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Highlighting the Factors of Energy Intensity Change in Malaysia: Input-Output Approach

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Abstract *– This study aims to investigate the changes in Malaysia's energy intensity during the 1991-2010 period. This study analyses the energy intensities for the three sub-periods of 1991-2000, 2000-2005 and 2005-2010 using the structural decomposition analysis. The analysis investigates five contributing factors for energy intensity change. They are the energy mix, sectoral energy efficiency, production structure, final demand structure and final demand components factors. The results indicate that the energy intensity has increased sharply during the first sub-period, decreased in the second sub-period and decreased again in the third sub-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 first and second sub-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 third sub-period. Several policy implications are discussed based on the findings of this study.*

Keywords **–** Energy efficiency, energy intensity, input-output model, Malaysia, structural decomposition analysis.

1. INTRODUCTION

The role of each country's energy sector is becoming increasingly important. Energy consumption has indisputably enhanced the well-being of the world's population. As an input in a production process, energy plays a vibrant role in economic growth and thus its future limitations would limit economic growth [1]. The world of energy is rapidly changing and the global perspective on energy has experienced astonishing changes since the oil crisis of the 1970s. Since then, a vast number of empirical studies has been conducted to investigate the association between energy consumption and economic growth (see [2]). For instance, it is found that a higher GDP gives rise to energy consumption in developed and developing countries [3]. Despite its importance, regrettably, there are two major challenges of energy consumption: peak oil and climate change. In terms of peak oil challenges, 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 [4]. Though we have successfully delayed peak production, a permanent drop in total production seems inevitable. Concerning climate change challenges, human activities that emit large amounts of greenhouse gases (GHG) into the atmosphere has resulted in rising global temperature. Energy-related carbon dioxide (CO_2) is the majority of GHG emissions, mainly from the burning of fossil fuels to produce energy by power and industrial sectors [5].

Recently, major developing countries including Malaysia have grown in terms of their GHG emissions due to rapid increase in energy consumption [3]. 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 [6]. Malaysia is the third largest economy in Southeast Asia and it is the third leading energy consumer in the region [7]. Since 1988, Malaysia's energy demand is growing faster than the ability of indigenous production to keep apace [8]. This scenario indicates that the country is facing a crucial challenge in terms of energy security and reliability of energy supply [9]. A forecast indicates 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) [10]. By 2040, fossil fuels will remain dominant in Malaysia's energy mix with its share still exceeding 90% [7]. Globally, Malaysia was ranked 26th in 2012 when it came to CO_2 emission from fuel combustion. It was also categorised as one of the top-10 CO_2 emitters among developing countries [11]. It contributed to 0.62% of global emissions each year, and the surface mean temperature of the country went up by 0.14^o to 0.25^o Celsius every 10 years [12]. Malaysia's economic growth is a major contributor to CO_2 emissions and its energy consumption has elevated emissions intensity [13]. Also, there is a relationship between Malaysia's industrial productivity with its CO_2 emissions level [14]. Fortunately, Malaysia has taken the initiatives to reduce its GHG emissions intensity of GDP by 45% by 2030 relative to the level in 2005 [15].

The concerns on energy efficiency initiatives are relatively new in Malaysia. In 2010, the country has begun to promote energy efficiency improvement by introducing the National Energy Efficiency Master Plan (NEEMP). Regardless of strategic planning and giving

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high priority to energy resources management in its development plans since 1979, unfortunately, Malaysia has inconsistently achieved a remarkable performance in energy consumption. 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 increased again in 2013 and 2014.

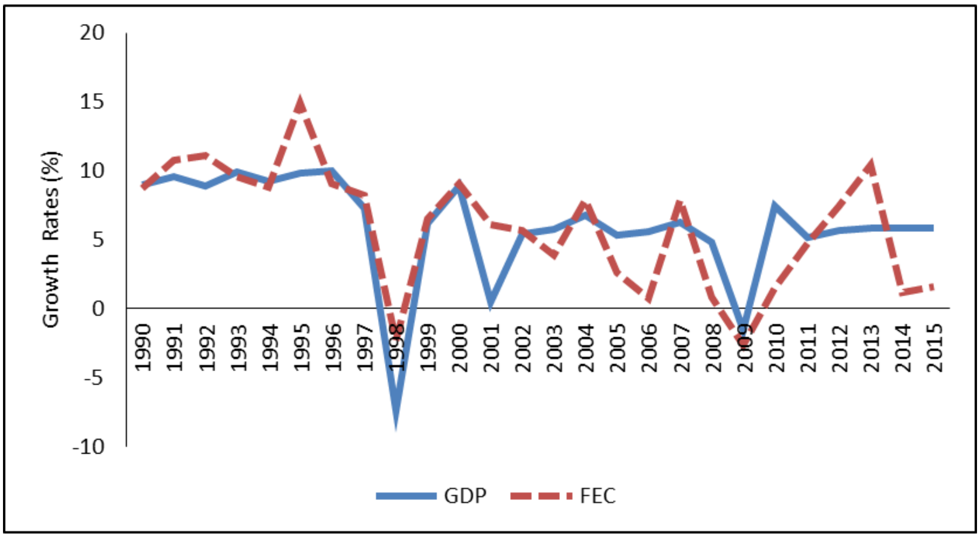

Fig. 1. Rates of GDP and final energy consumption. ***Source: [16]***

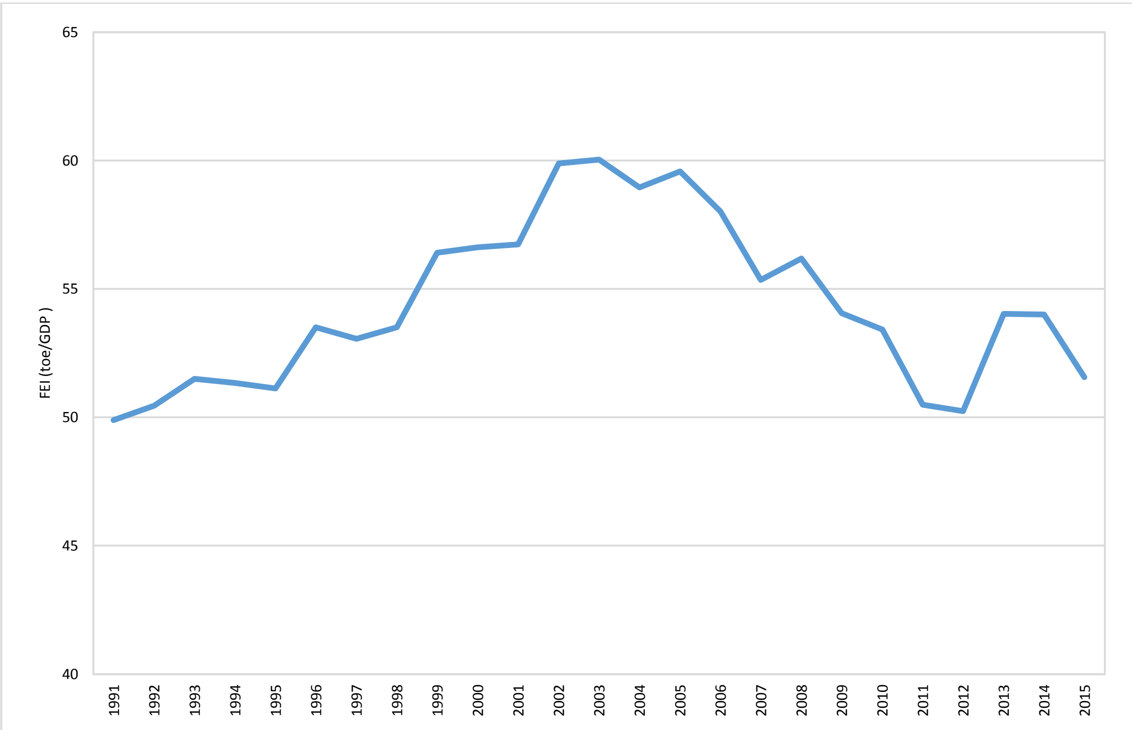

Fig. 2. Final energy intensity. ***Source: [16]***

Earlier studies have explored numerous aspects of Malaysia's energy issues primarily using econometric analyses that examine the relationships between energy consumption and economic variables, particularly economic growth as well as their causalities. Investigating only the relationship between energy consumption 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 consumption. This study aims to examine the contributing factors for energy intensity change in 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 consumption of each sector in a national economy. Compared with other methods in the research of energy consumption, it becomes a major research tool to study energy problems because of its outstanding advantages. SDA studies are limited in Malaysia. To the researchers' best knowledge, so far only three energy-related studies using SDA available for the country. The earliest two SDA studies are limited to only investigate factors responsible for changes in household energy consumption and industrial CO_2 emissions due to energy consumption, respectively (see [17], [18]). On the other hand, the third study is classified as the first Malaysia's SDA that uses full Dietzenbacher and Los (D&L) method and it is also the first SDA study in the country that investigated the factors responsible for the changes in economy-wide energy consumption [19]. The SDA study in [19] and in the current study are written by the same authors and both applied the same SDA method for different periods of investigation. In [19] the period of 2005—2010 was examined, while in the current study, a longer period was investigated which comprises of three sub-periods between the 1991-2010 duration. The sub-periods are 1991-2000, 2000-2005 and 2005-2010. It is important to highlight that, most of the sectors investigated in both studies 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 [20]. Hence, this study contributes toward studying energy consumption changes in their subsectors, which are more appropriate in the policymaking process. Given the expectations for Malaysia's future energy consumption and the GHG emissions reduction target as stated earlier, hence, conducting energy consumption 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.

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 consumption. 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 consumption changes. Shift-share analysis (SSA), index decomposition analysis (IDA) and SDA are the three types of decomposition analyses used to gauge the driving forces of energy consumption changes. But, IDA and SDA are the two widely used techniques. Both are established independently and applied extensively in energy studies. Traditionally, IDA is employed to examine past development of changes of an aggregate. The growth of IDA literature is exponential due to its fewer data requirements. The methodology of SDA is nearly similar to that of SSA [21]. 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.

There are three important review articles that summarize the development of SDA studies. SDA studies prior to 1999 are already reported in [22]. Those that are published during 1999-2010 are reported in [23]. Meanwhile, [24] reported those that are published during 2010-2015. The SDA can be implemented in either two ways; additive or multiplicative. The additive SDA has been more popular prior to 2012. However, the multiplicative SDA has increasingly been applied recently due to the availability of time-series I-O tables and it is more convenient than using additive SDA [24]. Most of the multiplicative SDA studies have been applied to emissions investigations such as [25], [26]. The example of its application on energy study can be seen from [27]. Furthermore, apart from investigating specific country's indicator using SDA, the method can also be applied to regional studies, which is called as spatial SDA. The study that applied this method on energy use is [28]. The methods of SDA can be divided into three groups; 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).

Generally, in the earlier years, many studies were reported using ad hoc SDA (see [22]). 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 consumption are those that examined energy consumption changes in Taiwan and in the USA in the early 1990s (see [29], [30], [31]). There are also studies done for energy consumption changes in Japan (see [32], [33], [34], [35]), China and India (see [36], [37]). Regrettably, ad hoc methods generally give imperfect decomposition mainly due to its results that contain a residual term, which complicates results interpretation.

The D&L SDA is an ideal decomposition method that uses an average of all *n!* equivalent exact decomposition forms. It guarantees exact decomposition of an aggregate and at the same time satisfies other conditions of the factor reversal test [21]. However, 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 consumption changes. For instance, [38] demonstrates that a structural change in foreign trade patterns can intensify domestic energy demand. [39] shows that Japan's total energy requirement has increased largely because of changes in the non-energy final demand, while the product-mix changes have contrary effects, that is, energy savings. For Thailand, [40] discovers that the final demand effect is the strongest factor in determining the decline in energy consumption, whereas the energy efficiency effect is not an effective factor in reducing energy consumption. Several studies employ a full or equivalent D&L method for energy consumption. For Vietnam, [41] shows 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, [42] 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, [43] indicates that overall decrease in total embodied energy requirements resulted in a better energy-use technology. Furthermore, [44] demonstrates that escalating total exports and growing exports of energy-intensive goods tend to increase energy consumption. [27] summarises that energy intensity was significantly reduced by changes in energy input coefficients and technology coefficients rather than by final demand shifts. [45] shows that sectoral energy efficiency improvements contributed the most to the energy intensity decline. For Portugal, the main drivers for increased energy consumption was final demand and direct energy intensity [46]. The energy and economic transitions led to energy consumption decline.

Other than the full D&L method, SDA grounded on LMDI is another ideal decomposition method. The LMDI method has been adopted in some recent SDA studies. For Brazil, [47] investigates the sources of changes in energy consumption of industries and households. The growth of energy consumption was mainly due to the changes in affluence, population, and inter-sectoral dependencies, while changes in direct energy intensity and per capita residential energy consumption had a retarding impact on energy consumption. For China, [48] indicates that the fluctuation of energy intensity was mostly due to technology advances and the corresponding change in industrial structure. Reference [49] reveals that energy consumption is investment-led demand. There also are energy consumption studies using SDA based on other DIMs that include the use of the parametric Divisia methods. For example, reference [50] concludes 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, [51] discovers 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 (see [52], [53], [32];[36]). For Malaysia, only [17], [18] and [19] use SDA in their energy studies. [17] demonstrates 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 consumption in the production sector for consumer goods. On the other hand, [18] indicates that the export sector was the biggest contributor of industrial CO_2 emissions due to its energy consumption for the 1991–2005 period. Reference [19] shows that there was a decline in Malaysia's energy intensity for the 2005-2010 period and final demand components factor was the most responsible factor leading to the decline. Owing to the gap of the previous studies, further SDA studies on Malaysia's energy consumption changes are vital. Moreover, a longer period of study also is needed in order to see the importance of each contributing factor over longer phases of economic development. Forecasting of energy consumption in the future has to be based on information and understanding of developments in the past [53]. A study using more factor decompositions also is important in order to further scrutinize the causes of changes in country's energy consumption.

3. DATA

This study employs four I-O tables for the years 1991, 2000, 2005 and 2010 published by the Department of Statistics Malaysia (DOSM) [54], [55], [56] [57]. There are 92, 94, 120 and 124 activities (commodities) classification for each table respectively. Each table is aggregated to 41 sectors, which include five energy sectors and 36 non-energy sectors.[2] 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 [36] 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 is 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 [45] 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 [59], 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. [60] states that, if one is concerned on the

[2] Aggregation details are available with authors upon request.

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 [32], [61], [50], [38], [67], [39], [63], [64], [28], [65], [66], [67], [68], [69], [40]. Furthermore, this study utilises a commodity-by-commodity type of I-O tables, which is best for identifying energy consumptions (see [70]). The current price I-O tables are adjusted for inflation using the double deflation method, as introduced by [71] and the year 2005 is used as the base year. This study employs a hybrid units approach as initially introduced by [72]. The physical values of energy data are obtained from the National Energy Balance (NEB) for the years 1991, 2000, 2005 and 2010. Sectoral classification in NEB is too aggregated, therefore requires a substantial effort for harmonising it with data from I-O tables.

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:

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

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

Aggregate energy consumption of the production sectors in a given period can be written as follows [60]:

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

where, e_t is a scalar of energy consumption for all production sectors, *r'* is a row vector demonstrating energy efficiency of each sector (*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:

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

Instead of studying the changes in energy consumption, this study investigates the changes in energy intensity. Reference [22] states 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

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

where, e is energy intensity and g is a scalar representing GDP.

Substituting e_t in Equation 3 with e as defined above, it is rewritten as in Equation 5.

$$e = r'N\frac{f}{g} \tag{5}$$

Based on [27], the sectoral energy efficiency (*r'*) in Equation 5 is further decomposed to include an energy mix factor (*M*), as indicated in Equation 6.

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

where, τ is a unit row vector conformable for matrix multiplication, M is a matrix demonstrating shares of different energy types in each sector and $\hat{r}$ is 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.

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

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

Different from [45], 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.

$$e = \frac{\tau M\hat{r}Nf^s f^c \mathrm{g}}{\mathrm{g}} \tag{8}$$

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

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

Table 1 summarises the variables used in this study.

The change of energy intensity (*e*), from the basic year (*0*) to target year (*1*) can be articulated as in Equation 10.

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

where $e = e_1 - e_0 = \tau M_1\hat{r}_1N_1f_1^s f_1^c - \tau M_0\hat{r}_0N_0f_0^s f_0^c$.

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 21. Using additive decomposition, Equation 10 is extended as in Equation 11.

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

where,

$$\Delta M = M_1 - M_0$$

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

$$\Delta N = N_1 - N_0$$

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

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

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^s), and final demand components (Δf^c), when keeping other factors constant. One can rewrite Equation 11 as in Equation 12.

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

Table 1. List of variables and their definitions.

Variable	Definition	Dimension
Energy intensity (*e*)	Energy consumption per unit of GDP for the entire economy.	1 x 1
Energy mix (*M*)	Shares of different types of energy consumption in production sectors. 5 is the number of energy sectors. 41 is the number of production sectors.	5 x 41
Sectoral energy efficiency, ($\hat{r}$)	Diagonal matrix signifying energy efficiency in production sectors measured by energy consumption per unit output.	41 x 41
Production structure (*N*)	Leontief inverse matrix demonstrating production structure of the economy.	41 x 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 x 4
Final demand component (f^c)	Shares of each final demand component in GDP.	4 x 1

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 $M\hat{r}Nf^sf^c$, but it could just as well have been $NMf^sf^c\hat{r}$. Following the principles in Equation (12), ΔM appears in the first term and $\Delta \hat{r}$ in the next and so on. [21] reveals 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 [73]. 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 study, 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.[3] Based on the full D&L method, Section 5 demonstrates the results for energy intensity changes in Malaysia for the three sub-periods of 1991-2000, 2000-2005 and 2005-2010 and provides discussion.

5. RESULTS AND DISCUSSION

Table 2 illustrates the energy intensities for the years 1991, 2000, 2005 and 2010. For the 1991-2000 sub-period, the energy intensity increases tremendously by 95.47%. Contrarily, for the 2000-2005 sub-period, there is a decline in energy intensity by -34.78%. For the 2005-2010 sub-period, the energy intensity indicates a further decline but unfortunately at a minimal level by only -4.20% reduction.

Table 3 demonstrates the contribution of each factor to the changes in energy intensity in each sub-period.

Based on the results demonstrated in Tables 2 and 3, the explanations on each contributing factor are provided in Subsections 5.1 until 5.5.

[3] Further description of the 120 decomposition forms is provided upon request.

Table 2. Energy intensity (ktoe/GDP).

Year	*e*	Δ*e*	% Δ*e*
1991	0.00018	-	-
2000	0.00036	0.00018	95.47
2005	0.00023	-0.00012	-34.78
2010	0.00022	-0.00001	-4.20

Notes: The computation of e for each year is based on Equation (9). The computation for Δe using the average of all 120 decompositions gives the same results as indicated in the above table. The numbers are rounded to the nearest decimals.

Table 3. Percentage contribution of each factor to overall change in energy intensity.

Factor	1991-2000	2000-2005	2005-2010
ΔM	-7.36689E-15	1.93917E-15	3.08874E-14
$\Delta \hat{r}$	1.56304	-0.47314	117.34054
ΔL	30.80000**	-4.13128**	-144.58957***
Δf^S	80.60689*	-91.96236*	160.62530**
Δf^C	-12.96993***	-3.43321***	-233.37626*
Total	100	100	100

*Notes: Numbers with asterisk *, ** and *** representing the first, second and third largest contributors to the changes in energy intensity in each sub-period.*

5.1 Energy Mix

Holding other factors constant, the energy mix factor has always been the least important factor for the changes in energy intensity throughout all sub-periods; indicating a negative effect in the 1991-2000 period, and positive effects in the later two sub-periods. Considering the energy mix of energy sub-sectors in Malaysia, the 'electricity and gas' is the most energy-intensive sector due to its requirements of all sorts of energy inputs for power generation. During the 1991-2000 period, the use of 'crude oil and natural gas' in 'electricity and gas' sector has increased. This is mostly due to gradual increase in the use of natural gas for substituting fuel oil after the implementation of Four-Fuel Diversification Policy in 1981. Unfortunately, in the later two sub-periods, the energy mix factor indicates positive effects when a greater share of coal is used for power generation compensating the reduction in the use of 'petrol refinery' products in the 'electricity and gas' sector. It is important to highlight that the share of 'hydropower' in 'electricity and gas' energy mix also continuously became smaller in the later two sub-periods.

Throughout all the sub-periods, most of the non-energy sectors experience reductions in the use of 'petrol refinery' products by compensating them with 'electricity and gas' for their production processes. However, '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 significantly negative changes in energy intensity because 'electricity and gas' sector itself is highly energy-intensive.

5.2 Sectoral Energy Efficiency

Compared with the weakest effect showed by the energy mix factor, the sectoral energy efficiency factor has always been the second least important contributor to the changes in energy intensity for all sub-periods. During the 1991-2000 sub-period, the factor contributes positively to overall increase in energy intensity. This finding is in line with a study for Thailand, where the energy efficiency effect contributes to an increase in energy consumption too [40]. However, the result is different from the finding for China, which demonstrates that sectoral energy efficiency improvements contributes most to overall energy intensity decline [45]. This finding designates that sectors in Malaysia use more energy for each output they produced in 2000 compared with that of 1991. During this sub-period, 16 sectors experience reductions in energy efficiencies led by 'crude oil and natural gas', 'textiles and leather', 'real estate and dwellings', 'beverages and tobacco', 'amusement and recreation' and 'food' sectors.

During the 2000-2005 sub-period, most sectors become more energy efficient, which lead to a small negative effect of sectoral energy efficiency on overall decline in energy intensity. Out of the five energy sub-sectors, only 'crude oil and natural gas' and 'coal' indicate efficiencies in their energy use. In terms of non-energy sectors, 29 sectors experience energy efficiencies led by 'other agriculture', 'rubber plantation', 'oil palm plantation', 'food', 'waterworks', 'beverages and tobacco' and 'healthcare'. The efficiencies can be partly explained by an increase in diesel pump price, which led to a reduction in diesel demand in 2005.

During the 2005-2010 sub-period, once again, the sectoral energy efficiency factor contributes positively to overall increase in energy intensity as experienced during the 1991-2000 sub-period. With regard to energy sub-sectors, the 'crude oil and natural gas' and 'electricity and gas' indicate energy inefficiencies while other sub-sectors indicate efficiencies. In terms of non-energy sectors, 19 sectors become inefficient led by 'other agriculture', 'rubber plantation', 'oil palm plantation', 'fishing' and 'forestry and logging'.

5.3 Production Structure

The production structure factor contributes as the second largest factor for the overall upsurge in energy intensity during the 1991-2000 sub-period. This result is in line with a study done for Brazil [47], which reveals that the production structure was among the main factors for the increase in energy consumption. Conversely, for the USA and Japan, the authors reveal that production structure was the most responsible factor for energy consumption decline [74], [34]. This result can be supported by the economic transformation in Malaysian economy that witnessed a reduction in agricultural share in GDP while other sectors experience larger shares especially manufacturing and services after experiencing an economic crisis in the early 1980s. The new segment in the nation's development has emphasized on export-oriented, high value-added, high technology and capital-intensive industries through the implementation of the first two phases of Malaysia's Industrial Master Plan (IMP) (*i.e.* IMP1: 1986-1995 and IMP2: 1996-2005). In addition, the implementation of the second round of import substitutions has also contributed to a greater share of manufacturing sector in GDP and led to a larger energy use. However, it has to be noted that, the occurrence of the 1997/1998 Asian Financial Crisis (AFC) has prevented a larger positive effect of production structure factor to overall increase in energy intensity due to slower performance of manufacturing and construction sector after the crisis.

During the 2000-2005 sub-period, once again the production structure contributes as the second largest factor to overall change in energy intensity, but at an opposite direction; negative effect. This negative effect can be explained by a larger increase in the share of services sector in GDP compared to the increase in the share of manufacturing sector during the sub-period. Furthermore, due to the AFC, a further decline in the construction sector's contribution to GDP during this sub-period has negatively affected the performance of other energy-intensive industries such as non-metallic mineral and iron and steel.

During the 2005-2010 sub-period, holding other factors constant, a further negative effect of the production structure factor is demonstrated. The negative effect can be supported by a further decline in the manufacturing sector performance due to the occurrence of 2007/2008 Global Financial Crisis (GFC). Continuously larger contribution of services sector to GDP has also led to the negative effect of the production structure factor due to its less energy-intensive nature. A larger negative effect by the factor is dampened by the positive performance of the 'construction' and other sectors after the implementation of the two stimulus packages implemented in 2008 and 2009.

5.4 Final Demand Structure

The final demand structure factor plays its dominant role as the largest factor contributing to the upsurge in energy intensity in 1991-2000 sub-period. This result is in line with the findings for India, Japan, China, Thailand, and Portugal, which also reveal that the final demand structure contributes positively to changes in energy consumption (see [37], [39], [65], [27], [46], [40]). However, for the USA, final demand structure contributes negatively to energy intensity change [74]. The changes in sectoral shares within each final demand component play a significant role resulting in the upsurge of energy intensity. There are 20 sectors in the private consumption component of final demand that indicate positive changes in their shares. Among the sectors are those that under the category of energy-intensive sectors such as 'petrol refinery', 'electricity and gas' and 'transports'. The same goes to in investment demand with 15 sectors indicate increases in their shares. Investment in 'construction' sector has consistently been the largest investment directions in 1991 and 2000. This situation can be attributed to the substantial development of heavy industries and several capital-intensive projects during this period under the 6th and 7th Malaysia Plans implementations (1991-1995 and 1996-2000), which contribute to a larger energy intensity due its nature as an energy-intensive industry. The investment in several other energy-intensive industries also indicate larger shares such as 'electrical and electronic', 'machineries', 'crude oil and natural gas' and 'forestry and logging'. Sectoral shares in exports demand has also experienced a significant change with 19 sectors show increases in their shares led by 'machineries', 'electrical and electronics' and 'transport'. Sectoral shares in imports also demonstrate changes with 24 sectors indicate reductions led by 'transport and transport equipment', 'basic metals', 'machineries', 'petrol refinery' and 'other manufacturing'. Reducing imports can partly explain higher energy use due to producing those products domestically to meet local demand.

During the 2000-2005 sub-period, once again, the final demand structure plays the most prominent role, but now at an opposite direction; negative effect to overall decline in energy intensity. This sub-period reveals negative changes of 20 sectoral shares in private consumption mainly the demand on 'financial services' and 'petrol refinery' products. There are 15 sectors indicate negative changes in their shares within the investment demand component led by 'construction' sector that was largely affected by the 1997/1998 AFC. Looking at exports, 17 sectors experience reductions in their shares led by 'electrical and electronics', 'transport' and 'machineries'. In terms of imports, 23 sectors experience higher shares especially 'other chemical' and 'petrol refinery'.

During the 2005-2010 sub-period, the final demand structure factor contributes positively to overall decline in energy intensity. Private consumption demand for 19 sectoral output has increased especially the outputs of 'wholesales and retail trade', 'petrol refinery', 'communication' and 'amusement and recreation'. Looking at investment demand, 16 sectors experience increases in their shares led by 'construction' sector due to the stimulus packages implemented in 2008 and 2009 after the 2007/2008 GFC. In terms of exports, 17 sectors experience positive changes in their shares led by 'petrol refinery' and 'food'. However, the exports of 'machineries' is deteriorated. On the other hand, 13 sectors indicate lower shares in import demand led by 'electrical and electronics' and 'machineries'.

During all sub-periods, government consumption experience the least changes in its sectoral shares due to its zero demand on most sectoral output. The government changes its demand structure by consuming output from 11 sectors in 1991, but has reduced the sectoral number to only 6 in 2000 and 5 in 2005 and 2010. Throughout all sub-periods, the largest portion of government consumption has been for 'other services' followed by 'education' and 'healthcare'.

5.5 Final Demand Components

The final demand components factor has consistently indicated negative effects on overall changes in energy intensity throughout all sub-periods. During the 1991-2000 sub-period, the most prominent final demand component that experiences change is imports and followed by exports. Both components demonstrate increases in their shares but the increase in imports is larger. An increase in import is expected to lessen the amount of domestic energy use due to the utilisation of energy from exporting countries. However, higher shares of exports, private consumption, government consumption and investment had reduced the overall negative effect demonstrated by final demand components factor on overall increase in energy intensity during the sub-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 [38]. For China, its continuously rising proportion of investment became among the important contributors for the increase in energy intensity [45].

During the 2000-2005 period, once again, the final demand components factor indicates negative effect on overall decline in energy intensity. All final demand components experience reductions in their shares with the largest reduction is demonstrated by imports and it is followed by the reductions in exports and investment. During this sub-period, Malaysia's momentum of growth has slowed down largely due to the 1997/1998 AFC.

The final demand components factor demonstrates its largest contribution in the 2005-2010 sub-period when it becomes the most prominent factor for energy intensity decline. Unfortunately, the remarkable contribution demonstrated by final demand components factor is offset by combination effects of other factors, which in the end leads to only a minor decline in overall energy intensity. During this period, all final demand components indicated increases in their shares except the import component, which experience a reduction. Malaysia's final demand components especially investment experiences significantly negative changes due to the 2007/2008 GFC [75], [76]. However, each final demand component has gained its momentum after the implementations of two stimulus packages in 2008 and 2009.

6. CONCLUSION AND POLICY IMPLICATIONS

This study examines the energy intensity changes in Malaysia for the 1991-2010 period with three sub-periods of 1991-2000, 2000-2005 and 2005-2010. It uses SDA, which is based on the full D&L method. The energy intensity has significantly increased in 1991-2000 sub-period, decreased in 2000-2005sub- period and decreased again in 2005-2010 sub-period but only at a minimal level. Among the five contributing factors investigated, the energy mix factor has always been the least important factor contributed to changes in energy intensity, while the sectoral energy efficiency factor has always been contributed as the second least important factor. The final demand structure factor has been prominently responsible for the changes in energy intensity during 1991-2000 and 2000-2005 sub-periods, while in the 2005-2010 sub-period the final demand components factor plays its dominant role.

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

- Energy mix: Among the five energy sectors, the energy mix of 'electricity and gas' sector becomes a major concern. Malaysia's electricity sector demonstrates a remarkable achievement of the Four Fuel Diversification Policy (1981) when its high dependence on fuel oil has significantly reduced, replaced by increasing use of natural gas followed by higher utilisation of coal. Unfortunately, these changes led to only a minimal reduction in Malaysia's energy intensity. Furthermore, the concentration of non-energy sectors on the use of either 'petrol refinery' or 'electricity and gas' in their energy mix has resulted in insignificant change in overall energy intensity, although there are changes in the consumption shares of each secondary energy sources especially towards greater 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 is relatively slow. Through its Eighth Malaysia Plan (2001–2005), the country had targeted to generate 5% of its electricity from RE by 2020. Unfortunately, in 2014, only 0.5% electricity was generated from RE [77]. In its 11th Plan (2016–2020), a higher RE target is set: to achieve 7.8% of total installed capacity in Peninsular Malaysia and Sabah by 2020 [20]. Hopefully, this new target is achievable.
- Sectoral energy efficiency: Proactive steps need to be implemented in order to make this factor

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 [78]. Thus far, it is 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 experience significantly 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.

- Production structure: 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 consumption and therefore helps to reduce its CO_2 emissions. Unfortunately, several industries under the services sector are 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 encourages investment for some industries that are categorised as being energy-intensive. Although using more advance 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 rationalising Malaysia's production structure by shifting away from energy-intensive to less energy-intensive industries.
- Final demand structure: In Malaysia, it is found that the allocations for 'electricity and gas' and 'petrol refinery' in private consumption expenditures have increased. Households 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 tax deduction for the expenses incurred to implement certain types of energy efficiency renovations or use of RE in existing homes (see [79]). 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 [80]. 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 helps to increase the energy efficiency of the country.

For future research, it is vital to examine the changes in Malaysia's energy intensity in the following periods. Continuous investigation using the latest available I-O data is important in order to determine suitable energy-related policies and therefore, achieving sustainable energy in the country. The use of multiplicative SDA is also another great option as different ways of investigations give different results.

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