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RESEARCH ARTICLE

Analysing CO2 Emissions from Transportation Expenditures by Malaysian Households

Norlaila Abdullah Chik*, Khalthum Hassan, Wahida Ayob

School of Government, College of Law, Government and International Studies, Universiti Utara Malaysia,06010 Sintok, Kedah, Malaysia.

***Corresponding Author: Norlaila Abdullah Chik**

Abstract

This study analyses the impact of Malaysian household consumption on the transportation sector regarding CO2 emissions by using the Hybrid Input Output Table from 1991, 2000, 2005 and 2010. Initially, this study calculates CO2 emissions intensity for every sector. Results show that the sector with the highest CO2 emission intensity was Transportation at 1.16 (T- CO2/M-MyR). By using the hybrid, I-O table, the average values of the total CO2 emission intensity caused by energy consumption in Malaysia were found to be 0.272 (T- CO2/M-MyR). Transportation sector contributed the relatively high level of consumption and produces the highest amount of CO2 emission in 1991, 2000, 2005 and 2010. Our analysis shows that continuously increasing consumption in the Transportation sector will continue to affect the environment. Thus, through encourage consumers to use hybrid or solar cars and the imposition of a carbon tax on old vehicles, owners will reduce their CO2 emissions. By imposing a carbon tax, motor vehicle owners will strive to reduce their CO2 emissions by consuming renewable energy or use energy saving techniques in their everyday lifestyle.

Keywords -CO2 emission, Transportation, Expenditure, Hybrid input-output analysis, Households.

Introduction

Since its remarkable change from an agriculture country to an industrialized country, Malaysia has seen its GDP grow from RM105 billion in 1990 to RM1,012 billion in 2014. There is a strong relationship between income and expenditure because when incomes increase, expenditure patterns tend to change [1].

Households benefited from the continued increase in disposable income arising from high export earnings and economic growth, which also generated full-employment and income-earning opportunities among Malaysians. Moreover, the availability of affordable, low-interest credit provided further support to more household spending particularly on motor vehicles.

In general, consumption is obviously something good and the more the consumption, the better enhanced is a person's lifestyle. With increasing consumption, households have been able to improve the material lifestyles more than previously possible [2][3]. Based on Fig. 1, household spending is due to the introduction of GST on 1 April 2015.

In Malaysia, most families having more children spend much of their total consumption expenditure on housing, food, transportation and travel, which is a consumption pattern that is different for small households with fewer children living in small houses and spending most of their money on transportation and travel. However, transportation does not account for a large part of total household expenditure, as shown in Fig. 1.

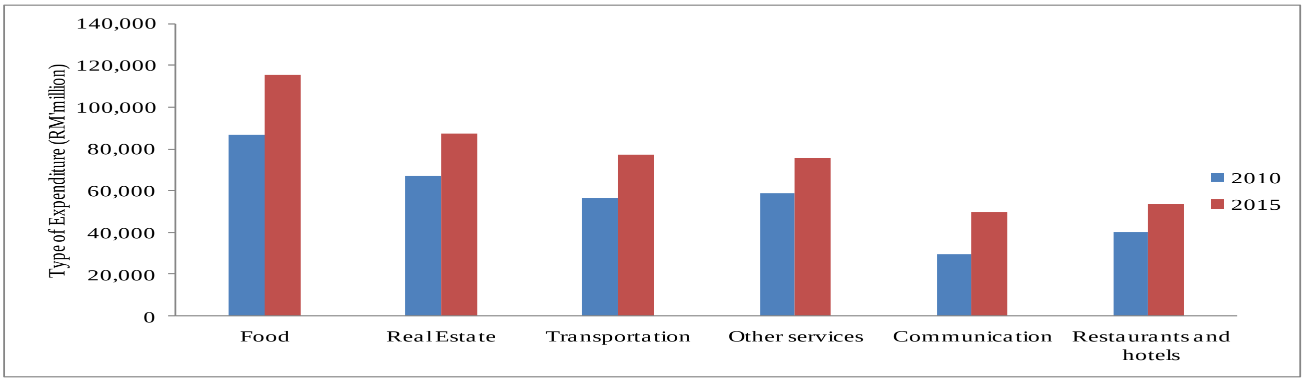

Figure 1: Type of Expenditure by Malaysian Households
Sources: Department of Statistics, Malaysia (2016)

According to the [4], about 13.8 percent of total private consumption came from Transportation. However, in terms of energy consumption, the Transportation sector accounted for the highest level of energy consumption, as shown in Fig. 2.

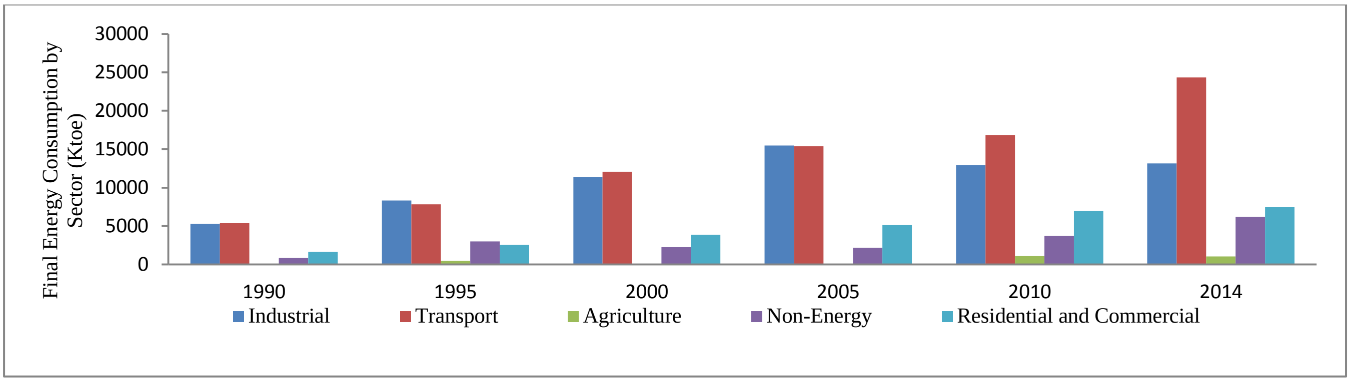

Figure 2: Final Energy consumed by Sectors
Sources: Source: National Energy Balance (2015)

Energy consumption by the Transportation sector only competes with that by the Manufacturing sector. Energy consumption by the Transportation sector represents energy used for all kinds of transportation except international marine bunkers. This sector covers road, air, railway and internal navigation. Demand of households on the Transportation sector contributed the highest CO_2 emissions due to the number of private motor vehicles and public transportation on Malaysian roads steadily increasing, thereby increasing the population and energy consumption pattern shown in Fig. 3.

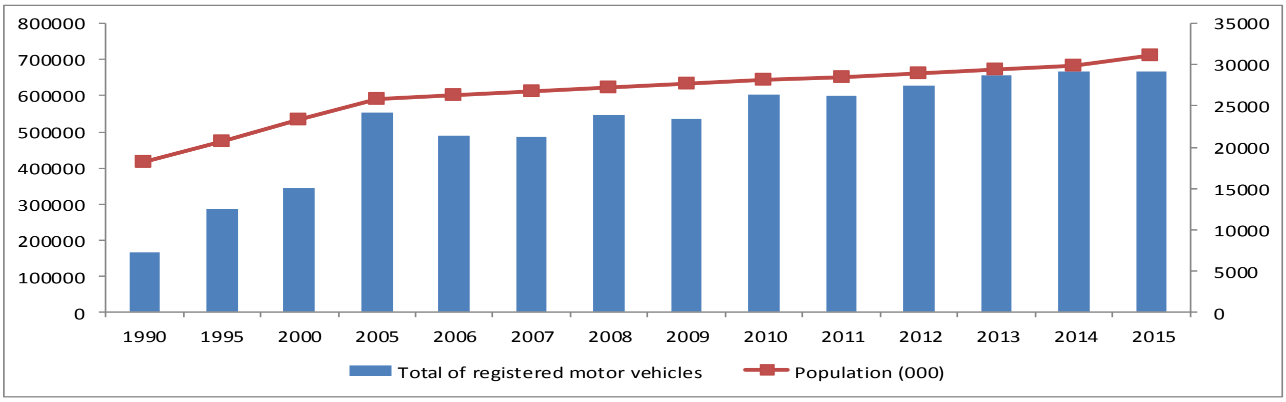

Figure 3: Relationship between total of registered motor vehicles and population
Source: Ministry of Transportation and United Nation Statistic Division, WDI (2015)

Besides that, petroleum products used by motor vehicles also causes side effects on the environment. The growth rate of motor car ownership tends to slacken over time as the diffusion rate increases. This is the same trend seen for most other household durable goods because they are near the point of dispersion. Increased transportation usage, combined with inadequate road systems, has caused unendurable traffic congestion in large cities, such as Kuala Lumpur, Penang and other developing cities. This in turn has effected huge economic losses as well as worsened the environment in Malaysia.

Private motor vehicles pollute the environment by emitting CO_2 and other greenhouse gases (GHG) from fuel combustion, fuel supply, vehicle manufacture and disposal. Road transportation is the most significant contributor to environmental impact in Malaysia, which consumed about 36% of the total energy [5][6].

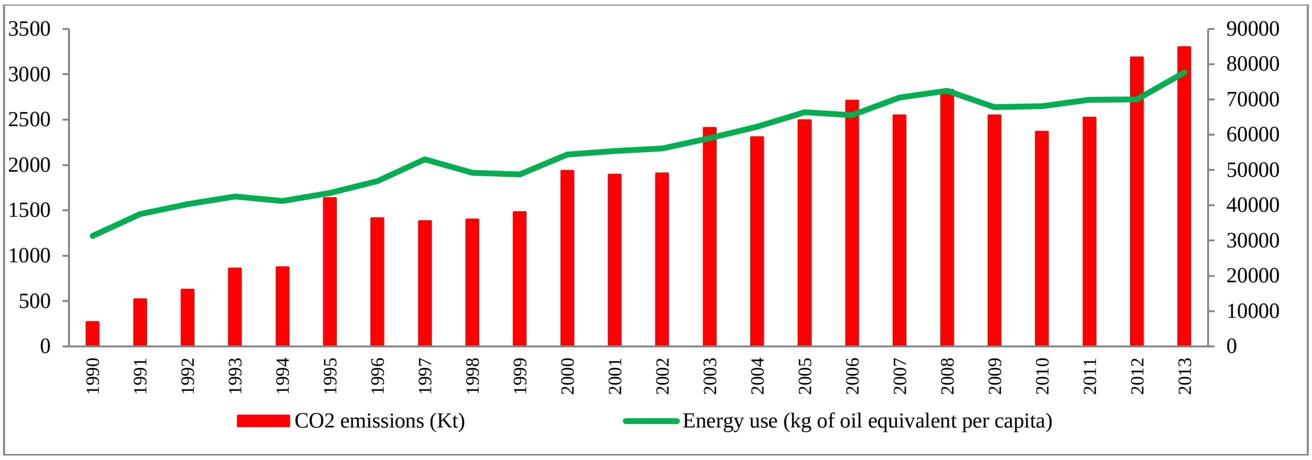

Figure 4: Relationship between energy consumption and carbon dioxide (CO_2) emission
Sources: United Nation Statistic Division, WDI (2015)

Currently, many countries struggle to achieve the goal of emitting zero carbon from energy consumption, but this is very difficult to achieve. Although, carbon dioxide can be cleaned, this requires both short- and long-term investments [7] and is mainly for countries with high GDP. The trade-off between economic growth and environmental degradation is a national and local concern. It is very important to save the environment through efficient energy management and consumption before the reduction in quality of the environment becomes irreversible (see Fig. 4).

With rapid development, the transportation sector has contributed significantly to development of socioeconomic of the country and its contradiction to quality of environment. Recently, the transportation sector accounts for 28% of total CO 2 emissions, of which 85% comes from road transport [8]. However, the threat posed by the generation of CO_2 emissions was not appreciated but has grown over time and now appears as serious global warming causing climate changes [9].

Household activities are among the major contributors to the generation of CO_2 emissions through burning of fossil fuels for private motor vehicles and the provision of public transportation. In recent years, the number of private motor vehicles on Malaysian roads has steadily increased, thereby increasing the consumption of fossil fuels.

Moreover, even though Malaysia is a non-annex 1 country in the Kyoto Protocol, Malaysia has shown its concern for the environment in its declaration to reduce the amount of carbon dioxide in the air by up to 40 percent by the year 2020 in comparison to the 2005 level.

According to the [10], the trend of energy consumption and production will continue to rise in the next few years. In that case, a shortage of energy will occur in the future if consumers use energy inefficiently and the amount of related CO_2 emissions continues to increase.

Given the situation, this study analyses the impact of Malaysian household consumption on the transportation sector towards CO_2

emissions using the Hybrid Input Output Tables from 1991, 2000, 2005 and 2010. This paper is organized as follows. Section 2 presents a literature review of energy consumption and CO_2 emission by the Transportation sector. Section 3 describes an overview of the model employed in this study. Section 4 presents results and findings. Conclusions and Policy implications of the results are discussed in Section 5.

Literature Review

The relationships between population, economic growth, energy consumption and the environment have been greatly analysed over last two decades. [11] States that far from being a hazard to the environment in the long term, economic growth is necessary to maintain and improve environmental quality.

Population density, energy consumption and economic growth have a positive relationship to CO_2 emissions both in the short-run and long-run [12]. Many studies analysed the CO_2 emissions and various implementing policies and planning strategies to reduce CO_2 emissions. Therefore, various studies previously conducted focused on the reduction of CO_2 emissions. [13] used a simple method to estimate changes in consumption that were assessed during the period of survey by suggesting a way for households to use energy efficiently.

Several researchers applied an econometric model for environmental analysis. For instance, [14] studied the linkages among economic growth, energy consumption, financial development, trade openness and CO_2 emission by using the Zizot-Andrew unit root test and ADRL found that the variables are cointegrated. [15] found that economic growth influences energy demand and CO_2 emission. While [16] found that the relationship between urbanization and CO_2 emissions is U-shaped.

Increases in population size effects the environment through energy consumption by transportation sector because the relationship between them very significant in various countries. [17] found that about 43% of total GHG emission is attributable to 10% of households in UK from personal travel. [18] studied the causal relationships between transportation energy consumption and CO_2 emission generated by transportation using the Johansen multivariate cointegration approach. [19] found that that there is a positive relationship between CO_2 emission and road transportation value added and population.

The current study uses the methods of input output analysis and hybrid analysis that are combinations of two units, which are monetary and physical units [20]. The use of input output analysis for energy requirement was applied by [21] and [22].

Their work was followed by the overview on input output energy requirement by [23] and emissions as an external multiplier to the model as mentioned by [24]. The Hybrid analysis is also work intensive and requires complete data, as shown in the method of firm calculation by [25] previously proposed by [26] followed by [27] and [28].

This form of analysis was increasingly used for energy analysis and the environment as shown in the work by [29] [27] and [30]. [31] and [32] estimated energy intensity and GHG emission intensity in Korea using Hybrid input output analysis (HIO), [33] proposed hybrid physical input-output model for energy analysis (HPIOMEA).[34] and [35] developed the GHG emission embodiment.[36] found that energy requirements are influenced by urban forms, income levels and demographics.[37] found that declining energy intensity contributes the most to emission reductions followed by residential lifestyle in Beijing. Households are the most significant contributors to the generation of CO_2 because of the direct impact of their energy consumption and the indirect impact of their demand for products and services [38] [39] [40].

Among all final demand factors, the impact of household consumption on energy consumption and CO_2 emission has drawn significant attention in recent years, particularly on the Transportation sector. There are few studies on energy consumption and CO_2 emissions using the Input Output Model. [41] discussed that the Transportation sector consumes more energy compared to the Service sector because the flow of indirect energy of this sector is high. Research literature reveals that the energy consumption caused by household consumption is high and more importantly emphasizes that indirect energy consumption accounts for a large proportion in total energy consumption. [42] found that the primary positive drivers of carbon emissions in the Transportation sector and negative drivers are the transportation intensity and energy structure.

In Malaysia, there are limited studies and reports on topics that apply hybrid input-output analysis (HIOA). In other words, the process of analysis was used to calculate the energy requirement of the energy intensive products while the input–output analysis was applied to calculate that of other products.

Moreover, HIOA is an important method in the analysis of energy consumption, especially for resources to meet energy demand and the impact of final use of energy by different sectors such as the energy consumed both directly and indirectly by households.

Methodology

The basic I-O model extended into environmental I-O analysis considers additional intersectoral flows, for instance natural resources (energy) and pollution (greenhouse gas) in addition to conventional economic flows. In this study, to extend a standard I-O model into an environmental input-output (E-IO) model, the direct CO_2 emission matrix (W) was introduced.

In order to calculate indirect CO_2 emission by the household, the CO2 intensity or multiplier in equation (1) was used by using the extended input-output model first introduced by [43] and later extended by others, for example [44][45][46][31]. The basic environmental I-O model can be represented using the equation as follows:

$$W = (m \# r) f' \qquad \text{Eq. (1)}$$

Equation (1) can be represented in matrix form: -

$$\begin{bmatrix} W_1 \\ \cdot \\ \cdot \\ W_{13} \\ \cdot \\ \cdot \\ W_{40} \end{bmatrix} = \left(\begin{pmatrix} m_{11} & \cdot & m_{17} & \cdot & m_{111} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ m_{17} & \cdot & m_{77} & \cdot & m_{711} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ m_{111} & \cdot & m_{711} & \cdot & m_{4011} \end{pmatrix}^{\#} \begin{bmatrix} r_1 \\ \cdot \\ \cdot \\ r_{13} \\ \cdot \\ \cdot \\ r_{40} \end{bmatrix} \times \begin{bmatrix} f_1 \\ \cdot \\ \cdot \\ f_7 \\ \cdot \\ \cdot \\ f_{11} \end{bmatrix} \right)$$

where W denotes a scalar of CO_2 emission intensity for sector 1 to sector 40, # denotes element by element multiplication (cell by cell), *f* is the transpose of an 1x11 vector of CO_2 emissions per unit of energy consumption of each of the 11 energy types or is considered as CO_2 emission factor; mis a 40x11 matrix of energy mix or energy consumption in the production sectors for sector 1, i.e. the demand for 11 energy types per unit of total demand for energy for all production sectors; *r* is a 40x1 vector of total energy intensity for sector 1, i.e. total energy consumption per unit of all 40 sectors.

Total CO_2 emissions by sectors

Firstly, the quantity of CO_2 emission for each industry can be expressed in matrix form as follows:

$$E_c = W.\,(I-A)^{-1}.C \qquad \text{Eq. (2)}$$

Equation (2) can be represented in matrix form: -

$$\begin{bmatrix} E_1 \\ \cdot \\ \cdot \\ E_{13} \\ \cdot \\ \cdot \\ E_{40} \end{bmatrix} = \begin{pmatrix} W_{11} & \cdot & W_{113} & \cdot & W_{140} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ W_{113} & \cdot & W_{1313} & \cdot & W_{1340} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ W_{140} & \cdot & W_{1340} & \cdot & W_{4040} \end{pmatrix} \begin{pmatrix} (1-a_{11}) & \cdot & -a_{113} & \cdot & -a_{140} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ -a_{113} & \cdot & (1-a_{1313}) & \cdot & -a_{1340} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ -a_{140} & \cdot & -a_{1340} & \cdot & (1-a_{4040}) \end{pmatrix}^{-1} \begin{pmatrix} C_{11} & \cdot & C_{113} & \cdot & C_{140} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ C_{113} & \cdot & C_{1313} & \cdot & C_{1340} \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ C_{140} & \cdot & C_{1340} & \cdot & C_{4040} \end{pmatrix}$$

where E_c is denoted as a scalar of total CO_2 emission from the production sectors, W is a 40x1 vector of CO_2 emission intensities, i.e. total CO_2 emission per unit of production sector in all 40 sectors; $(I-A)^{-1}$ is the 40 x 40 Leontief inverse matrix, C (Private consumption). With the last equation, changes in the total emission of CO_2 can be attributed to changes in the factors W (CO_2emission intensity), L (Leontief inverse), and C (private consumption).

Data Sources

This study utilized two kinds of data:

The first set of data was based on four Malaysian input-output tables for the years 1991, 2000, 2005 and 2010 from the Department of Statistics (DOS).

The second set of data regarding the energy consumption for the years 1991-2015 were taken from the National Energy Centre (PTM).

The *CO_2 emission factors* were calculated based on the carbon contents of the fuels (as shown in the IPCC revised 1996-Module 1-Tier 1).

High embodied energy intensity effects CO_2 emission intensity through energy consumption. The results from quantifying the CO_2 emission intensities show that the sector with the highest CO_2 emission intensities. Regression analysis can be applied to determine the relationship between CO_2 emissions intensity and household consumption for 2010 based on private consumption [47] (Final demand, 2010). By using the hybrid, I-O table, the average values of the total CO_2 emission intensity caused by energy consumption and household expenditure in Malaysia were found to 0.272 (T- CO_2/M-RM) and RM 8, 787,622 thousand, respectively as shown in Figure 5. This figure is divided into quadrants of low-high (Quadrant I), high-high (Quadrant II), low-low (Quadrant III) and high-low (Quadrant IV). Most of the sectors lie on average values except for the Cements and Transportation sectors. The main concern of this study is the Transportation sector due to it having the highest CO_2 emission intensity at 1.16 (T-CO_2/M-MyR), even households consume less on this sector.

Results and Discussions

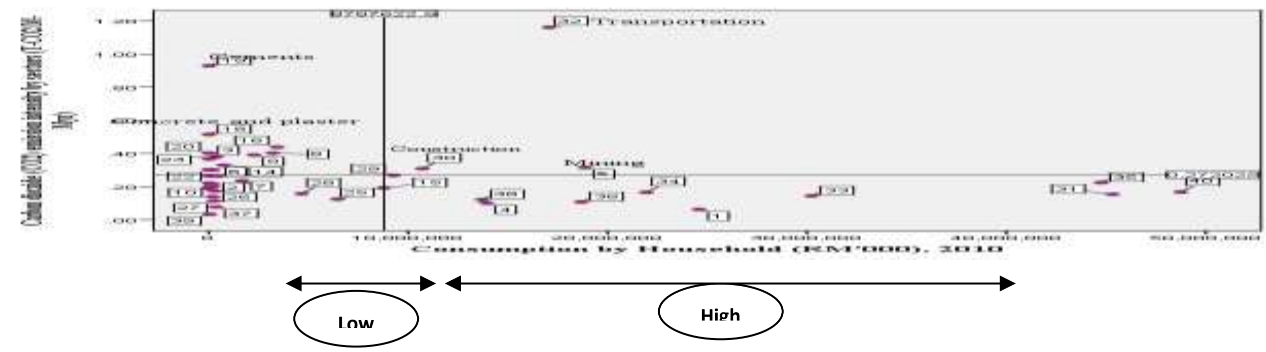

Figure 5: Distribution of 40 sectors from total energy use in 2010

In an effort to reduce CO_2 emissions, CO_2 emissions intensity must be reduced in the initial stage. The way to reduce CO_2 emissions intensity is through changes in lifestyle, the use of solar power, green tech products and encouraging people to consume renewable energy.

This study also applied regression analysis to estimate the relationship between consumption and CO_2 emission produced, as shown in Fig. 6, 7, 8 and 9 based on Equation 2. The result from Equation 2 shows that in the case of total energy use in 1991, 2000, 2005 and 2010, the average values of consumption by sector and CO_2 emission intensity of the 40-economic sector, including energy and non-energy sectors, were shown in every figure. Those figures show the relationship between consumption by sector and CO_2 emission produced in by consumption.

Every scatter plot was divided into four quadrants, i.e. quadrant I, II, III and IV. Most of the Transportation sector lays in quadrant II and III compared to quadrant I and IV. The sector that lies in quadrant I indicates that this sector contributed high consumption with low CO_2 emission while the sector that lies in quadrant II indicates that this sector contributed high consumption with high of CO_2 emission. The sector that lies in quadrant II indicates that this sector contributed low consumption with low CO_2 emission. The sector that lies in quadrant IV indicates that this sector contributed high in consumption with low CO_2 emission.

The sectors lie in quadrant I and II are produced high CO_2 emission products. Figure 6 show the relationship between consumption and CO_2 emission from consumption in 1991. From this figure, it is shown that there were fewer sectors in quadrant I and IV. Most sectors lie in quadrant II and III. By observing quadrant II, transportation has contributed the relatively high of consumption and produces the highest of CO_2 emission. In 1991, the transportation sector is the most polluted due to the highest of CO_2 emissions intensity. Even consumption by households is less than consumption on real estate and wholesale and retail trade (Fig. 6).

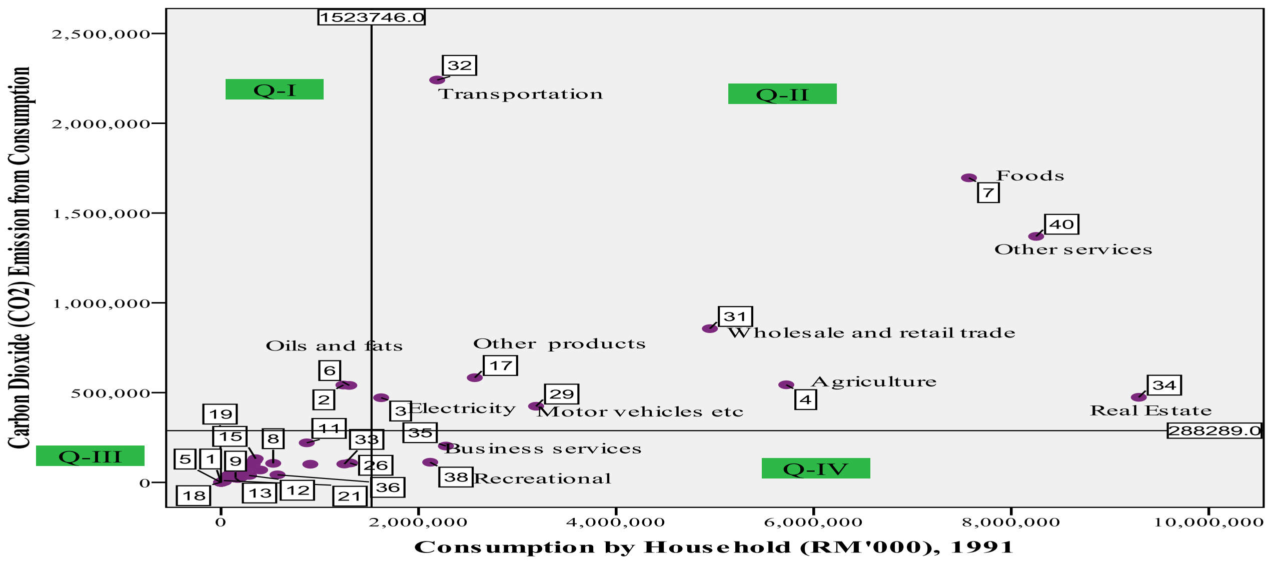

Figure 6: Distribution of 40 sectors from the private consumption, 1991

However, Fig. 7 shows the relationship between CO_2 emissions and consumption by households in 2000. The average value of consumption and CO_2 emissions increased by 98% from 1991 to 2000, the sectors that lie in that scatter diagram have remained unchanged if compared to Fig. 6. The transportation still contributed the relatively high level of consumption and produced the highest of CO_2 emission in 2000.

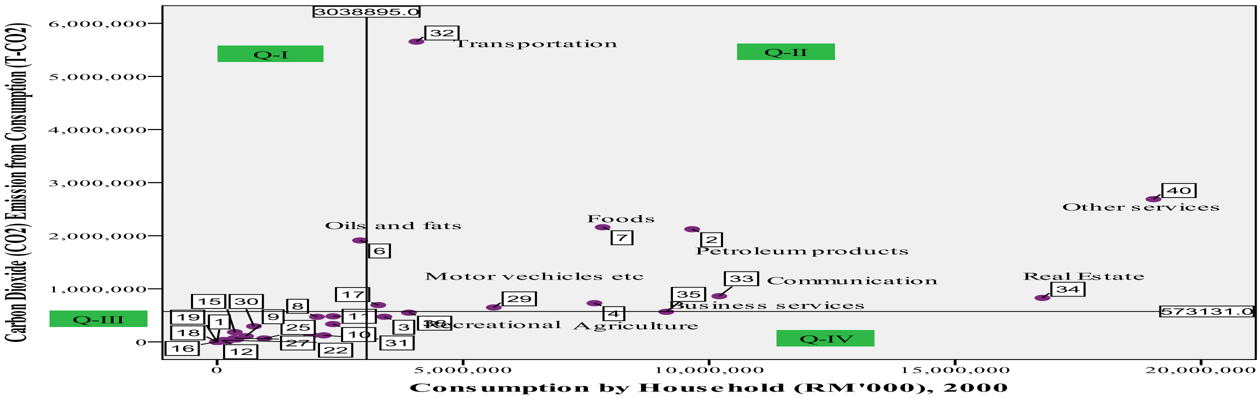

Figure 7: Distribution of 40 sectors from the private consumption, 2000

Fig. 8 shows the transportation sector still contributed the relatively high of consumption and produced the highest of CO_2 emission in 2005. However average value of consumption and CO_2 emissions increased by 44.8% and 92.8%, respectively.

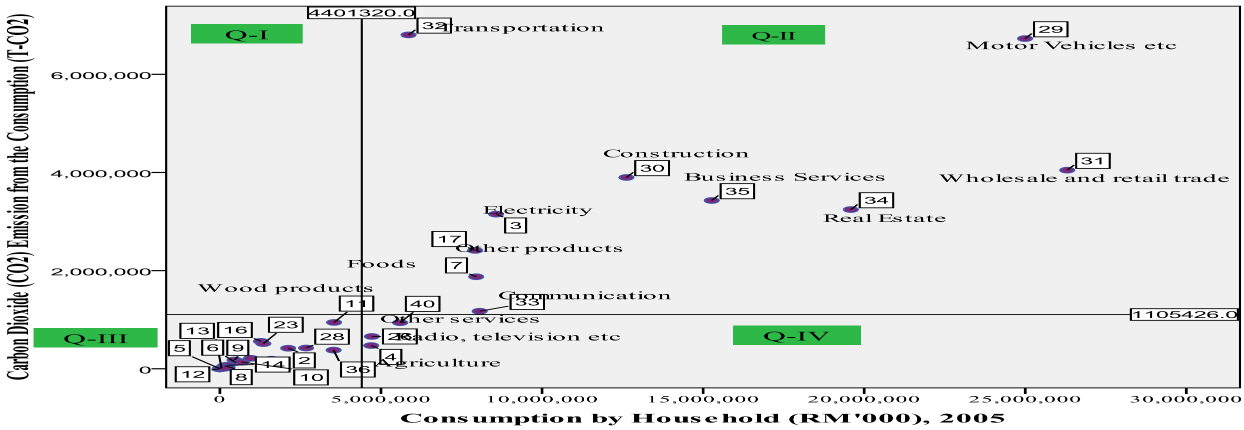

Figure 8: Distribution of 40 sectors from the private consumption, 2005

More sectors in Quadrant II in 2005 moved near to Quadrant IV in 2010 (as shown in Fig. 9). Transportation still contributed the highest CO_2 emissions in 2010. However, the transportation sector still contributed the relatively high level of consumption and produced the highest CO_2 emissions in 2010. Private Consumption increased about 51 percent from 2005 to 2010. Based on National Account, private consumption contributed 91 percent in GDP 2015 after exports.

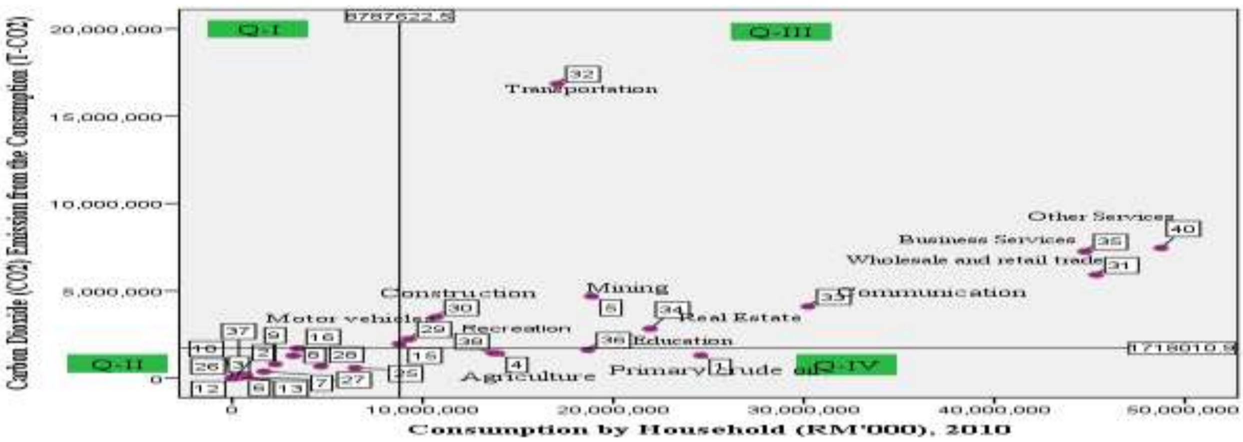

Figure 9: Distribution of 40 sectors from the private consumption, 2010

Most of sectors are in quadrant III and IV, which indicates that this sector as low dependence on energy sources and is characterized by industries that use environmentally friendly processes in terms of energy use because this sector remains below the horizontal average value line for CO_2 emission.

This distribution is very important in order to identify the energy intensive sectors because more energy use will produce more CO_2 emissions. This study estimates that consumption in the Transportation sector still will contribute the highest CO_2 emissions in the future. Based on data of Private Final Consumption Expenditure 2016, expenditure by households on Transportation increased by 36% from 2010 to 2015 compared to 2005 through 2010 consumption on that sector increased by 29%.

This figure shows that expenditure on Transportation continues to increase, causing the level of CO_2 emissions also to rise. In addition, the Malaysian transportation sector has generated about 28% of the total CO_2 emission, of which 85% comes from road transportation.

Conclusion and Policy Implication

The trend of private consumption shows that when consumer income rises, the consumption pattern also changes, particularly the demand on transportation, wholesale and retail trade, construction and electricity [48]. From Fig. 6, 7, 8 and 9, demand on motor vehicles is the highest after wholesale and retail trade and this sector produced the highest level of CO_2 emission. Based on [10] energy consumption of that sector still is relatively high particularly for road transportation, which contributed the largest share (82%) of total CO_2 emissions [8].

Based on this analysis, CO_2 emissions intensity of Transportation is difficult to reduce due to growing of Malaysian economy and demands on motor vehicles continues to grow. Therefore, the conclusion is that Malaysia will have difficulty achieving its target of reducing its CO_2 intensity, but Malaysia can achieve the target if it gradually changes to renewable energy such as biomass, solar power, nuclear and hydropower as well as from educating people to change their lifestyle and behaviour towards green tech and environmentally sustainable and low emission CO_2 products.

To achieve environmental impact reduction goals, management of public transportation also must be efficient because it can encourage people to use mass public transportation, particularly bus and train. Moreover, public transport only contributed about 5% of total CO_2 emissions of the road transportation sector in Malaysia and motorcars as well as motorcycles contributed 52% and 15%, respectively [8]. From this percentage, most Malaysians prefers to use private transportation rather than public transportation for travelling. This study also provides information to the government and policy makers in identifying the sectors that consume a large amount of energy and produce a large amount of CO_2 emissions.

Final Conclusion

In this study, energy consumption was shown to be is increasing for the Transportation sector. Therefore, CO_2 emissions will rise. This sector has not been able to achieve their voluntary targets in reducing their CO_2 emissions due to increasing demand for motor vehicles. With this information, the government can encourage consumers to use hybrid or solar cars and impose a higher carbon tax on old vehicles owners so that they become moreconcerned about the current environment level. Old engines may cause incomplete combustion that generates more CO2 compared to new vehicles. By imposing a carbon tax, motor vehicle owners will strive to reduce their CO_2 emissions by consuming renewable energy and otherwise reducing their carbon footprint. A measure such as this need to be taken because this sector is still results in high CO_2 emissions and high CO_2 emission intensity. The findings of such future study have the potential to indicate the best way in the short term to curtail or control growth in CO_2 emissions because domestically, consumption is the highest contributor to GDP compared to government spending. This responsibility to protect the environment rests on the household due to its important place in the economy

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