution to GDP also had experienced significant positive changes. These also have contributed to higher energy intensity in the country.

Fourth, the final demand structure (f^s) had become the second largest responsible factor, which contributed to a 29.9% upsurge in energy intensity. This result is in line with the findings for India, Japan, China, Thailand, and Portugal, which also revealed that the final demand structure contributed positively to 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, for the USA, final demand structure contributed negatively to energy intensity change (OTA, 1990). In the current study, it is found that Malaysia's private consumers increased their expenditure allocation mainly for financial services, communication, wholesale and retail trade, and education. Government consumption expenditures on other services also has increased. Positive investment change was found to occur mainly in electrical and electronics equipment, business services, wood-based, and food while investment in construction experienced the largest negative change. In terms of exports, electrical and electronics equipment sector was found to experience the largest positive change, followed by petrol refinery, machinery and the wholesale and retail trade, while the largest negative change was experienced by textiles and leather. There were reductions in imports, mainly in machinery, transport and transport equipment, industrial chemicals, and other manufacturing. All the sectoral positive changes in private consumption, government consumption, investment, and exports as well as the negative changes in imports partly contributed to higher energy intensity for the 1991-2010 period.

Fifth, the negative effect of final demand components (f^c) at −47.2% has prevented a higher increase in energy intensity. This result can be supported by smaller positive net exports with larger imports compared with exports during the 1991-2010 period. For Denmark, higher imports reduced energy intensity. Unfortunately, the reduction in energy consumption due to higher imports was outweighed by a large positive effect from increasing exports (Jacobsen, 2000). Smaller positive net exports are accompanied by a reduction in Malaysia's investment, which also helps to further strengthen the negative effect of final demand components. Also, the investment was severely hit by the 1997/1998 Asian financial crisis and the 2007/2008 global financial crisis (Nambiar, 2009, Bekhet and Yasmin, 2014). For China, its continuously rising proportion of investment became among the important contributors for the increase in energy intensity (Zeng et al., 2014). During the 1991-2010 period, Malaysia's investment in construction and machinery, which are classified as energy-intensive sectors, experienced significantly negative changes. Lower investment mainly in these two sectors had reduced the positive effects of other final demand components on energy intensity change.

6. CONCLUSION AND POLICY IMPLICATIONS

This study examines the energy intensity change in Malaysia for the 1991-2010 period. It uses SDA, which is based on the full D&L method. For the 19 year duration, energy intensity increased mainly due to the change in the production structure that was mostly due to the growing energy intensive manufacturing activities irrespective of the dominant contribution of the services sector to GDP. The changes in final demand structure and sectoral energy efficiency also have increased the energy intensity. A further upsurge in energy intensity was mostly offset by the negative effect of final demand components. Lower investment and higher imports led to the overall negative effect of final demand components on energy intensity. The energy mix factor also contributed negatively but at a minimal level.

Based on the findings of this study, some policy implications are provided as below:

The energy mix factor is the least significant contributor to energy intensity change. Among the five energy sectors, the energy mix of electricity and gas sector becomes a major concern. Malaysia's electricity sector has shown its remarkable achievement of the Four Fuel Diversification Policy (1981), where its high dependence on fuel oil has been significantly reduced, replaced by increasing use of natural gas and coal. Unfortunately, these changes had only led to a minimal reduction in Malaysia's energy intensity. Furthermore, the concentration of nonenergy sectors on the use of either one of the two secondary energy sources (i.e., petrol refinery or electricity and gas) in their energy mix has resulted in the insignificant change in overall energy intensity, although there were changes in the consumption shares of each secondary energy sources. Many sectors had shifted their energy input from the use of petrol refinery products to the use of electricity and gas. Still, electricity generation is highly energy intensive, as it uses all sorts of energy sources in its production process. Energy mix factor must play a significant role in reducing Malaysia's energy intensity. Having a large share of RE in Malaysia's energy mix is crucial. In 2000, the country has introduced RE as the fifth fuel under the Five Fuel Diversification Policy. Regrettably, the development in using RE (other than hydropower) as part of inputs for electricity generation has been slow. Malaysia, through its Eighth Malaysia Plan (2001-2005) had targeted to generate 5% of its electricity from RE by 2020. Unfortunately, in 2014, only 0.5% electricity was generated from RE (EC, 2016b). In its 11th Plan (2016-2020), a higher RE target was set: To achieve 7.8% of total installed capacity in Peninsular Malaysia and Sabah by 2020 (EPU, 2015). Hopefully, this new target is achievable.

Sectoral energy efficiency factor was also found not to contribute to energy intensity decline. Proactive steps need to be implemented in order to make it becomes as among the important contributor for energy intensity decline. The Malaysian government has implemented many initiatives to stimulate energy efficiency. Unfortunately, some industries are still facing high energy intensities due to lack of awareness of energy conservation measures by operational management such as in terms of lighting, cooling, and the possibility to generate RE (Muhamad et al., 2015). Thus far, it has been discovered that the energy audits implemented were only focused on the manufacturing sector. Therefore, it is more valuable if an energy auditing project could be extended to other sectors, which also experienced significant positive energy intensity changes such as forestry and logging, and fishery industries under the agriculture sector as well as financial services, real estate and dwellings, and amusement and recreation under the services sector.

Sectoral energy efficiency and production structure factors are supposed to contribute negatively to the changes in energy intensity. Malaysia's decision for increasing the share of the services sector in GDP is in tandem with its target to reduce the level of energy use and therefore helps to reduce its CO_2 emissions. Unfortunately, several industries under the services sector were found not energy efficient. Therefore, vigilant steps must be executed in order to guarantee energy efficiency in the services sector. Also, the accompanying stronger growth of manufacturing sector, guided with the three phases of the IMPs will largely result in higher energy intensity. Under the manufacturing sector, Malaysia is encouraging investment for some industries that are categorised as being energy-intensive. Although using more advanced equipment can lead to energy intensity reduction, reducing the share of energy-intensive industries in GDP is a better way for addressing future energy challenges. Therefore, more proactive steps need to be implemented for improving sectoral energy efficiency and at the same time rationalising Malaysia's production structure by shifting away from energy-intensive to less energy-intensive industries.

Final demand structure should also help in reducing Malaysia's energy intensity. In Malaysia, it is found that the allocations for electricity and gas and petrol refinery in private consumption expenditures have increased. Household demand for other products will indirectly contribute to higher energy demand, too. Malaysia could implement the ideas that have been applied in other countries in order to vigorously stimulate its energy conservation and energy efficiency measures among the public. For instance, allowing income taxes deduction for the expenses incurred to implement certain types of energy efficiency renovations or use of RE in existing homes (Alberini and Bigano, 2015). In terms of government consumption, there are various ways in which the government also could contribute to energy conservation and energy efficiency. Apart from the existing energy efficiency initiatives such as energy efficient building showcase models that involve low energy office (LEO), green energy office (GEO), and diamond building, reduction in energy consumption also could be done in other areas. For example, for Malacca, the state plans to reduce energy consumption by installing new energy efficient street lighting (Murali, 2016). In 2015, Malacca also has become the first state in Malaysia to undergo energy performance contracting (EPC). These initiatives should be extended to other states of the country as well. Furthermore, regarding the certification of ISO 50001 energy management systems (EnMS), only one government organisation (Public Works Department) was successfully certified with EnMS out of 16 organisations. This policy is important for all government departments in order to encourage the private sector to obtain certification as well and therefore increase the energy efficiency of the country.

For future research, it is vital to examine the changes in Malaysia's energy intensity in the subperiods within 1991-2010. Based on the available Malaysia's I-O data, the periods of 1991-2000, 2000-2005, and 2005-2010 can be investigated. These detailed investigations are important in order to efficiently determine suitable energy-related policies and, therefore, achieving sustainable energy in the country.

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