# Energy consumption, $CO_2$ emission and economic growth: empirical evidence for Malaysia


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**Abstract:** This study focuses on the relationship among the energy consumption, carbon emission and economic growth of Malaysia by using a time series data from 1980–2016. The study findings are shown by an econometric analysis that energy consumption, total and per capita $CO_2$ emission and gross domestic product (GDP) has increased vastly between 1980 and 2016. The Johansen cointegration test confirms the existence of the long run relationship of energy consumption with carbon emission and economic growth. Moreover, the Granger causality test reveals the unidirectional causality of energy demand and population with carbon emission. The positive and significant relationship between GDP and carbon emission is a critical issue in Malaysia that needs to be addressed with care as economic growth is necessary but increase of carbon emission is undesirable. Therefore, this study recommends to promote green energy, green growth (GDP) that will ensure both energy security and energy sustainability in Malaysia over time.

**Keywords:** energy consumption; carbon emission; economic growth; green energy; policy; Malaysia.

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## 1 Introduction

Malaysia is a higher middle-income country in Southeast Asia which aims to transform its economy from developing to a developed country. Though Malaysia is currently facing economic challenges, the economy is growing over years. The economic growth and developmental activity require higher energy demand which is affecting the growth of energy consumption in Malaysia (Ong et al., 2011; Begum et al., 2017). Transport and industrial sectors in Malaysia are the major energy user that has combinedly used 70% of the total energy consumption in 2016 (Energy Commission, 2018). On the one hand, energy sector is highly dependent on fossil fuels (oil and coal) and natural gas which contributes about 20% of Malaysian gross domestic product (GDP) (Begum et al., 2017). On the other hand, extensive use of energy generates or produces higher level of greenhouse gas (GHG) emission. It is evident that emission of GHGs due to fossil fuel combustion contributes significantly to the global warming and climate change (Milner et al., 2012). Carbon dioxide ($CO_2$) emission is considered as the leading GHG among the GHGs which influence largely to the climate change (World Bank, 2007). Thus, a link has found that increase energy consumption and economic expansion leads to increase $CO_2$ emission (Asafu-Adjaye, 2000).

It is evident that Malaysia is facing an increasing demand of energy consumption over the past years (Begum et al., 2017). In line with energy demand, Malaysia has also experienced increasing trend of $CO_2$ emission from 1980–2016. Therefore, the country is highly concern about the growing emission intensity especially from energy sector. Thus, the country is committed to reduce its GHG emissions intensity of GDP by 45% by 2030 relative to the emissions intensity of GDP in 2005 which includes 35% on an unconditional basis and a further 10% is conditional based on the receipt of climate finance, technology transfer and capacity building from developed countries. Therefore, it is crucial to analyse the nexus among the energy demand, $CO_2$ emission and economic growth that would provide indication for policy options. Thus, this article explores the pattern of relationship between $CO_2$ emission with energy consumption and economic growth by using econometric analysis based on time series data from 1980 to 2016. This study would contribute to specify the relationship among the selected macro variables and enrich the existing literatures of Malaysia as not many studies have addressed this issue.

A number of studies have examined the relationship energy consumption, $CO_2$ emission and economic growth with a varying degree of results. Some of the studies have found unidirectional relationship between energy consumption and economic growth (Stern, 2000; Shiu and Lam, 2004) as well as energy consumption and $CO_2$ emission (Jalil and Mahmud, 2009; Asafu-Adjaye, 2000) while some other studies have revelled bidirectional relationship between energy consumption and economic growth (Soytas and Sari, 2003; Oh and Lee, 2004; Yoo, 2005) as well as energy consumption and $CO_2$ emission (Hwang and Yoo, 2015). Unidirectional relationship indicates that an increase of energy consumption directly affects $CO_2$ emissions while bidirectional relationship shows both influences each other. Moreover, $CO_2$ emission is also significantly influenced by the economic expansion as economic growth is estimated as the most important driver that affects $CO_2$ emission (Cranston and Hammond, 2010). Akbostanci et al. (2009) examined the cointegration relationship between economic growth and $CO_2$ emissions for Turkey and found a monotonically increasing long run relationship between $CO_2$ and per capita income. Jaunky (2010) investigated the cointegration and causal relationship between economic growth and $CO_2$ emissions for 36 high-income countries. Saboori et al. (2012) was found the existence of a long run relationship between per capita $CO_2$ emissions and real per capita GDP.

It has also been identified that both per capita energy consumption and per capita GDP has a long-term positive impact with per capita $CO_2$ emission (Begum et al., 2015). Thus, it is mentioned that a variety of relationship among the variables existed in the current literatures that demand further study. There is a need to understand what types of relationship exist among the selected variables in Malaysia which would be useful for long-term action and policy decision towards sustainable energy and economy as well. However, from the literatures, the casual relationship among the population, energy consumption, $CO_2$ emission and economic growth is summarised in Figure 1. Therefore, this study attempts to examine the relationship using the following null hypothesis in case of Malaysia.

1 There is no relationship between energy consumption and $CO_2$ emission.

2 There is no relationship between energy consumption and economic growth.

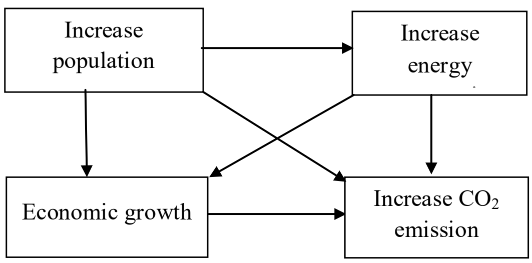
3 There is no relationship between population and $CO_2$ emission.

4 There is no relationship between energy consumption and population growth.

5 There is no relationship between population and economic growth.

6 There is no relationship between economic growth and $CO_2$ emission.

**Figure 1** Casual relationship among the selected variables




## 2 Methods

This study determines and explains the relationship among the energy consumption, $CO_2$ emission and economics growth of Malaysia using the time series data from 1980–2016 (Table 6 in Appendix). Data has been collected from the Energy Commission (2018) of Malaysia and the World Development Indicators of the World Bank (2018). This study presents the trends of the selected indicators as well as their annual growth that is calculated by equation (1). The indicators include total energy demand (consumption), GDP, total population, total $CO_2$ emission and per capita $CO_2$ emission of Malaysia. A number of analytical tests such as unit root test, Johansen cointegration, Granger casualty test and vector error correction model (VECM) are conducted to explain the relationship among the indicators or variables.

$$Annual\ growth\ (\%) = \left(\frac{Current\ year - previous\ year}{previous\ year}\right) \times 100 \quad (1)$$

The relationship among the $CO_2$ emissions, energy consumption, population and economic growth (GDP as a variable of economic growth) can be presented by equation (2) that can be expressed in a functional form by equation (3).

$$CCO_2 = \left(GDP, GDP^2, END, POP\right) \quad (2)$$

$$LCO_2 = \alpha_0 + \alpha_1 LGDP_t + \alpha_2 LGDP_t^2 + \alpha_3 LEND_t + \alpha_4 LPOP_t + \mu_t \quad (3)$$

where

| | |
|---|---|
| $LCO_2$ | the log of $CO_2$ emission |
| $LGDP_t$ and $LGDP_2$ | the log of GDP and its square term |
| $LEND$ | the log of energy consumption demand |
| $LPOP$ | the log of population |
| $\mu_t$ | the regression error term. |

## 2.1 Unit root test

The unit root test explains the consistency of a given time series data with a unit root process as the presence of unit roots could lead to false inferences in analytical result from time series data (Mbanasor et al., 2015). All variables included in this study were tested using augmented Dickey-Fuller (ADF) test which examines the presence of unit root in the time series data. It has found that all the variables were not stationary at levels but when first difference was done, all variables become stationary. Thus, non-stationary data converted onto stationary data by first difference in the unit root test using Eviews software.

## 2.2 Johansen cointegration

To explore the long run relationship among the variables, the Johansen cointegration test was conducted by this study. If there is found existence of cointegration at least one linear combination among the variables, it indicates that there exists a long run relationship among the selected variables. However, the hypothesis of the cointegrated equations is determined by the probability of trace and maximum eigenvalue statistic derived from the Johansen (1988).

## 2.3 Granger casualty test

To explain the casual relationship among the variables, this study run Granger casualty test. It helps to determine whether the relationships are unidirectional or bidirectional between the variables. The null hypothesis of the Granger casualty test can be rejected if the probability value is below 0.05 level.

### *2.4 VECM*

As Johansen provides long run relationship, this study also conducts VECM as it provides short run estimates. In this model, all variables are considered as endogenous one after another where the number of equations is equal to the number of variables. The VECM method uses the function of each dependent variable with its own lags, error correction term and the random error term (Ali et al., 2015). The model can be expressed as follows:

$$\Delta LCO_{2_t} = \alpha_1 + \sum_{i=1}^{p} \beta_{1i} \Delta LCO_{2_{i-1}} + \sum_{i=1}^{q} \beta_{1i} \Delta LGDP_{i-1} + \sum_{i=1}^{r} \beta_{1i} \Delta LGDP_{i-1}^{2} + \sum_{i=1}^{q} \beta_{1i} \Delta LEND_{i-1} + \mu_{1t}$$

$$\Delta LGDP_t = \alpha_2 + \sum_{i=1}^{p} \beta_{2i} \Delta LCO_{2_{i-1}} + \sum_{i=1}^{q} \beta_{2i} \Delta LGDP_{i-1} + \sum_{i=1}^{r} \beta_{2i} \Delta LGDP_{i-1}^{2} + \sum_{i=1}^{q} \beta_{2i} \Delta LEND_{i-1} + \mu_{2t}$$

$$\Delta LEND_t = \alpha_3 + \sum_{i=1}^{p} \beta_{3i} \Delta LCO_{2_{i-1}} + \sum_{i=1}^{q} \beta_{3i} \Delta LGDP_{i-1} + \sum_{i=1}^{r} \beta_{3i} \Delta LGDP_{i-1}^{2} + \sum_{i=1}^{q} \beta_{3i} \Delta LEND_{i-1} + \mu_{3t}$$

$$\Delta LPOP_t = \alpha_4 + \sum_{i=1}^{p} \beta_{4i} \Delta LCO_{2_{i-1}} + \sum_{i=1}^{q} \beta_{4i} \Delta LGDP_{i-1} + \sum_{i=1}^{r} \beta_{4i} \Delta LGDP_{i-1}^{2} + \sum_{i=1}^{q} \beta_{4i} \Delta LEND_{i-1} + \mu_{4t}.$$

## 3 Results

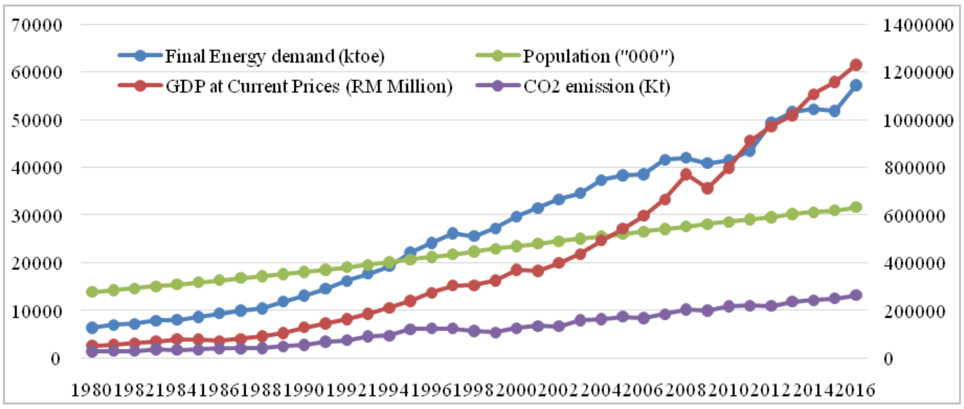
### *3.1 Trends of energy consumption and related variables*

As a growing economy, energy consumption is increasing over the year in Malaysia. Figure 2 shows an increasing trend of total energy demand along with other variables in Malaysia over time. The total energy demand in Malaysia was 6,385 ktoe in 1980 which was increased tremendously at 57,216 ktoe in 2016 meaning about 8.96 times increase within 37 years (Energy Commission, 2018). It also indicates that Malaysia has faced a doubling of its energy consumption by four years interval. The sectoral energy consumption in Malaysia is dominated by the transport and industrial sector together combinedly 70% of the total demand. It is found that transport sector has used about 42% of the total energy consumption in 2016 while industrial sector has consumed 28% in

2016 (Energy Commission, 2018). The country has also experienced an increasing trend of its population. The population of Malaysia has increased from 13.88 million in 1980 to 31.66 million in 2016 which reveal that Malaysia's population has become more than double within 1980–2016.

Besides, Malaysia has achieved a greater expansion of its GDP over time. Malaysia's economy has been transformed into industrial and service sector domination from an agrarian economy. In 1980, the GDP of Malaysia was estimated to MYR53,308 million which was rapidly increased after 1990. After 1980, Malaysian GDP becomes double within the first ten years, and later ten years Malaysian, GDP become triple. Thus, the country has marked 23 times increased of its GDP within 37 years (1980–2016). However, with the expansion of population, GDP and energy consumption, Malaysia is also facing a larger increase of $CO_2$ emission that is really a big concern to the policy makers. The total $CO_2$ emission has increased more than 9.41 times from 27,998 kt in 1980 to 263,592 kt in 2016. Thus, the increase of $CO_2$ emission is larger than the increase of population and energy consumption in Malaysia.

**Figure 2** Trend of energy demand, population, GDP and $CO_2$ emission of Malaysia (see online version for colours)




The average annual growth of the selected variables is calculated and presented in Figure 3. It is found that average annual growth of energy consumption is estimated by 6.37%, where annual GDP growth and population growth is determined by 9.30% and 2.32%, respectively. The annual growth of $CO_2$ emission is measured by 6.79% which is found to higher than the annual energy demand/consumption of Malaysia. Malaysia is also facing an increasing trend of per capita $CO_2$ emission which has been increased from 2.02 tonnes in 1980 to 8.30 tonnes in 2016. The average annual growth rate of the per capita $CO_2$ emission is found to 8.94% that is much higher than energy demand and population growth. Thus, it is crucial to address the higher growth rate of $CO_2$ emission for achieving the target of intended nationally determined contribution (INDC) of Malaysia.

Sectoral share of $CO_2$ emission in Malaysia from 1980–2014 is presented in Figure 4. It is mentioned that 54% of the total $CO_2$ emission comes from the power (electricity) generation in Malaysia while the second major source of $CO_2$ emission is transport sector that contributes 29% of the total $CO_2$ emission. Thus, it can be highlighted that energy consumption is dominated by the transport and industry where $CO_2$ emission are mostly produced by the power and transport sector. Another important source of $CO_2$ emission is the industrial and manufacturing sector which has emitted 13% of the total $CO_2$ emission. Though transport sector is increasing from some past years, $CO_2$ emission from industrial and manufacturing sector is decreasing from 2007. The $CO_2$ emission form residential and commercial sector has found 1.89% in 2014 which has decreased from the 5.66% of the total $CO_2$ emission in 1980. The lowest contributor of $CO_2$ emission in Malaysia is the agriculture sector that only contributed 1.39% in 2014 (see in Table 7 in Appendix). However, due to increase of $CO_2$ emission from power and transport sector, the total $CO_2$ emission is increasing over time in Malaysia.

**Figure 3** Growth comparison among the selected macroeconomic indicators of Malaysia (see online version for colours)

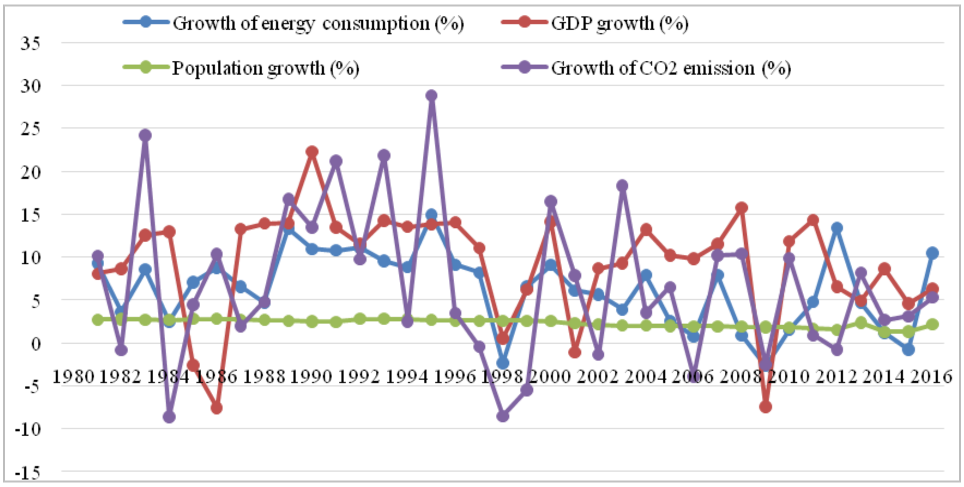
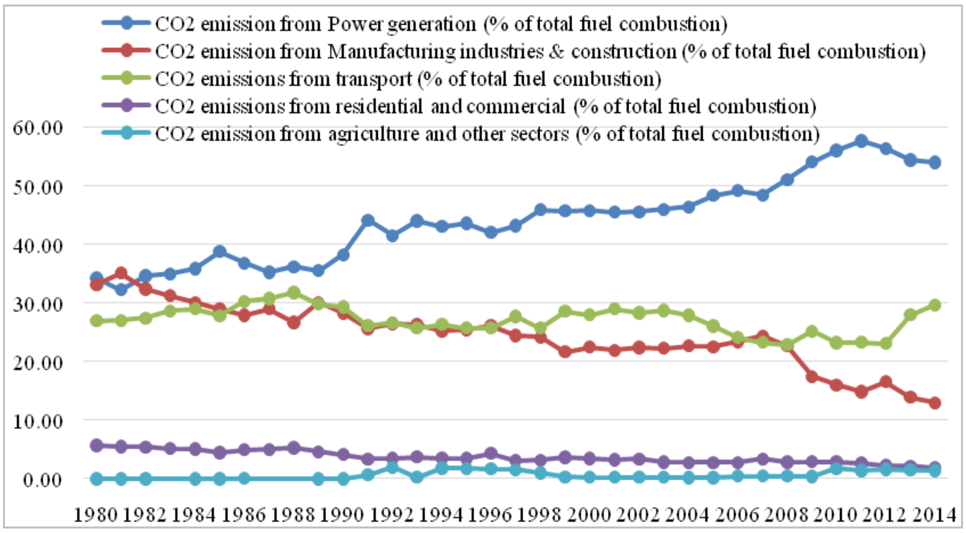



**Figure 4** Percentage of sectoral $CO_2$ emission in Malaysia from 1980–2014 (see online version for colours)



### 3.2 Result of unit root test

The result of unit root test for the time series data of the selected variables is presented in Table 1. The ADF test is applied to check stationarity of the time series data used in this study. The result shows that all the variables were not found as stationary at level but when first differences are done, all the series become stationary which is called integration of order one. The conversion of non-stationary to stationary is useful to achieve feasible results of the other model applied in this study.

**Table 1** Results of ADF unit root test for different indicators

| *Variables* | *t-statistics* | | *Order of integration* |
|---|---|---|---|
| | *Level* | *First difference* | |
| *$LCO_2$* | –1.406444 | –6.522296 | I (1) |
| *LEND* | –2.287511 | –4.298264 | I (1) |
| *LGDP* | –0.825230 | –5.028051 | I (1) |
| *LPOP* | –0.703723 | –2.999031 | I (1) |

Note: Critical value of ADF test: 1% = –3.66, 5% = 2.96 and 10% = –2.61.

### 3.3 Result of optimum lag selection

This study uses vector autoregression (VAR) to select optimum lag order for the time series data. For assessing a dynamic relationship among the variables, there is need to determine the optimum lag after the stationarity test. A number of criteria such as Hannan Quinn (HQ), Akaike information criteria (AIC), Schwartz information criteria (SC), likelihood ratio (LR) and final prediction error (FPE) are used to select the optimal lag length that help to provide reliable result (Ali et al., 2015). According to most of the criteria, this study has determined lag 1 as the optimal lag which is shown in Table 2.

**Table 2** Optimal lag selection for the time series data of this study

| *Lag* | *LogL* | *LR* | *FPE* | *AIC* | *SC* | *HQ* |
|---|---|---|---|---|---|---|
| 0 | –220.0620 | NA | 9.282035 | 13.57951 | 13.76091 | 13.64055 |
| 1 | –16.05723 | 346.1899* | 0.000105* | 2.185287 | 3.092261* | 2.490456* |
| 2 | –5.856355 | 14.83764 | 0.000157 | 2.536749 | 4.169302 | 3.086053 |
| 3 | 10.88896 | 20.29735 | 0.000170 | 2.491578 | 4.849711 | 3.285018 |
| 4 | 36.93992 | 25.26154 | 0.000119 | 1.882429* | 4.966142 | 2.920005 |

### 3.4 Result of Johansen cointegration test

Johansen cointegration test observe whether any long run relationship between the variables exist or not. This test is very efficient as it can offer more than one co-integrating equation or relationship if exist between the variables. The results of Johansen cointegration are provided in Table 3 based on trace and maximum eigenvalue test. The null hypothesis is rejected under both trace and maximum eigenvalue test as the probability is found less than 0.05 level. Thus, Johansen cointegration test confirms that there exists one co-integrating equation. It is concluded from the trace and maximum eigenvalue that there exists long-term relationship among energy demand, GDP, population and $CO_2$ emission of Malaysia.

**Table 3** Johansen cointegration test result

| *Hypothesised no. of CE(s)* | *Trace* | | | |
|---|---|---|---|---|
| | *Eigenvalue* | *Statistic* | *Critical value* | *Prob.** (0.05)* |
| None* | 0.570145 | 53.86634 | 47.85613 | 0.0123 |
| At most 1 | 0.385647 | 24.31560 | 29.79707 | 0.1874 |
| At most 2 | 0.183007 | 7.264085 | 15.49471 | 0.5471 |
| At most 3 | 0.005406 | 0.189730 | 3.841466 | 0.6631 |
| *Hypothesised no. of CE(s)* | *Maximum eigenvalue* | | | |
| | *Eigenvalue* | *Statistic* | *Critical value* | *Prob.** (0.05)* |
| None* | 0.570145 | 29.55074 | 27.58434 | 0.0276 |
| At most 1 | 0.385647 | 17.05152 | 21.13162 | 0.1696 |
| At most 2 | 0.183007 | 7.074355 | 14.26460 | 0.4804 |
| At most 3 | 0.005406 | 0.189730 | 3.841466 | 0.6631 |

Notes: Trace test and max-eigenvalue test indicates one co-integrating equation(s) at 0.05 level, *denotes rejection of the hypothesis at 0.05 level and **MacKinnon-Haug-Michelis (1999) p-values.
Lags interval (in first differences): 1 to 1.

## *3.5 Long run relationship between the variables*

The study has derived long run relationship between dependent and independent variables using vector error correction estimate. Here, the dependent variable is $LCO_2$ emission and independent variables are *LEND*, *LGDP* and *LPOP*. The coefficient values of independent variables and their corresponding t-statistics are presented in Table 4. The coefficient value of energy demand (*LEND*) is found as 0.028 which is positive and indicates that if energy demand increases by 1%, $CO_2$ emission will be increase by 0.28%. Again, the coefficient of the GDP is determined by 0.24 which means that there is a positive relationship between $CO_2$ emission and GDP where by 1% increase of GDP will increase of 0.24% of $CO_2$ emission. Moreover, this result is significant as the t-statistics value (2.53) is more than 2. Cranston and Hammond (2010) also found a significant relationship economic growth and $CO_2$ emissions.

**Table 4** Long run results based on Johansen cointegration

| *Regressors* | *Coefficient* | | *t-statistics* |
|---|---|---|---|
| *LEND* | 0.284365 | | 0.67213 |
| *LGDP* | 0.249045 | | 2.53107 |
| *LPOP* | 2.315225 | | 3.94523 |
| Adj. R-squared | | 0.517568 | |
| F-statistic | | 2.956340 | |

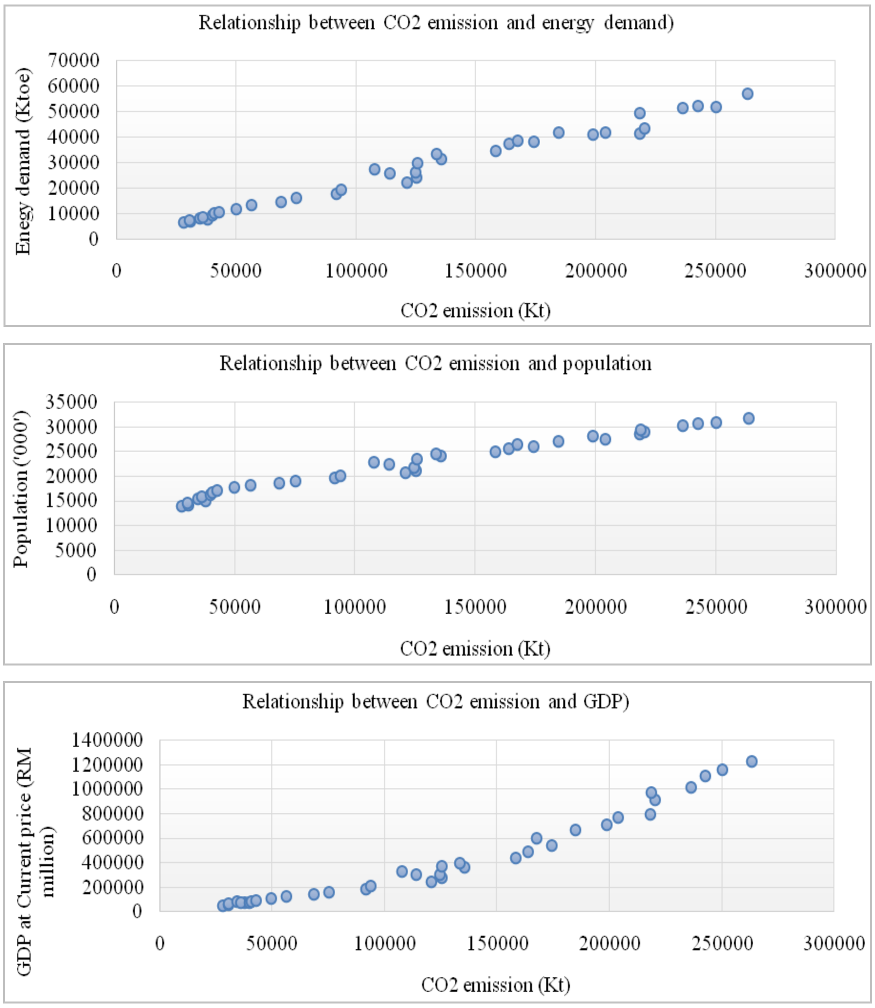
Note: Dependent variable: $LCO_2$.

The relationship between $CO_2$ emission and population is also revealed positive and significant as the coefficient value is 2.315 and t-statistic is 3.94. This result also indicates that if population rises by 1%, $CO_2$ emission will be increased by 2.31%. The adjusted $R^2$ is estimated by 0.52 which indicates that about 52% of the variation can be explained by the independent variables included in the model. Thus, the result confirms the long run relationship between $CO_2$ emission with other variables and the Johansen long run equation derived by VECM model can be written as follows:

$$LCO_2 = 15.588 + 0.284LEND + 0.249LGDP + 2.315LPOP$$

Figure 5 provides a snapshot of the relationship between $CO_2$ emission with energy demand, GDP and population of Malaysia. It is also evident that with the increase of energy demand, GDP and population in Malaysia, $CO_2$ emission increases over time. Parka and Hong (2013) determined positive correlation between energy consumption, $CO_2$ emission and economic growth. The result of this study is supported by some other studies (Asafu-Adjaye, 2000; Ali et al., 2015; Sarkar et al., 2018).

**Figure 5** Relationship between $CO_2$ emission with energy demand, population and GDP in Malaysia (see online version for colours)



### *3.6 Result from Granger casualty test*

This study has also run pairwise Granger causality test to explain whether the relationship is unidirectional or bidirectional between the variables. Table 5 shows that energy demand and population have unidirectional relationship with $CO_2$ emission as the null hypothesis rejected at 0.05 level. It indicates that if energy demand increases, $CO_2$ emission will also increase but increase of $CO_2$ emission does have any Granger cause on energy demand. This result is supported by some of the studies those also established a unidirectional relationship between economic growth and emissions (Jobert and Karanfil, 2007; Jalil and Mahmud, 2009; Faisal et al., 2017). Similar indication is found between population and $CO_2$ emission of Malaysia. The results also reveal two more unidirectional relationships that are derived found between population and GDP as well as population and energy demand. It means that increase of population causes to increase of energy demand and GDP. This study did not find any bidirectional relationship between the variables for Malaysia. However, Asafu-Adjaye (2000) has determined a combination of unidirectional and bidirectional causality relationship between energy consumption and economic growth in case of four selected developing countries. Moreover, Pao and Tsai (2011) estimated strong bidirectional causality between emissions and foreign direct investment (FDI). Thus, causality relationship varies in different studies depending on the methods, data, variables and the characteristics of the country (Faisal et al., 2017).

**Table 5** Results from the pairwise Granger causality test

| *Null hypothesis* | *F-statistic* | *Prob.* |
|---|---|---|
| *LEND* does not Granger cause $LCO_2$ | 3.13585 | 0.0330* |
| $LCO_2$ does not Granger cause *LEND* | 0.33912 | 0.8488 |
| *LGDP* does not Granger cause *LPOP* | 1.94178 | 0.1360 |
| *LPOP* does not Granger cause *LGDP* | 2.81110 | 0.0480* |
| *LEND* does not Granger cause *LPOP* | 1.21105 | 0.3320 |
| *LPOP* does not Granger cause *LEND* | 2.72036 | 0.0534* |
| $LCO_2$ does not Granger cause *LPOP* | 1.64362 | 0.1960 |
| *LPOP* does not Granger cause $LCO_2$ | 3.37221 | 0.0252* |
| *LEND* does not Granger cause *LGDP* | 1.41841 | 0.2581 |
| *LGDP* does not Granger cause *LEND* | 0.73996 | 0.5740 |
| $LCO_2$ does not Granger cause *LGDP* | 1.02548 | 0.4143 |
| *LGDP* does not Granger cause $LCO_2$ | 0.53194 | 0.7135 |

Note: *Null hypothesis rejected at 0.05 level.

## 4 Discussion and recommendations

The study determines the relationship of $CO_2$ emission with energy consumption, population and the economic growth of Malaysia. It shows that Malaysia is facing an increasing trend of $CO_2$ emission due to the casual relationship with other variables as the study identifies a long run positive relationship of $CO_2$ emission with energy consumption, population and the economic growth. The positive relationship indicates that increasing demand of energy use leads to increase $CO_2$ emissions in Malaysia. In addition, increase of GDP and population size might cause further increase of energy consumption. Rapid transformation of Malaysian economy and population expansion and rapid urbanisation are combinedly increasing energy demand and consumption that results higher $CO_2$ emission in the country.

Therefore, the increasing trend of energy demand and $CO_2$ emission calls for special attention to the policy makers. Thus, Malaysia has set the target to reduce its emission intensity by 45% by 2030 compared to 2005 level as indicated in the INDC submitted to United Nations Framework Convention on Climate Change (UNFCCC). Ministry of Energy, Science, Technology, Environment and Climate Change, Sustainable Energy Development Authority (SEDA) and Malaysian Green Technology Corporation (MGTC) are currently working on clean development mechanism (CDM) and green technology development, renewable energy promotion and small-scale decarbonisation. The country is also practicing eco-labelling in the industry, promotion of energy-efficient appliances and green building index (GBI) towards emission reduction.

Malaysia has already taken a large number of policy initiatives including Fuel Diversification Policy (1981), National Biofuel Policy (2006), National Energy Policy (2008), Five-Fuel Policy (2001) National Green Technology Policy (2009), National Policy on Climate Change (2009), Renewable Energy Policy and Action Plan (2010), Low Carbon Cities Framework (2011) and National Automotive Policy (2014), National Energy Efficiency Action Plan 2016–2025 towards sustainable energy use and emission reduction. In spite of taking those initiatives, the country's $CO_2$ emission has maintained an increasing trend in recent years. The country should break its current trends where increase of energy demand and GDP leads to increase $CO_2$ emission.

Thus, there is need to address the country's growing energy demand as well as emission by promoting policy implementation through short-term (awareness raising, carbon tax application and eco-labelling in the industry), medium-term (increase the share of renewable energy, decarbonisation of electricity grid, promotion of green technology, improvement of energy efficiency and conservation and cleaner fuel) and long-term (increase clean and green energy supply options, hydrogen and electric vehicle and sustainable transport system) strategies. It is also crucial to promote research and development (R&D) of energy generation and uses. Government should provide incentives for renewable and green energy enhancement in the country. Therefore, Malaysia needs to focus green energy, green growth and green GDP where GDP increase would result a reduction of $CO_2$ emission which ultimately ensures energy security and energy sustainability of the country.

## 5 Conclusions

This study addresses the relationship among carbon emission, energy consumption and economic growth in Malaysia from 1980–2016. To have a sustained understanding of the multidimensional connection, a minimum 36-year of time series data from the year 1980 to 2016 is utilised by an econometric analysis. The results carried out thoroughly by Johansen cointegration, Granger causality and unit root tests indicate the positive existence of the long run relationship among energy consumption, carbon emission and economic growth over the years. A policy recommendation is drawn following the study outcomes to promote green energy and green growth that will ensure both economic and environmental sustainability. This study would help national policymakers to take a right decision for a sustainable program over the long run in Malaysia.

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## Appendix

**Table 6** Statistics of the selected indicators of Malaysia from 1980 to 2016

| *Year* | *Final energy demand consumption (ktoe)* | *GDP at 2000 prices (MYR million)* | *Population (thousand)* | *$CO_2$ emission (kilo tonne)* | *$CO_2$ emission per capita (tonne)* |
|---|---|---|---|---|---|
| 1980 | 6,385 | 53,308 | 13,879 | 27,998 | 2.0 |
| 1981 | 6,979 | 57,613 | 14,257 | 30,825 | 2.2 |
| 1982 | 7,233 | 62,599 | 14,651 | 30,572 | 2.1 |
| 1983 | 7,850 | 70,444 | 15,048 | 37,972 | 2.6 |
| 1984 | 8,045 | 79,550 | 15,450 | 34,697 | 2.3 |
| 1985 | 8,612 | 77,470 | 15,883 | 36,237 | 2.3 |
| 1986 | 9,368 | 71,594 | 16,329 | 39,985 | 2.5 |
| 1987 | 9,983 | 81,085 | 16,774 | 40,762 | 2.5 |
| 1988 | 10,456 | 92,370 | 17,219 | 42,724 | 2.5 |
| 1989 | 11,848 | 105,233 | 17,662 | 49,882 | 2.8 |
| 1990 | 13,146 | 128,658 | 18,102 | 56,593 | 3.1 |
| 1991 | 14,563 | 145,991 | 18,547 | 68,591 | 3.7 |
| 1992 | 16,185 | 162,800 | 19,068 | 75,298 | 4.0 |
| 1993 | 17,728 | 186,042 | 19,602 | 91,723 | 4.7 |
| 1994 | 19,287 | 211,181 | 20,142 | 94,011 | 4.7 |
| 1995 | 22,164 | 240,365 | 20,682 | 121,132 | 5.9 |
| 1996 | 24,181 | 274,138 | 21,223 | 125,375 | 6.0 |
| 1997 | 26,167 | 304,458 | 21,769 | 124,821 | 5.8 |
| 1998 | 25,558 | 306,022 | 22,334 | 114,187 | 5.2 |
| 1999 | 27,228 | 324,952 | 22,910 | 107,934 | 4.8 |
| 2000 | 29,699 | 370,817 | 23,495 | 125,734 | 5.4 |
| 2001 | 31,515 | 366,841 | 24,031 | 135,620 | 5.7 |
| 2002 | 33,290 | 398,714 | 24,543 | 133,743 | 5.5 |
| 2003 | 34,586 | 435,708 | 25,038 | 158,257 | 6.4 |
| 2004 | 37,322 | 493,223 | 25,542 | 163,827 | 6.5 |
| 2005 | 38,284 | 543,578 | 26,046 | 174,487 | 6.8 |
| 2006 | 38,564 | 596,784 | 26,550 | 167,703 | 6.4 |
| 2007 | 41,606 | 665,340 | 27,058 | 184,817 | 6.9 |
| 2008 | 41,968 | 769,949 | 27,568 | 204,032 | 7.5 |
| 2009 | 40,846 | 712,857 | 28,082 | 198,876 | 7.2 |
| 2010 | 41,477 | 797,327 | 28,589 | 218,476 | 7.8 |
| 2011 | 43,456 | 911,733 | 29,062 | 220,405 | 7.7 |
| 2012 | 49,288 | 971,252 | 29,510 | 218,707 | 7.5 |
| 2013 | 51,584 | 1,018,821 | 30,214 | 236,510 | 8.0 |
| 2014 | 52,209 | 1,106,580 | 30,598 | 242,821 | 8.0 |
| 2015 | 51,806 | 1,157,139 | 30,996 | 250,324* | 8.1 |
| 2016 | 57,216 | 1,230,120 | 31,661 | 263,592* | 8.3 |

*Source:* Energy Commission (2018), *estimated from the National Energy Balance (2017) and World Bank (2018)

**Table 7** $CO_2$ emission from energy consumption by sector from 1980–2014 in Malaysia

| *Year* | *Percentage (%) of the total fuel combustion* | | | | |
|---|---|---|---|---|---|
| | *$CO_2$ emission from power generation* | *$CO_2$ emission from manufacturing industries and construction* | *$CO_2$ emissions from transport* | *$CO_2$ emissions from residential and commercial* | *$CO_2$ emission from agriculture and other sectors* |
| 1980 | 34.23 | 33.18 | 26.97 | 5.66 | 0.00 |
| 1981 | 32.27 | 35.15 | 27.06 | 5.52 | 0.00 |
| 1982 | 34.68 | 32.42 | 27.45 | 5.42 | 0.00 |
| 1983 | 35.01 | 31.24 | 28.66 | 5.13 | -0.03 |
| 1984 | 35.84 | 30.11 | 29.01 | 5.06 | 0.00 |
| 1985 | 38.78 | 28.91 | 27.87 | 4.44 | 0.00 |
| 1986 | 36.84 | 27.90 | 30.31 | 4.95 | 0.03 |
| 1987 | 35.28 | 28.99 | 30.77 | 4.98 | -0.03 |
| 1988 | 36.20 | 26.70 | 31.83 | 5.24 | -0.03 |
| 1989 | 35.52 | 30.07 | 29.80 | 4.59 | 0.00 |
| 1990 | 38.27 | 28.25 | 29.34 | 4.13 | 0.00 |
| 1991 | 44.15 | 25.68 | 26.13 | 3.35 | 0.67 |
| 1992 | 41.49 | 26.52 | 26.63 | 3.42 | 1.94 |
| 1993 | 44.01 | 26.29 | 25.73 | 3.69 | 0.27 |
| 1994 | 43.07 | 25.24 | 26.38 | 3.51 | 1.80 |
| 1995 | 43.63 | 25.44 | 25.73 | 3.47 | 1.73 |
| 1996 | 42.09 | 26.17 | 25.72 | 4.33 | 1.66 |
| 1997 | 43.20 | 24.48 | 27.69 | 3.08 | 1.55 |
| 1998 | 45.93 | 24.17 | 25.74 | 3.18 | 0.97 |
| 1999 | 45.76 | 21.67 | 28.59 | 3.67 | 0.31 |
| 2000 | 45.81 | 22.46 | 27.99 | 3.46 | 0.28 |
| 2001 | 45.54 | 21.94 | 29.03 | 3.24 | 0.25 |
| 2002 | 45.61 | 22.46 | 28.31 | 3.39 | 0.23 |
| 2003 | 46.02 | 22.26 | 28.71 | 2.79 | 0.23 |
| 2004 | 46.41 | 22.72 | 27.94 | 2.74 | 0.19 |
| 2005 | 48.38 | 22.53 | 26.12 | 2.77 | 0.20 |
| 2006 | 49.21 | 23.43 | 24.10 | 2.77 | 0.48 |
| 2007 | 48.47 | 24.38 | 23.32 | 3.35 | 0.46 |
| 2008 | 51.11 | 22.69 | 22.92 | 2.83 | 0.44 |
| 2009 | 54.13 | 17.44 | 25.18 | 2.92 | 0.34 |
| 2010 | 56.10 | 16.04 | 23.23 | 2.93 | 1.71 |
| 2011 | 57.70 | 14.90 | 23.31 | 2.65 | 1.44 |
| 2012 | 56.41 | 16.56 | 23.12 | 2.27 | 1.63 |
| 2013 | 54.42 | 13.92 | 27.99 | 2.16 | 1.50 |
| 2014 | 54.04 | 12.97 | 29.71 | 1.89 | 1.39 |

*Source:* World Bank (2018)