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Investigating Factors Affecting CO_2 Emissions in Malaysian Road Transport Sector

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ABSTRACT

Today the unprecedented increase in CO_2 emissions has become an important global issue because of the intensification in demand from the transport sector due to an upward surge in urbanization and rapid economic growth. The demand for transport services is expected to rise further, causing the CO_2 emissions level to increase as well. In Malaysia, the transportation sector accounts for 28% of total CO_2 emissions, of which 85% comes from road transport. This has led to strong interest in how the CO_2 emissions in this sector can be reduced effectively. This study aimed to investigate factors that influence the CO_2 emissions. A multiple regression model was used based on fuel-based technology data for 1990-2013. Many factors influencing CO_2 emissions, i.e., fuel consumption, fuel efficiency (FE), fuel price (FP) and distance travel (DT), were examined for the road transport sector in Malaysia. The results demonstrated that FE, FP and DT were the main factors influencing the CO_2 emissions growth. Some policy implications from the empirical results were proposed for CO_2 emissions reduction.

Keywords: CO_2 Emissions, Energy Consumption, Road Transportation, Regression Model, Malaysia
JEL Classifications: C13, Q48, N75, R41

1. INTRODUCTION

The issue of climate change due to increasing levels of CO_2 emissions has emerged as the most challenging environmental problem in recent decades. Rapid economic development around the world causes increased energy consumption and CO_2 emissions. The global CO_2 emissions have increased by 1.9% per annum from 20.9 billion tons of CO_2 in 1990 to 32.3 billion tons of CO_2 in 2013 (IEA, 2014a). The transport sector accounts for about 23% or 7.2 billion tons of global CO_2 emissions and its contribution relative to other sectors is projected to grow substantially in the near future. The increase in the number of vehicles is one of the main emissions growth reasons. Currently, there are almost 1 billion vehicles around the world consuming petroleum fuels at about 13.1 billion barrels annually and emitting about 5.4 billion tons of CO_2 annually (Sang and Bekhet, 2015). With growing energy demand and increasing use of vehicles, the global CO_2 emissions from the transport sector is projected to go up by about 50% by 2030 and over 80% by 2050 (IEA, 2012).

The unbounded increase in CO_2 emissions has become an important global issue (IPCC, 2007). Therefore, the reduction of these emissions, especially in the transport sector, has become an imperative agenda item in countries around the world. Figure 1 shows comparative CO_2 emissions between Malaysia and a few developed and developing countries. While the developed countries (Sweden, Switzerland and France) are conventionally the main emitters of CO_2 emissions, developing countries' (Malaysia, China) emissions are now seen to surpass developed country's emissions due to rapid economic development growth in recent decades (den Elzen et al., 2009; World Bank, 2014). The declining trend of CO_2 emissions per capita in developed countries is due to adoption of environmental policies toward expansion of clean energy development, which have led to the decoupling of gross domestic product (GDP) growth from CO_2 emissions (Karlsson and Meibom, 2008). Figure 1 shows that Malaysia has surpassed many developed countries in terms of CO_2 emissions. Owing to these facts, the 2007 Bali Declaration by climate scientists emphasized the joint efforts by both developed and developing countries to take measures against climate change (Shahid et al., 2014). Consequently, many developing countries including Malaysia have declared the commitment to reduce their CO_2 emissions. In 2009 at the 15th Conference of Parties in

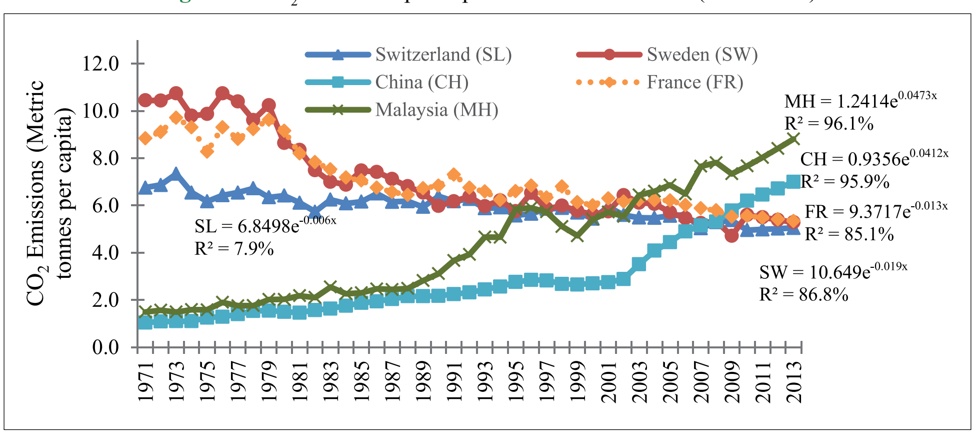
Copenhagen, Malaysia stated a voluntary target of reducing its CO_2 emissions intensity by 40% (based on its 2005 levels) by 2020 (NRE, 2011).

The move towards high income and developed nation status by 2020 (EPU, 2015) is a challenge for Malaysia. This is because as the country progresses, the demand for energy will increase in tandem, which will directly result in an increase in CO_2 emissions. Figure 2 shows that between 1990 and 2013, the GDP and CO_2 emissions annual growth rate was 5.2% and 6%, respectively. This suggests that the CO_2 emissions in Malaysia increased in line with GDP growth. Since CO_2 emissions intensity is measured as CO_2 emissions per GDP, the strategy for reduction of the CO_2 intensity is by increasing the GDP sufficiently while maintaining the total CO_2 emissions or constraining the increase of total CO_2 emissions. With the growing economy in Malaysia that requires emissions to rise, it is obvious that the alternative strategy to achieve this target is by reducing the total CO_2 emissions. Therefore, Malaysia needs to take effective measures for environmental friendly development of transportation to fulfill its aspirations.

The transport sector is regarded as an important component of the economy that greatly contributes to the socioeconomic development. In Malaysia, the energy consumption from the transport sector is also the highest among all of the sectors in the country. In 2013, the share of energy consumption was recorded at 43.3%, consuming about 22.4 million tons of energy, of which 85% (19 million tons) largely came from the road transportation modes (EC, 2014; Lim and Lee, 2012). The number of motor vehicles also increased by 7.4% per annum to reach 21 million in 2013, with motor cars and motor cycles together accounting for 92% of total vehicles in the country (MOT, 2013). The insufficient public transportation infrastructure has also aided the ever increasing motor vehicle population. In 2013, public transportation modes in Malaysia have only an 8% share of the total registered vehicles. In terms of CO_2 emissions, the transport sector continued to be among the largest emitters after electricity generation. As shown in Figure 3, the CO_2 emissions in Malaysia's energy sector has increased over the years. In 2013, a total of 208 million tons of CO_2 emissions was emitted from the energy sector (IEA, 2014b). Electricity generation, transport, manufacturing and other sectors contributed 46%, 22%, 19% and 13% of the total CO_2 emissions with annual growth increases of 6.4%, 4.4%, 3.6% and 13.9% in the respective sectors. It can be observed that the transport sector has superseded the manufacturing industry in terms of CO_2 emissions in recent years.

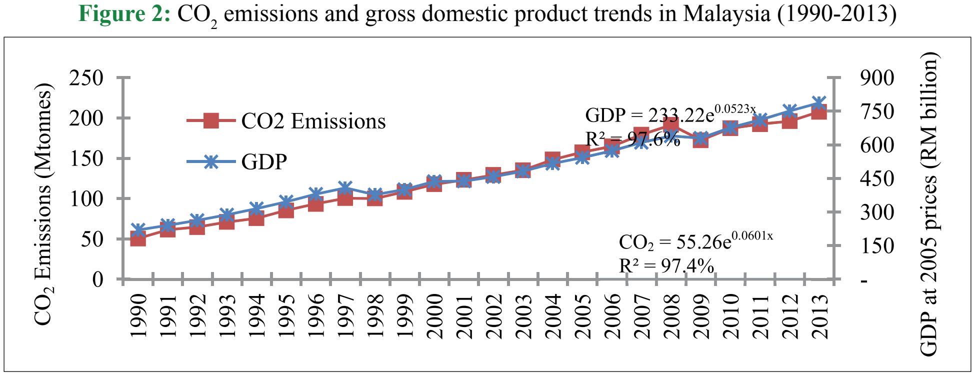
The increasing growth in the economy, rapid urbanization and rising incomes caused a rapid increase in the demand for passenger transport services (Kasipillai et al., 2008). Conclusive evidence also advocates that as people have an increased income, they make use of faster modes of transport which could lead to detrimental effects on the environment (Profillidis et al., 2014). Currently, road transportation accounts for the largest share with 85.2% of total CO_2 emissions in the transportation sector, followed by aviation, maritime and rail in Malaysia. Private vehicles (motorcars and

Figure 1: CO_2 emissions per capita in several countries (1971-2013)



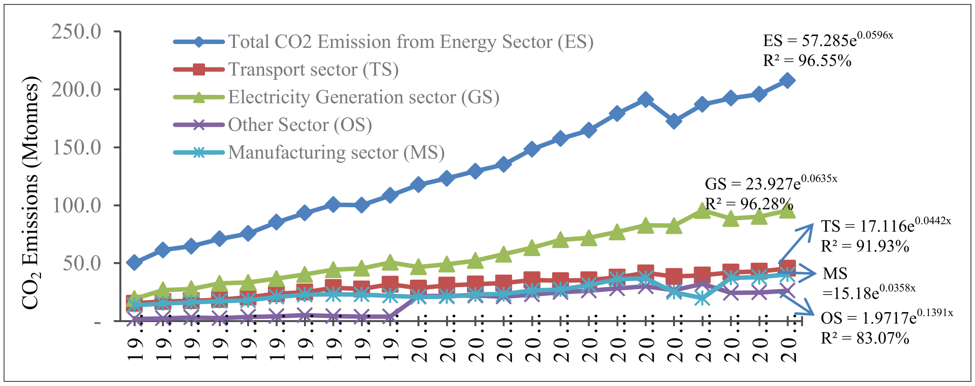
Source: World Bank (2014)

Figure 2: CO_2 emissions and gross domestic product trends in Malaysia (1990-2013)



Source: DOSM (2013) and IEA (2014b)

Figure 3: Trends of CO_2 emissions from energy sub-sectors in Malaysia (1990-2013)



Source: IEA (2014b)

motorcycles) represent the largest share of CO_2 emitters, with about 70% of the total road transportation sector (Ong et al., 2011). Presently, this sector relies heavily on petroleum products, especially petrol (66%) and diesel (32%), while gas (2%) has a marginal fuel share (Indati and Bekhet, 2014). Its heavy reliance on petroleum products is a worrying trend for the future in terms of energy security and its CO_2 emissions contribution (Silitonga et al., 2012; Mofleh, 2010).

Undoubtedly, in the light of unprecedented growth in the prevalence of private cars and the projected increase for passenger transport services, the road transport sector will be a pivotal sector to address in the fulfillment of the goals of CO_2 emissions reduction (Cheng and Lu 2015). Some concerns are raised that the CO_2 emissions reduction efforts will affect the growth in the transportation sector, which in turn will have a negative impact on national economic growth. However, advancements of vehicle technology could decelerate the CO_2 emissions level growth and be able to decrease the CO_2 emissions intensity by increasing fuel efficiency (FE) without affecting the economic growth (Khalid, 2014; Aizura et al., 2010). This possibility is in tandem with the Environmental Kuznets Curve, which hypothesizes an inverted U-shaped relationship between emissions and policy measures of a country by technological measures (Dinda, 2004; World Bank, 1992).

Therefore, this study aimed to investigate the factors that are influencing the CO_2 emissions in the road transport sector and examine the underlying policy initiatives that are effective to fulfill the national aspiration for CO_2 emissions reduction. The remaining sections are structured as follows: Section 2 discusses the previous empirical findings. The data sources and the methodology are discussed in Section 3. Section 4 presents the results of the study analysis. The conclusions and policy implications drawn from the study results are presented in Section 5.

2. LITERATURE REVIEW

In relevant literature, considerable efforts were made to support sustainable energy and environmental policy planning in different countries. A number of modeling approaches and techniques were employed to investigate the influencing factors and mitigation policies that impact the CO_2 emissions growth in various energy sectors. Generally, past studies in this context used time series analysis, regression analysis, decomposition and optimization models.

The first line of research employed time series analysis. The increased energy consumption raised concerns about the environment due to increasing CO_2 emissions (Egilmez and Tatari, 2012). Using time series analysis, Sultan (2010) found co-integration of income per capita and fuel price (FP) on transport fuel consumption (FC), while Ozturk (2015), Al-Mulali et al. (2015), Bekhet and Yasmin (2013), Ozturk and Uddin (2012), Wang et al. (2011), Bekhet and Yusop (2009), Ang (2008) and Ediger and Akar (2007) found a long-term relationship between energy consumption and CO_2 emissions. Begum et al. (2015) studied the impact of GDP, FC and population growth on the CO_2 emissions. Consistent with Ivy and Bekhet (2015), their study suggested that the FC and CO_2 emissions growth could be reduced by employing low-carbon technologies. Ackah and Adu (2014) found that transport demand is price inelastic implying that continual FP subsidy is economically inefficient and investment in productivity is found to be able to restraint CO_2 emissions in the transport sector.

Using regression analysis, Sadorsky (2013; 2014) investigated the relationship between energy intensity, urbanization, income and GDP and found that reduction in CO_2 emissions could derive from increases in FE and fuel switching from fossil fuels to renewables energy. Xu and Lin (2015) investigated GDP, energy intensity, urbanization level, cargo turnover and private vehicle inventory on CO_2 emissions. They found that with increasing economic growth, low carbon vehicles such as high-speed rail and hybrid cars should become the mainstay of passenger and freight vehicles. Shu and Lam (2011) found that the CO_2 emissions were largely concentrated on the dense road network of urban areas with high population density. Xu et al. (2014) investigated the effects of population, energy structure, energy intensity and GDP on CO_2 emissions. Their study found that the driving factors of CO_2 emissions were the GDP followed by the population scale and energy structure. The study suggested that technology advancement was the most effective way to increase the FC efficiency.

Rapid economic growth and urbanization has resulted in a greater need for mobility and increases the distance travel (DT) by road transport among the people. This raises concerns with regard to the increasing demand for fuels to sustain this trend (Kari and Rasiah, 2008). Using decomposition analysis, Lakshmanan and Han (1997) attributed the change in transport sector CO_2 emissions to growth in DT, population and GDP. Wu et al. (2005) investigated how changes in transport DT, energy intensity and the number of vehicles affected energy-related CO_2 emissions. Timilsina and Shrestha (2009) decomposed CO_2 emissions growth into components associated with changes in modal shift, fuel mix, emission coefficients and transportation energy intensity, along with GDP growth.

A number of optimization models were also developed for sustainable energy planning and CO_2 emission reduction. Using linear programming models, Borjesson and Ahlgren (2011), Wang et al. (2008) and Bai and Wei (1996) investigated the cost-effectiveness of possible CO_2 mitigation options for the energy industries. On the other hand, using a mixed integer linear programming model, Hashim et al. (2005) studied the effects of fuel switching and fuel balancing options on power generation. Their studies found that FE and fuel switching offered the best option to reduce CO_2 emissions. Tan et al. (2013) used mixed integer linear programming analysis for the optimal planning of waste to energy that minimizes electricity generation costs and CO_2 emissions for Iskandar Malaysia. Kamarudin et al. (2009) developed a model to determine the minimum cost and optimum hydrogen delivery network in Peninsular Malaysia.

Table 1 summarizes some relevant literature with the main features including methodology employed and main factors investigated. It is evident from Table 1 that most previous studies in Malaysia, i.e. Ivy and Bekhet (2014), Ivy and Bekhet (2015), Ang (2008) and Begum et al. (2015), found that GDP, population and FC were the key determinants of CO_2 emissions. While there exists other factors such as FE, FP and DT, empirical results so far explaining the effects of these factors on road transport CO_2 emissions are rather limited (Begum et al., 2015). Therefore, this study considered these variables and investigated the relationship and impact of FC, FE, FP and DT on the CO_2 emissions of the transport sector in Malaysia by considering them simultaneously using a multiple regression analysis.

3. CONCEPTUAL FRAMEWORK OF CO_2 EMISSIONS REDUCTION MODEL

The aforementioned literature highlights the importance of linking FC, FE, FP and DT to CO_2 emissions. Building upon the existing literature, the conceptual framework was designed to investigate the factors that influenced the CO_2 emissions in the road transportation. The dependent variable was CO_2 emissions, which is the primary interest of the study. The variance in the dependent variable can be explained by the four independent variables of FC, FE, FP and DT, which are interrelated to each other.

FC is the type and volume of fuel used by vehicles in the road transport sector. As FC is proportional to CO_2 emission, the less fuel consumed by vehicles means less CO_2 emissions can

Table 1: Summary of previous studies on energy and environmental planning

Study	Sector/country	Methodology/approach	Related factors of study
Ang (2008)	Energy/Malaysia	Johansen co-integration VECM	GDP, CO_2 emissions, FC
Ackah and Adu (2014)	Transport/Ghana	Structural time series	Income, FC, price, human capital, efficiency
Bai and Wei (1996)	Electricity/Taiwan	Linear programming	Optimization on CO_2 emissions and electricity production
Begum et al. (2015)	Energy/Malaysia	Time series, ARDL approach	GDP, FC, population, CO_2 emissions
Bekhet and Yasmin (2013)	Energy/Malaysia	Time series, ARDL approach	CO_2 emissions, GDP, export, import, FC
Bekhet and Yusop (2009)	Energy/Malaysia	VECM	Oil price, GDP, employment, FC
Borjesson and Ahlgren (2011)	Transport/Sweden	Linear programming	Optimization on CO_2 emissions and economic cost
Ediger and Akar (2007)	Energy/Turkey	ARIMA	FC
Hashim et al. (2005)	Electricity/Ontario	Mixed integer programming	Optimization on CO_2 emissions and economic cost
Ivy and Bekhet (2014)	Residential/Malaysia	Time series, ARDL approach	Electricity consumption, GDP, FP, population
Ivy and Bekhet (2015)	Residential/Malaysia	Time series, ARDL approach	Electricity consumption, GDP, FP, population, FDI
Kamarudin et al. (2009)	Transport/Malaysia	Mixed integer programming	Optimization on economic cost
Lakshmanan and Han (1997)	Transport/USA	Decomposition	CO_2 emission, FC, DT, population and GDP
Sadorsky (2013)	76 developing countries	Panel regression	Energy intensity, income, urbanization and GDP
Sadorsky (2014)	16 emerging countries	Panel regression	Energy intensity, income, urbanization and GDP
Shu and Lam (2011)	Transport/Louisiana	Panel regression	CO_2 emission, population, urban area, income and road density
Sultan (2010)	Transport/Mauritus	Time series, ARDL approach	FC, FP, per capita income
Tan et al. (2013)	Waste/Malaysia	Mixed integer programming	Optimization on CO_2 emissions and economic cost
Timilsina and Shrestha (2009)	Transport/Asian countries	Decomposition	CO_2, fuel mix, modal shift, GDP, population, emission coefficients and energy intensity
Wang et al. (2008)	Iron and Steel	Multi-objective optimization	Optimization on CO_2 emissions and production cost
Wang et al. (2011)	Transport/China	Decomposition	CO_2 emissions, FC, modal share, transport intensity
Xu and Lin (2015)	Transport/China	Non-parametric regression	CO_2 emission, GDP, population, FC
Xu et al. (2014)	China	Decomposition	CO_2 emission, FC, GDP, energy intensity

VECM: Vector error correction model, GDP: Gross domestic product, FC: Fuel consumption, FP: Fuel price, DT: Distance travel, FDI: Foreign direct investment, ARDL: Autoregressive distributed lag, ARIMA: Autoregressive integrated moving average be reduced in road transport (Begum et al., 2015). However, in the case of utilizing non-fossil fuels, which contain less carbon content, CO_2 emissions can be lowered without reducing the amount of fuel needed by the road vehicles. Thus, the greater utilization of non-fossil fuels, the greater CO_2 emissions reduction is taking place (Ong et al., 2012).

FE refers to the energy efficiency of vehicles, given as the ratio of vehicle travel distance per unit of fuel consumed. The greater improvement in FE will increase the DT but will decrease the FC required for travel and hence reduce the CO_2 emissions level (Beuno, 2012).

FP is the cost of fuel used by vehicles. When the FP increases, the FC may be reduced as a result of reducing demand (Haldenbilen, 2006; Johanssons, 2009). Thus, the increase in FP also adds the probability of reduced CO_2 emissions.

DT is the travel demand that refers to the unit quantity of DT by passengers and freight in the road transport sector. The increase in DT will increase the FC and the level of CO_2 emissions (Zanni and Bristow, 2010). The option of having more efficient cars will increase the DT but reduce the FC and CO_2 emissions. The transport demand may increase as long as people do not reach their budget which related to FP. The assumptions of these relationships are shown schematically in Figure 4.

Accordingly, it is hypothesized that:
H1: There are significant relationships between CO_2 emissions and its determinants (FC, FE, FP and DT).
H2: There are statistically significant impacts from FC, FE, FP and DT on CO_2 emissions.

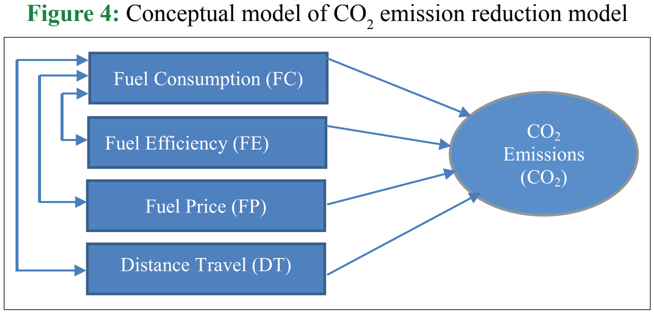
4. DATA SOURCE AND METHODOLOGY

4.1. Data Sources

The data on FC, FE, FP and DT of road transport for the current study was collected from various official data sources for 1990-2013 (Table 2). The data sets were on the road transport sector. The vehicle types covered in this sector were motorcars, motorcycles, taxis, hire and drive cars, goods vehicles and buses. This data was summed according to vehicle technology type that was based on three different fuels: Petrol, diesel and natural gas for the study period.

In Malaysia, petrol vehicles dominated the road transport and made up the greatest percentage at 93% (dominated by motorcars and motorcycles) while diesel vehicles constituted 6% (dominated by goods vehicles, buses and taxis) and the share of natural gas vehicles (used by taxis and buses) was marginal at about 1%. Considering that natural gas vehicles constituted a small share of total vehicles, they were not included in the analysis. Hence, the data sets were split into two: Data sets for petrol vehicle technology and diesel vehicle technology, respectively.

Figure 4: Conceptual model of CO_2 emission reduction model



The annual FC, FP and CO_2 emissions were collected mainly from official data sources' statistical reports of the Energy Commission, (EC, 2012, 2014) Ministry of Domestic Trade and International Energy Agency respectively. The transport data for DT and FE were not readily available. However, there was a record of the annual vehicle numbers, average annual mileage, occupancy/load factors and average FE by vehicle types from published literature and sources (Indati and Bekhet, 2014). Data from these sources was used to estimate relative DT and FE of different vehicle technology categories. SPSS Statistics, version 21 was used to perform the study analysis. The collected data sets are summarized in Table 2.

4.2. Methodology

The primary objective of the current study was to investigate the relationship and impact between CO_2 emissions and its determinants in the road transport sector in Malaysia. The testing procedure consisted of two parts, namely descriptive statistics with inter-relationship analysis and multiple regression analysis.

The first part of the analysis was undertaken to observe the conditions and normality distribution of the data. The mean values and standard deviations were used to observe the data quality, while the skewness, kurtosis and Shaphiro–Wilk tests were used to observe the normality distribution of the data. Then the inter-relationship analysis was conducted to determine the strength and direction of the linear relationships between the allocation factors and CO_2 emissions.

The second part was a multiple regression model to investigate the impact between CO_2 emissions and its determinants comprising FC, FE, FP and DT. The linear relationship-stepwise techniques were carried out to test the effects of these factors on CO_2 emissions. The regression analysis was performed iteratively using the SPSS Statistics software package.

Table 2: Variables, description and sources

Variables	Description	Unit	Sources
FC	FC by type of fuel	ktoe	EC (2000-2014)
FE	Average FE by vehicle technology	km/L	IEA (2012); Aizura et al. (2010); IANGV (2000)
FP	Average market price of fuel by type of fuel	RM/L	MDTCA (2012); EC (2009-2014)
DT	Average DT in transport sector by vehicle technology	Bpkm	MOT (2000-2013); Masjuki et al. (2004); Indati and Bekhet (2014)
CO_2 emissions (E)	CO_2 emissions in transport sector	Million ton	IEA (2014b)

Bpkm: Billion passenger km, FC: Fuel consumption, FP: Fuel price, DT: Distance travel, FE: Fuel efficiency

In general, CO_2 emissions rise with FC and DT and decrease when FE and FP increase (Wohlgemuth, 1997). In this model, the dependent variable is CO_2 emissions of the transport sector. Four factors i.e. FC, FE, FP and DT were used as independent driving variables for the CO_2 emissions in the models. The model for the regression analyses was generally formulated as in Equation (1).

$$E = \beta_0 + \beta_1 FC_1 + \beta_2 FE_2 + \beta_3 DT_3 + \beta_4 FP_4 + \varepsilon \quad (1)$$

In this equation, $\beta_0 \ldots \beta_4$ are the regression coefficients to be estimated based on a record of observations while the last term in the equation, ε, is referred to as residual that is used for testing the overall significance (F-test) of the equation and the significance of each regression coefficient (t-test).

The vehicle technologies in the Malaysian road sector are driven by petrol and diesel vehicles (Section 4.1). Using the general Equation (1), the regression technique was conducted separately for two models. Model 1 represents the data sets of petrol vehicles technology and Model 2 represents the data sets of diesel vehicles technology. The option chosen for both models was the stepwise method. This method reiterates the analysis by each parameter in turn and independently considers the inclusion or exclusion of the parameters with every step. Although Equation (1) includes all the determinant factors assumed to have effects on CO_2 emissions, not all of these factors may be statistically significant in each vehicle technology type. The estimated coefficients of the models are shown and discussed in Section 5.

5. RESULTS AND DISCUSSION

5.1. Descriptive Statistics, Normality Analysis and Inter-Relationship

Table 3 shows the results of the statistical descriptions for each determinant. The first left side column in the table reported the data quality consisting of minimum, maximum, mean and standard deviation. A small standard deviation relative to the mean was observed for all factors, suggesting good data quality. The right side column of the table reported the normal distribution results of the data consisting of skewness, kurtosis and Shapiro–Wilk. The skewness was within the range of ±1 and kurtosis was within the range of ±3, suggesting good normality indicators for the factors investigated. Due to the small datasets (N = 24) under investigation, the normal distribution was further explored through the statistical technique called the Shapiro–Wilk test. The results in Table 3 indicate a good significance (P > 0.001) for all factors (Pallant, 2013).

For inter-relationships, the Pearson correlation coefficient was calculated for the factors to determine the strength and direction of the linear relationships between the independent variables (FC, FE, FP and DT) and the dependent variable (E). A correlation of <0.20 is considered a slight correlation; 0.20-0.40 is considered low; 0.4-0.7 is a moderate correlation; 0.7-0.9 is a high correlation; and more than 0.9 is considered very highly correlated (Sang and Bekhet, 2015). Table 4 shows the results of correlation coefficients. All factors have high correlation (>0.8) with CO_2 emissions. FC (FCP, FCD) and DT (DTP, DTD) show positive linear relationships with CO_2 emissions, indicating that higher consumption and DT are inclined to increase CO_2 emissions (Wang et al., 2012). FE (FEP, FED) and FP (FPP, FPD) of both diesel and petrol vehicles show a negative linear relationship with CO_2 emissions, indicating that higher FE and FP increases are inclined to reduce CO_2 emissions.

5.2. Impact Analysis between CO_2 Emissions and its Driving Factors

Multiple regression analyses were performed to understand the impact between CO_2 emissions and its influencing factors based on the step-wise method, which reiterates the analysis by each variable in turn and independently considers the inclusion or exclusion of the variables with every step (criteria: Probability-of-F-to-enter ≤0.05; probability-of-F-to-remove ≥0.1). During these iterations, outliers of the residual terms were eliminated because the statistics calculated during the linear regression analyses rely on normal distribution of these error terms.

The results of Model 1 (Table 5) reveals that only the cumulative effect of FE (FEP) and FP (FPP) on CO_2 emissions are most significant, with the t-test significance level of each factor at <0.05 and the value of the multicollinearity (variance inflation factor) is considerably good at 5.658. These results suggest that the effects of CO_2 emissions from road transport are significant when FE and FP are taken into account.

As shown in Model 1 of Table 5, the adjusted R^2 of 0.981 implies that the predictors (FEP and FPP) explain about 98.1% of the variance in CO_2 emissions. The ANOVA table also indicated that the F-test overall statistic of 595.7 is large enough to be acceptable statistically and the significance level is 0.000. The Durbin–Watson statistic of 1.978 suggests that the error terms were not auto correlated (Montgomery et al., 2006). The largest beta coefficient for FEP (−15.727) means that this factor makes the strongest contribution in explaining the CO_2 emissions, when the variance explained by all other predictor domains in the model is controlled for. It implies that any increase in FEP would lead to a decrease in CO_2 emissions (Beuno, 2012). The results also revealed that the strongest contribution to CO_2 emissions in ranking order were FEP and FPP. Hence, one can draw the conclusion that FE (Yang et al., 2015; Beuno, 2012; Pasaoglu et al., 2012; Mattila and Antikainen, 2011; Ong et al., 2011; Hickman et al., 2010; Hickman and Banister, 2007; Ichinohe and Endo, 2006; Gielen and Changhong, 2001) and FP (Klier and Linn, 2013; Allcott and Wozny, 2014) are the key factors influencing the CO_2 emissions level of petrol vehicles in Malaysia.

In contrast, the estimated coefficients of Model 2 (Table 5) reveals that only DT (DTD) affects the CO_2 emissions. The adjusted R^2 of 0.978 implies that the predictors explain about 97.8% of the variance in CO_2 emissions. The ANOVA table also indicated that the F-test overall statistic of 1018.076 is sufficiently acceptable and the significance is 0.000. T-test significance of the factor is <0.05. The Durbin–Watson statistic (=1.819) suggests that the error terms were not auto correlated (Braun et al., 2014). Model 2 shows that only DT of diesel vehicles (DTD) makes the strongest contribution in explaining the CO_2 emissions, implying that any increase in DTP

Table 3: Descriptive statistics

Variables	Min	Max	Mean	SD	Skewness	Kurtosis	Shapiro–Wilk P value
CO_2 (E)	15.37	45.50	31.02	8.905	−0.262	−0.952	0.404
FC							
Petrol (FCP)	2889.0	12288.00	6680.75	2328.08	0.146	−0.024	0.447
Diesel (FCD)	1351.24	4820.00	2934.86	1136.77	−0.138	−1.502	0.013
FE							
Petrol (FEP)	7.47	9.58	8.49	0.6842	0.161	−1.268	0.194
Diesel (FED)	5.80	8.12	6.97	0.7619	0.067	−1.251	0.194
FP							
Petrol (FPP)	0.29	0.80	0.5750	0.1875	−0.352	−1.546	0.004
Diesel (FPD)	0.34	1.03	0.7258	0.2523	−0.433	−1.429	0.005
DT							
Petrol (DTP)	106.40	591.25	309.24	156.22	0.472	−1.092	0.101
Diesel (DTD)	74.50	272.60	169.38	58.81	−0.036	−1.029	0.548

SD: Standard deviation, FC: Fuel consumption, FP: Fuel price, DT: Distance travel, FE: Fuel efficiency

Table 4: Correlation coefficient for road transport dataset

Factors	CO_2	FCP	DTP	FEP	FPP	FCD	DTD	FED	FPD
E	1.000								
FCP	0.963	1.000							
DTP	0.959	0.929	1.000						
FEP	−0.986	−0.957	−0.978	1.000					
FPP	−0.851	−0.845	−0.933	0.907	1.000				
FCD	0.936	0.923	0.907	−0.945	−0.863	1.000			
DTD	0.989	0.964	0.984	−0.995	−0.901	0.939	1.000		
FED	−0.984	−0.950	−0.985	0.999	0.911	−0.944	−0.996	1.000	
FPD	−0.836	−0.805	−0.912	0.869	0.899	−0.845	−0.863	0.876	1.000

Correlation is significant at the 0.01 level (two-tailed). FC: Fuel consumption, FP: Fuel price, DT: Distance travel, FE: Fuel efficiency

Table 5: Results of measurement Model 1 (petrol technology vehicles) and Model 2 (diesel technology vehicles)

Construct	Unstandardized coefficients β	Standard error	Standardized coefficients Beta	t-value	P-value	VIF
Model 1: Petrol technology vehicles						
Constant	157.812	5.912	-	26.692	0.000	-
FEP	−15.727	0.889	−1.208	−17.686	0.000	5.658
FPP	11.634	3.245	0.245	3.586	0.002	05.658
Model 2: Diesel technology vehicles						
Constant	5.644	0.840	-	6.719	0.000	-
DTD	0.150	0.005	0.989	31.907	0.000	1.000

Model 1: R=0.991, Adjusted R^2=0.981, F=595.675, significant=0.000, Durbin–Watson=1.978, Model 2: R=0.989, Adjusted R^2=0.978, F=1018.076, significant=0.000, Durbin–Watson=1.819

would lead to an increase in CO_2 emissions. Hence, one can draw the conclusion that for diesel technology, DT is the main factor of road transport CO_2 emissions growth (Zanni and Bristow, 2010; Bonilla, 2009). Differences between the markets of the petrol (mostly used for passenger transport) and the diesel (largely used for passenger transport and freights transport) could explain this result (González-Marrero et al., 2012). In Malaysia, the diesel-fuelled vehicles are mainly used for passenger transport such as buses and taxies and freight transport such as goods vehicles that are largely used by long distance drivers (Ong et al., 2012).

The results of the inter-relationship and impact statistical analysis of the variables are summarized in Tables 6 and 7, respectively. In terms of inter-relationship analysis (Table 6), the results indicated that all the predictors support the hypothesis of H1. However, in terms of impact analysis (Table 7), the current results generally revealed that only the predictors of FE, DT and FP support the hypothesis of H2, with the strongest contribution to CO_2 emissions in ranking order being FE, DT and FP respectively. Hence, one can draw the conclusion that the FE, DT and FP are the significant contributing factors for CO_2 emissions reduction in Malaysia's

Table 6: Results of hypothesis testing (H1) of inter-relationship analysis

Hypothesis	Petrol technology vehicles		Diesel technology vehicles	
	Correlation coefficients	Results	Correlation coefficients	Results
CO_2↔FC	0.963	Supported	0.936	Supported
CO_2↔FE	−0.986	Supported	−0.984	Supported
CO_2↔FP	−0.851	Supported	−0.836	Supported
CO_2↔DT	0.959	Supported	0.989	Supported

Correlation is significant at the 0.01 level (two-tailed). FC: Fuel consumption, FP: Fuel price, DT: Distance travel, FE: Fuel efficiency

Table 7: Results of hypothesis testing (H2) of impact analysis

Hypothesis	Petrol technology vehicles			Diesel technology vehicles		
	Standardized path coefficients	P value*	Results	Standardized path coefficients	P value*	Results
FC→CO_2	-	-	Rejected	-	-	Rejected
FE→CO_2	−1.208	0.000	Supported	-	-	Rejected
DT→CO_2	-	-	Rejected	0.989	0.000	Supported
FP→CO_2	0.245	0.002	Supported	-	-	Rejected

*Significant at the 5% level ($P<0.05$). FC: Fuel consumption, FP: Fuel price, DT: Distance travel, FE: Fuel efficiency

road transport. Even though FC is not supported in both models, the FE improvement ultimately affects FC, which corresponds to the growth of CO_2 emissions level (Bonilla, 2009).

6. CONCLUSIONS AND POLICY IMPLICATIONS

This study investigated the driving forces of CO_2 emissions in the road transport sector by using multiple regression analyses for 1990-2013 data. It examined the relationship and impact built upon assumptions that FC, FE, FP and DT had effects on the CO_2 emissions of the road transport sector in Malaysia. The results showed significant linear effects between CO_2 emissions and its determinants. The study further revealed that the FE, FP and DT were the main impact factors on CO_2 emissions for road transport sector. This is in line with empirical results reported in other studies that suggested increases in FE (Yan and Crookes, 2009; Ekins et al., 2011), FP (Klier and Linn, 2013) and DT (Beuno, 2012) significantly influenced the energy consumption and CO_2 emissions level in this sector. This also seemed to support the previous empirical research that pointed out clean energy and energy efficient policies are able to reduce CO_2 emissions without affecting the country's economy and mobility growth (Saboori et al., 2012; Matilla and Antikainen, 2011; Hickman et al., 2010).

From the energy planning point of view, increasing demand in the road transport sector due to economic development will cause large amounts of CO_2 emissions. The results obtained suggest that FE improvement, FP mechanisms and DT management provide important policy implications to address the CO_2 emissions problem in road transportation. As most of the passenger vehicles run on petrol (93%), the increasing use of efficient vehicle technology, such as hybrid and electric vehicles to substitute for conventional vehicles, can reduce the CO_2 emissions in this sector (Sang and Bekhet, 2014). Thus, government should intensify the promotion of these vehicles and continue to provide necessary fiscal incentives to accelerate the use of these vehicles. Furthermore, the government has to improve energy saving technology using fiscal instruments such as encouraging the car manufacturers to engage energy saving technologies through preferential policies such as fuel economy policy (Silitonga et al., 2012; Mahlia et al., 2002). This policy would help to increase the penetration rate of efficient vehicle technologies substituting for conventional vehicles.

The experiences in other areas (Japan, United States, Europe and Singapore) that have implemented fuel economy policies signal that these measures reduce fuel use and CO_2 emissions. However, to establish the fuel economy standard on vehicles, a regulatory authority needs to be institutionalized and capacity must be built to implement this policy in Malaysia. The current fuel economy initiatives around the world and in the Association of Southeast Asian Nations (ASEAN) countries to achieve vehicle efficiency and reduce CO_2 emissions provide a good platform for promoting competitiveness and inducing a market transformation among car manufacturers in Malaysia to produce efficient vehicles.

As FC is proportional to CO_2 emissions, the less fuel consumed by vehicles means less CO_2 emissions can be reduced in the road transport. As DT has been regarded as the important factor for diesel vehicles, the fuel switching options can be implemented to reduce FC while meeting the mobility needs. This can be done by intensifying the use of alternative fuels such as biofuels (which contain less carbon content) so that CO_2 emission reductions can be achieved (Xu and Lin, 2015; Borjesson & Ahlgren, 2011). The B5 (blend of 5% palm biodiesel and 95% petroleum diesel) and B7 (blend of 7% palm biodiesel) that are currently used in diesel vehicles seems to support reducing the country's CO_2 emissions. The plan to increase the biodiesel blend to B17 (blend of 17% palm biodiesel) by 2020 is an effective means for CO_2 emissions reduction in the country (EPU, 2015). Moreover, if the government adopts the use of bioethanol in road transport, the CO_2 emissions reduction would be higher as a much larger portion of the passenger vehicles runs on petrol (Cucchiella et al., 2015). Moreover, energy efficient vehicles such as hybrid, electric and eco cars could reduce fuel demand and CO_2 emissions for the transportation sector (Pongthanaisawan and Sorapipatana, 2013). As many diesel vehicles are largely used by industries, a "green" logistics strategy could be one of the options for CO_2 emissions reduction.

As FP is also indicated as having significant impact on reducing the CO_2 emissions level, the government's decision on removal of the FP subsidy for both petrol and diesel vehicles in 2014 is commendable. However, as the global oil price is declining, the increase in FP would cause marginal impact due to the increasing affordability of both purchasing and using private modes of transportation. Thus, additional demand management measures, such as increasing vehicle taxes, a carbon tax and congestion charges in city areas, can be implemented to both reducing the FC and CO_2 emissions.

The results of the current study provided a basis to understand the potential for reducing CO_2 emissions and offered support for identifying mitigation measure decisions in the local context for this sector. However, the study only focused on the road transport sector from a national perspective and excluded other modes of transportation. Among many policies, a shift from private vehicles to public transportation (light rail transit and mass rapid transit) seems to be one of the effective mitigation strategies for CO_2 emissions reduction (Ong et al., 2012). In this sense, further research can be extended to include other modes of transportation such as rail, air and maritime to improve representation of the transportation infrastructure. To study the country's ability to achieve the CO_2 emissions reduction target, the work could be extended to examine the optimal level of CO_2 emissions reduction for the transportation sector. This could be further investigated by employing an optimization modeling approach to examine optimal energy reduction options that would be of interest to the country.

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