



## IMPACT OF ENERGY CONSUMPTION AND ENVIRONMENTAL POLLUTION IN MALAYSIA



Muhammad Aminu

Haruna<sup>1+</sup>

Suraya Mahmood<sup>2</sup>

<sup>1</sup>Department of Banking and Finance, School of Management Studies, Kano State Polytechnic, Nigeria

Email: [aharunamuhhammad@gmail.com](mailto:aharunamuhhammad@gmail.com) Tel: +601128206916

<sup>2</sup>Department of Economics, Universiti Sultan Zainal Abidin Terengganu Malaysia

Email: [surayamahmood@unisza.edu.my](mailto:surayamahmood@unisza.edu.my) Tel: +60179277814



(+ Corresponding author)

### ABSTRACT

#### Article History

Received: 9 October 2018

Revised: 13 November 2018

Accepted: 20 December 2018

Published: 17 January 2019

#### Keywords

Energy consumption  
Environmental pollution  
Government spending  
ARDL

#### JEL Classification:

C22, Q4.

Increasing concerned by authorities in developed and developing economies on environmental cleanliness cause government additional spending. Economic activities are achieved at the cost of environmental pollution and degradation. The aim of this study is to investigate how energy use affects the environment in the short and long run and government effort to deal with the resulting effect in Malaysia. This paper develops autoregressive distributive lag (ARDL) approach in analyzing the time series data from 1980-2017. The results show that energy consumption affect the environment in short and the long run and government spending do little to tackle the problem. The study proposes a shift from existing energy use to energy friendly by investing in renewable energy among others.

**Contribution/ Originality:** The contribution is findings energy use pollutes the environment and evaluate government spending towards alleviating the pollution. In literature, we elaborate on Malaysia environmental pollution. The robust methodology applies and no study conducted by acknowledging government spending on Malaysia pollution. Finally, documents the use of cost-effective renewable energy and modern technology.

## 1. INTRODUCTION

Draught, global warming and air pollution is the epicenter of global concerns over the past decades and the major causes of these problems have attributed to economic activities associated with carbon dioxide (CO<sub>2</sub>) emissions. The [IPCC \(2013\)](#) highlights the implication of CO<sub>2</sub> emissions towards green-house gas (GHG) emissions. It reports that 76.7% of GHG emissions consist of CO<sub>2</sub> emissions produced largely by developing nations whose purpose is to accelerate their growth rate and upsurge their gross domestic product in order to accomplish better economic situations. Therefore, understanding the aims behind the CO<sub>2</sub> emissions of developing economies is of paramount importance for policy makers. Paris agreement by 195 nations under the [UNCC \(2015\)](#) reached an agreement to dealt with greenhouse gas emission starting in the year 2020. Malaysia as a developing economy would not be excluded.

The environmental Kuznets curve (EKC) hypothesis suggests that there is an N-shaped relationship between environmental pollution and economic growth. This entails that environmental pollution increases at the initial stage of economic growth and then starts to decline during the later stages of growth ([Ozturk and Acaravci, 2010](#)). Over the last decade, the relationship between environmental pollutants and economic growth has been extensively tested in the energy economics literature using the EKC hypothesis (e.g. [Alam et al. \(2011\)](#)). The EKC hypothesis postulate that when a country's income level rises, environmental pollution of the country escalate at the initial stage of development, then after reaches to a certain point it starts to decline ([Dinda, 2004](#)).

The pollution haven hypothesis postulates that industries that are not environmentally concerned migrate from advanced and high income economies to middle and low income nations through the trading of goods and services. The dissemination, transfer, and diffusion of FDI inflows with outdated and polluting technologies, goods, and services to the less developed countries become the most important part of the challenge to attain the sustainable development goals (SDGs). However, over three decades Malaysia become one of the largest recipients of FDI and tourism in Asia these expand economic activities thereby increasing energy use and resulting to environmental pollution.

Considering the importance of climate change mitigation and its impacts, as emphasized in sustainable development goals (SDG) 13, the effect of investments inflows, economic development, and energy consumption on greenhouse gas emissions in developing countries needs further attention to be able to alleviate the impacts. The rest of the study is organized as follows. Empirical studies from the literature are discussed in Section 2, Section 3 provides the data and methodology of the study; empirical results are provided in Section 4, and Section 5 consists of the conclusion.

## 2. LITERATURE REVIEW

Studies on pollution haven hypothesis ([Behera and Dash, 2017](#); [Solarin et al., 2017](#)) confirm the validity of this hypothesis. [Solarin et al. \(2017\)](#) confirmed the pollution haven for Ghana employing the autoregressive distributed lag (ARDL) bounds testing approach. [Ang \(2007\)](#) examine the existence of EKC hypothesis in France by using autoregressive distributed lag (ARDL) bounds testing approach and the outcomes of the study validate the presence of the cointegration between CO<sub>2</sub> emissions, energy consumption, and economic growth. [Jaunky \(2011\)](#) examine the existence of EKC hypothesis for 36 high take-home countries by adopting [Narayan and Narayan \(2010\)](#) approach and state that EKC is valid for the case of United Kingdom, Malta, Portugal, Oman, and Greece for the period of 1980–2005.

[Sun et al. \(2017\)](#) examined the influence of FDI inflows, energy use, economic growth, economic freedom, financial development, urbanization, and trade openness on CO<sub>2</sub> emissions employing ARDL model. The study established the validity of the pollution haven in China and the positive effect of FDI inflows emanated from the huge contribution of the manufacturing sector, mining and electricity shifted from the advanced countries.

In addition, using the fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares regression, [Behera and Dash \(2017\)](#) established a positive effect of FDI inflows and the energy consumption on CO<sub>2</sub> emissions in 17 south and southeast Asian countries, hence, confirming the pollution haven hypothesis. [Zakarya et al. \(2015\)](#) found a long-run influence of FDI inflows, energy consumption on CO<sub>2</sub> emissions in Russia, Brazil, India, and China, consequently, confirming the pollution haven hypothesis through panel causality and FMOLS regression.

On the contrary, studies conducted by [Zhang and Zhou \(2016\)](#) and [Zhu et al. \(2016\)](#) disregards the pollution haven hypothesis. [Zhu et al. \(2016\)](#) used panel quantile regression to investigate the heterogeneous impact of FDI inflows, energy consumption, and economic growth on CO<sub>2</sub> emissions in Malaysia, Indonesia, Philippines, Singapore, and Thailand from 1981 to 2011. The study established an insufficient ground for the pollution haven hypothesis and however found the halo effect hypothesis in huge emission countries.

Zhang and Zhou (2016) maintain that FDI inflows with latest technologies largely contribute to CO<sub>2</sub> emissions lessening in China rather than environmental pollution. Dasgupta *et al.* (2002) and Dean (2004) found that less developed countries depend on sophisticated technology transfer through FDI inflows from advanced countries as their main primary source of acquiring technology. Henceforth, clean and upgrading from out-of-date to modern technologies help to decrease carbon emission levels.

Recently, Apergis and Ozturk (2014) investigate the validity of EKC hypothesis for 14 Asian countries from 1990–2011 by using panel data methodology and outcomes support the presence of an inverted U-shaped association between CO<sub>2</sub> emissions and income per capita. The rationality of the Kuznets curve in Vietnam is examined by Al-Mulali *et al.* (2015) from 1981–2011. Results of the study show a positive association between air pollution and economic growth both in the short and the long run which explains that the EKC hypothesis is not valid in Vietnam.

Nasir and Rehman (2011) investigate the relationship between air pollution, energy consumption, economic growth, and trade openness for the case of Pakistan, a developing country, for the period of 1972–2008 and suggest that these variables have long-run equilibrium relationship. Jalil and Feridun (2011) study the interactions between carbon emissions, economic growth, energy consumption, international trade, and financial development in China for the period of 1953–2006. Results confirm the long-run equilibrium relationship among variables used in the study and suggest the relevance of the EKC hypothesis. Findings also show that financial development effects air pollution negatively which means financial development of China causes a decrease in carbon emissions level. On the other hand, Du *et al.* (2012) study the relationship between carbon emissions, economic growth, urbanization, energy usage, technological improvement and trade openness for the case of China as well from 1995–2009 and, in contrast to Jalil and Feridun (2011) conclude that EKC hypothesis does not exist for the case of the Chinese economy.

Perkins and Neumayer (2009) verified the relationship between 114 economies and their FDI and CO<sub>2</sub> emission efficacy. The result shows that the “dirtier” economies improve their environment proficiency faster when they implement environmentally sound technologies and policies similar to those in “cleaner” countries, resulting in catch-up. Atici (2012) found that FDI has a small negative but significant effect, indicating that FDI does not tend to increase pollution levels in the region. And, FDI has an alleviating impact on the groups of developed countries, suggesting that FDI invests primarily in non-polluting sectors of these countries.

Asghari (2013) tested the validity of pollution haven and halo pollution hypotheses in the context of FDI by analyzing the correlation between carbon emissions and FDI inflow of seven Middle Eastern and North African (MENA) countries during the period of 1980–2011. The results show that FDI inflow has a weak and statistically significant negative relationship with CO<sub>2</sub> emission, which suggests weak support for the halo pollution hypothesis. Zhu *et al.* (2016) indicated that the effect of FDI on carbon emissions is negative in the middle and high emissions countries of the Association of South East Asian Nations (ASEAN), which supports the halo effect hypothesis.

### 3. DATA METHODOLOGY AND RESULT

#### 3.1. Data

The data used in this study are annual figures that cover the period of 1980–2017. Carbon dioxide emissions metric tons per capita, gross domestic product constant 2005 US\$, energy use (kt of oil equivalent), general government final expenditure (constant 2010 US\$), and total population ages (15–65 total) data is collected from WDI (2018).

The functional relationship between CO<sub>2</sub> emissions, energy consumption, economic growth, government expenditure, and total population can be represented in Equation [1]

$$LCO_2MT_t = \beta_0 + \beta_1 LENCN_t + \beta_2 LGDPC_t + \beta_3 LGEXC_t + \beta_4 LPOTL_t + \varepsilon_t \quad [1]$$

where  $\text{LCO}_2\text{MT}_t$ ,  $\text{LEN CN}_t$ ,  $\text{LGDPC}_t$ ,  $\text{LGEXC}_t$ , and  $\text{LPOTL}_t$  are the logarithmic forms of CO<sub>2</sub> emissions, energy consumption, gross domestic product, government expenditure, and total population, respectively.

### 3.2. Unit root test

Time series analysis requires series to be stationary and in deciding the order of integration of the series, [Maddala and Kim \(1998\)](#) present an impression of different stationarity test proposed in the literature. The diverse tests have weaknesses and strength under dissimilar circumstances. The most effective and generally applied unit root tests are Augmented Dickey-Fuller (ADF) test after [Dickey and Fuller \(1979\)](#) and Phillips-Perron (PP) test, after [Phillips and Perron \(1988\)](#). The ADF test is augmented from earlier adaptation as DF test. Assumed, the first order Autoregressive process of Y:

$$Y_t = \alpha_1 Y_{t-1} + \epsilon_t \quad [2]$$

$$\Delta Y_t = \rho Y_{t-1} + \epsilon_t \quad [3]$$

$$Y_t = \alpha_1 Y_{t-1} + \epsilon_t \quad [4]$$

$$Y_t - Y_{t-1} = \alpha_1 Y_{t-1} - Y_{t-1} + \epsilon_t \quad [5]$$

$$\Delta Y_t = (\alpha_1 - 1) Y_{t-1} + \epsilon_t \quad [6]$$

where Y is coefficient,  $\alpha_1$  stands for parameter and  $\epsilon_t$  represents white noise error term. Series Y assumed stationary in the absence of unit root. Meaning that the characteristic root of the processes:  $\alpha_1 < 0$  (or  $\rho < 1$ ), and non-stationary if  $\alpha_1 = 1$ . By subtracting from  $Y_{t-1}$  from Equation [2-6] the basic test is carried on.

### 3.3. Bounds Test for Level Relationship

The bounds test within the ARDL approach is conducted in order to investigate the long-run level relationship between the variables. ARDL approach is proposed by [Pesaran et al. \(2001\)](#) and can be applied regardless of the integration order of the regressors whether independent variables are purely I (0), purely I (1), or mutually co-integrated. The ARDL mechanism suggests the estimation of the following error correction model (ECM);

$$\begin{aligned} \Delta \text{LCO}_2\text{MT}_t = & \alpha_{0y} + \sum_{i=1}^n b_{iy} \Delta \text{LCO}_2\text{MT}_{t-i} + \sum_{i=0}^n c_{iy} \Delta \text{LEN CN}_{t-i} + \sum_{i=0}^n d_{iy} \Delta \text{LGDPC}_{t-i} \\ & + \sum_{i=0}^n e_{iy} \Delta \text{LGEXC}_{t-i} + \sum_{i=0}^n f_{iy} \Delta \text{LPOTL}_{t-i} + \delta_{1y} \text{LCO}_2\text{MT}_{t-i} + \delta_2 \text{LEN CN}_{t-i} \\ & + \delta_3 \text{LGDPC}_{t-i} + \delta_4 \text{LGEXC}_{t-i} + \delta_5 \text{LPOTL}_{t-i} + \epsilon_{1t} \end{aligned} \quad [7]$$

Where  $\alpha_{0y}$  is the intercept and  $\epsilon_{1t}$  is the error term. First and the second parts of the equation represent error correction dynamics and the long-run relationship, respectively. The null hypothesis of the bounds test is  $\delta_{1y} = \delta_2 = \delta_3 = \delta_4 = \delta_5 = 0$  which suggests the long-run relationship of the variables where the alternative

hypothesis is  $\delta_{1y} \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 = 0$ . The computed F-statistics is compared with the critical values of Narayan and Smyth (2005).

After revealing the long-run relationship between variables, ECM is employed in order to estimate short-run coefficients and error correction term. The ECM can be represented as follows;

$$\begin{aligned} \Delta LCo_2MT_t = & a_{0y} + \sum_{i=1}^n b_{iy} \Delta LCo_2MT_{t-i} + \sum_{i=0}^n c_{iy} \Delta LENCN_{t-i} + \sum_{i=0}^n d_{iy} \Delta LGDPC_{t-i} \\ & + \sum_{i=0}^n e_{iy} \Delta LGEXC_{t-i} + \sum_{i=0}^n f_{iy} \Delta LPOTL_{t-i} + \rho ECT_{t-1} + \varepsilon_{1t} \quad [8] \end{aligned}$$

Where  $ECT_{t-1}$  indicates the error correction term which denotes the speed of adjustment to the long run equilibrium level. The goodness of fit of the model is tested by the diagnostic and stability tests. Diagnostic tests help to examine the model for the existence of a serial correlation, functional form, normality, and heteroscedasticity. Pesaran and Pesaran (1997) suggest conducting Brown *et al.* (1975) cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMSQ) test for the stability of the model. An ARDL model is as shown in Equation [9]

$$\Delta Y_t = \beta_0 + \beta_1 \Delta Y_{t-1} + \beta_2 \Delta Y_{t-2} + \dots + \beta_n \Delta Y_{t-k} + \gamma_1 Y_{t-1} + \gamma_2 Y_{t-2} + \dots + \gamma_n Y_{t-k} + \epsilon_t \quad [9].$$

## 4. EMPIRICAL RESULTS

### 4.1. Descriptive Statistics

This section provides the explanation about the reliability as well as the degree of confidence of the employed data. Before estimating the carbon emission model, this study first described the summary of statistics for all variables utilized in the study.

Table 1, the data for Malaysia is normally and evenly dispersed. For instance, the mean value, 0.6833 for carbon emission  $LCoMT$  (metric tons per capita) variable corresponds to the standard deviation of 0.2166. This means, on the average at least 0.68 percent carbon emission (in metric tons per capita) were discharged by various economic activities put together and however, on the minimum 0.30 percent and a maximum of 1.03 carbon emission are discharge. Besides, energy consumption ( $LEN CN$ ) averagely is 3.25 and the standard deviation is 0.18, meaning the rate of energy use (kg of oil equivalent per capita) due fluctuate over time in response to the volume of economic activities, and the maximum rate of energy use is 3.47 and minimum of 2.93.

Similarly, the average value of  $LGDPC$  is USD11.13 relates to the standard deviation of 0.27 and the maximum of growth is USD11.56 billion at a time, while the minimum growth overtime is USD10.66 billion, meaning that investments are fast growing. In addition, the  $LPOTL$  mean value is 7.13, which correspond to the standard deviation of 0.13, and the maximum value of 7.34 and a minimum value of 6.89, this demonstrates the rapidly growing population in the major cities in Malaysia overtime. Equally, government spending  $LGEXC$  increases overtime indicating commitment towards growth and development. These justify that the standard deviation is lower than the mean for the observations. It means that the observation is closer to the mean. Therefore, the observation is normally distributed.

**Table-1.** Descriptive statistics

Variables	Mean	Median	Minimum	Maximum	Std. Deviation
<i>LCo<sub>2</sub>MT</i>	0.6833	0.7500	0.3073	1.0344	0.2166
<i>LENCN</i>	3.2553	3.2983	2.9354	3.4728	0.1813
<i>LGDPC</i>	11.1368	11.1777	10.6606	11.5615	0.2771
<i>LPOTL</i>	7.1329	7.1423	6.8950	7.3413	0.1387
<i>LGEXC</i>	10.2140	10.1623	9.7905	10.6754	0.2816

#### 4.2. Correlation Analysis

Table 2, shows the correlation between *LCo<sub>2</sub>MT* as the dependent variable and the independent variable of interest *LENCN* indicate a strong positive correlation and statistically significant. This finding is similar to [Soytas et al. \(2007\)](#); [Soytas and Sari \(2009\)](#); [Zhang and Cheng \(2009\)](#) and [Ang \(2007\)](#).

In addition, in the case of *LCo<sub>2</sub>MT* and *LGDPCN* indicate strong positive correlation and statistically significant. This finding is in line with the results of [Koçak and Şarkgüneş \(2017\)](#); [Ozturk et al. \(2010\)](#); [Lee and Chang \(2008\)](#); [Shiu and Lam \(2004\)](#). Thus *LCo<sub>2</sub>MT* with the remaining control variables *LGEXC* and *LPOTL* shows positive correlation and statistically significant, respectively.

**Table-2.** Correlation analysis for Malaysia

Variables	<b>LCo<sub>2</sub>MT</b>	<b>LENCN</b>	<b>LGDPCN</b>	<b>LGEXC</b>	<b>LPOTL</b>
LC02MT	1.0000				
	----				
LENCN	0.9834	1.0000			
	(0.0000)	----			
LGDPCN	0.9847	0.9904	1.0000		
	(0.0043)	(0.0029)	----		
LGEXC	0.9471	0.9585	0.9801	1.0000	
	(0.0701)	(0.0042)	(0.0037)	----	
LPOTL	0.9705	0.9846	0.9963	0.9858	1.000000
	(0.0036)	0.0025	(0.0013)	(0.0059)	----

Note: Figures in parenthesis represents p-values.

Since the ARDL specification in Equation [1]-[9] requires that some variables should be integrated at level I(0) and others at order one I(1), herein investigate the stationarity status of the variables using both the augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) tests for unit roots. The null hypothesis tested is that the variable under investigation has a unit root against the alternative that it does not. In each case, the lag-length is chosen using the Akaike Information Criteria (AIC) after testing at the level and for first-order serial correlation in the residuals.

Table 3 reports the results of testing for unit roots in the level variables as well as in their first difference. In the first, I(0) column of the table the null hypothesis that each variable has a unit root cannot be rejected with the exception of *LPOTL* variables by both tests. However, after applying the first difference, some tests reject the null hypothesis. Since some of the data appear to be stationary at level and in first differences, no further tests are performed. We, therefore, maintain the null hypothesis that some variable is integrated at level and order one.

**Table-3.** Unit root test

	<b>ADF</b>		<b>PP</b>	
Variables	I(0)	I(1)	I(0)	I(1)
<i>LCo<sub>2</sub>MT</i>	-0.7119 (0.8314)	-6.6151 (0.000) *	-0.6925 (0.8363)	-6.5881 (0.0000) *
<i>LEN CN</i>	-1.5229 (0.5111)	-6.3343 (0.000) *	-1.8382 (0.3569)	-6.4005 (0.0000) *
<i>LGDPC</i>	-1.1264 (0.6950)	-4.9367 (0.0003) *	-1.0814 (0.7128)	-4.9453 (0.0003) *
<i>LPOTL</i>	-3.1851 (0.0294) *	1.0827 (0.9999)	-3.6351 (0.0096) *	1.0827 (0.9999)
<i>LGEXC</i>	0.2503 (0.9722)	-6.2612 (0.0000) *	0.2503 (0.9722)	-6.2467 (0.0000) *

Notes: \* Represents statistically significant at 5 percent level of significance. Figures in parenthesis represent p-value.

#### 4.3. Test results for Cointegration

In Table 4, given the results of unit roots, we now use the Johansen (1988); Johansen (1991); Johansen (1992) and Johansen and Juselius (1990) techniques to test for cointegration between the variables within an ARDL model as specified in Equations [7]–[8]. Before applying the Johansen's procedure to estimate the parameter, it is necessary to determine the lag-length which should be high enough to ensure that the errors are approximately white noise, but small enough to allow estimation. Since the Johansen procedure is sensitive to the choice of the lag length, we based our decision on the Akaike's Final Prediction Error criterion and selection.

However, using this lag-length, we tested for normality and absence of serial correlation in the residuals to make sure that none of them violates the standard assumptions of the model. The results show that there is no cointegration thereby accepting the null hypothesis, i.e less than Narayan and Smyth (2005) critical value and further estimating ARDL short run and *ECM*.

**Table-4.** Bound test

F-statistic	1.82			
Significance	10%	5%	1%	Conclusion
I(0)	2.45	2.86	3.74	
I(1)	3.52	4.01	5.06	
H <sub>0</sub>				accepted

#### 4.4. Long Run Relationship

Table 5, portrays the long run estimation results of *LCo<sub>2</sub>MT*. The coefficient of *LEN CN* means that an increase by one percent of energy consumption causes carbon emission by 51 percent and statistically significant. This finding is consistent with the studies conducted by Fawcett and Parag (2017); Wang *et al.* (2017); Mousavi *et al.* (2017) and Nejat *et al.* (2015).

In addition, the coefficient of *LGDPCN* described that one percent increase in the level of economic growth will escalate the carbon emission by 64 percent and statistically significant this finding is similar to the study of Panayotou (2016); Kasman and Duman (2015); Begum *et al.* (2015) and Antonakis *et al.* (2017). Thus, an increase in population *LPOTL* drive energy demand by 46 percent this corresponds to the study by Yeh and Liao (2017). By implication, government spending *LGEXC* largely increases in order to curtail related environmental pollution. These results are in line with the studies of many empirical findings. For instance, studies by Zhang *et al.* (2017) and Ottelin *et al.* (2018).

**Table-5.** Long Run Coefficients Estimates of Independent Variables LCo.MT Model: ARDL (1,0,0,0,0)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LEN CN	0.5107	0.2236	2.2839	0.0187*
LGD PCN	0.6428	0.2704	2.3772	0.0000*
LPOTL	0.4652	0.5063	0.9188	0.0004*
LGEXC	0.3905	0.1202	3.2487	0.0269*
R <sup>2</sup>	0.985		AIC	-4.210
Adj. R <sup>2</sup>	0.983		D-W stat	1.715
F- stat	417.522		F- prob.	0.000

Note: \* represents 5 percent level of significance.

Further, the estimated R-squared in this Model is 99 percent, showing that, the explanatory variable explained the dependent variable by 99 percent. However, the adjusted R-squared reduces the influence of unnecessary explanatory variable by 98 percent in the model. Finally, the F-statistic of 417.52 and 0.000 jointly, the explanatory variable explained the dependent at 5 percent significant level. Durbin Watson statistic is close to two signifying the absence of heteroscedasticity.

#### 4.5. Short Run Relationship

Following the successful estimation of the long run relationships, the study further estimates the short run dynamic of the model. Table 6, shows the computed coefficients of the Model. The estimated energy consumption *LEN CN* coefficient is 0.25, this means that a one percent increase in *LEN CN* will increase the carbon emission by 25 percent and statistically significant. This finding is similar to the studies conducted by [Riahi et al. \(2017\)](#) and [Tang and Tan \(2015\)](#). In addition, the estimated *LGD PCN* is 0.50, meaning that if there is economic growth carbon emission will rise by 50 percent. In addition, population growth *LPOTL* aggravates the carbon emission than any other variables in question in the short run. However, government expenditure increases by 5 percent and statistically insignificant in the short run in response to carbon emission.

**Table-6.** Short Run Estimates: Independent Variable CO<sub>2</sub> Model: ARDL (1,0,0,0,0)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LEN CN)	0.2565	0.2035	1.2601	0.0310*
D(LGD PCN)	0.5014	0.3685	1.3606	0.0003*
D(LPOTL)	0.8285	0.5230	1.5841	0.0014*
D(LGEXC)	0.0539	0.1121	0.4811	0.6338
ECM(-1)	-0.9139	0.1663	-5.4935	0.0000*

Note: \* represents statistically significant at 5 percent level of significance.

The results of the Model clearly show that the coefficient of *ECT* found to be - 0.91 demonstrating the movement of the economy towards the equilibrium and statistically significant. This characterizes the fast speed to correct long-run equilibrium in a year. Signifying a reasonable long-run correction each year.

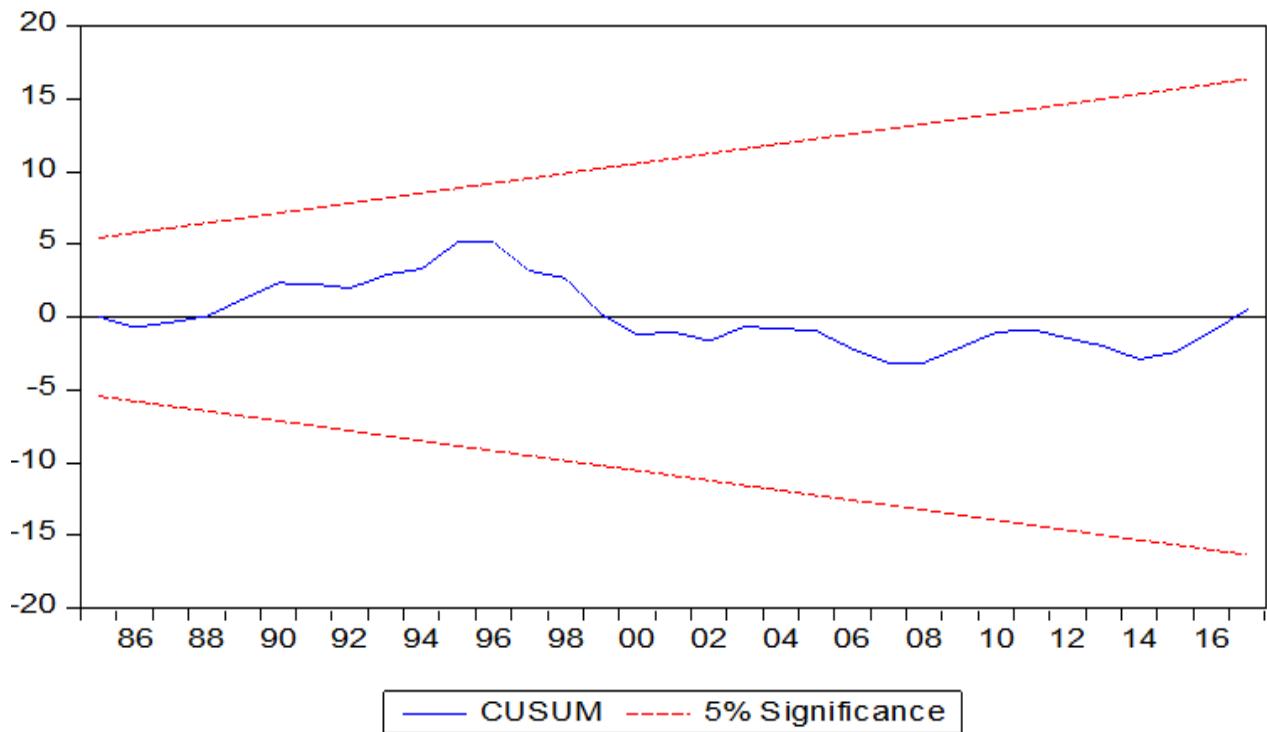
#### 4.6. Diagnostic Checking

The appropriateness of specified models could additionally confirm by diagnostic tests to ensure that the results are free from spurious inference. Table 7 displays how the results of a diagnostic test of the ARDL Model.

**Table-7.** Diagnostic checks of the ARDL Model

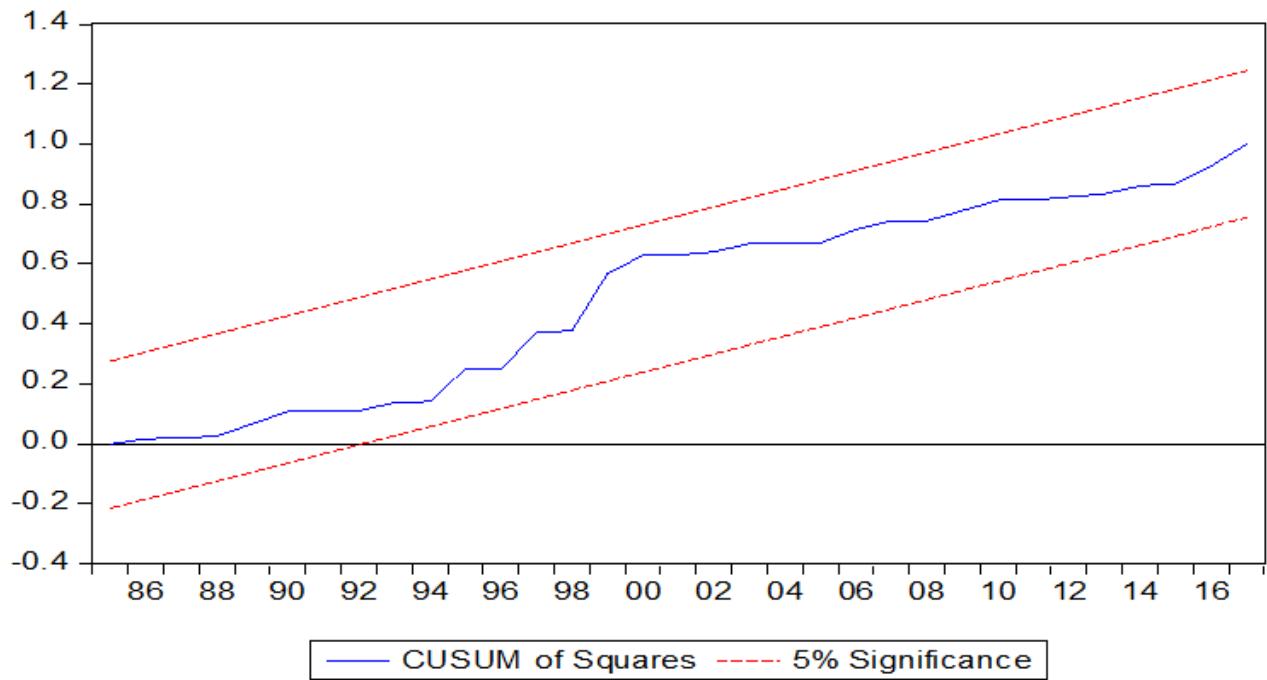
	F-statistic	Probability
Heteroskedasticity	1.840	0.1322
Serial correlation	0.392	0.6142
Normality	0.137	0.9334

The results from Table 7 establishes that null hypothesis of no autocorrelation, homoskedasticity, and normality of residuals distribution cannot be rejected. For this reason, it is resolved that the model passed the diagnostic test.



**Figure-1.** Cumulative sum

Note: The straight lines represent critical bounds at the 5% significance level.



**Figure-2.** Cumulative sum of squares

Note: The straight lines represent critical bounds at the 5% significance level.

## 5. CONCLUSION

The dependence on fossil fuel energy sources and the environmental consequences of fossil usage have brought attention by both policymakers and the general public for the need to develop a more sustainable energy

consumption mix. This study investigates energy consumption and environmental pollution in Malaysia. However, unit root test shows that the variables are integrated at the level and order one and the bound test prove no long-run relationship amongst the variables, this permit to employed ARDL and ECT.

The findings show that energy consumption as a result of economic growth, and population growth causes environmental pollution in the short and long run. Hence, government expenditure to curtail the pollution need to be improved. In addition, friendly energy use is not sufficient to solve the problem in the short and long run. Further, the economy base on error correction term is robust to adjust itself to equilibrium when there is a deviation. This study confirmed the validity of the pollution haven hypothesis.

Finally, though renewable energy consumption has increased, Malaysia is diversifying on energy sources. It is critical for the development of a sustainable energy consumption mix for policymakers to recognize that policy initiatives must focus on cost effective renewable energy sources and technologies that can effectively compete with fossil fuel based energy sources.

**Funding:** This study received no specific financial support.

**Competing Interests:** The authors declare that they have no competing interests.

**Contributors/Acknowledgement:** Both authors contributed equally to the conception and design of the study.

## REFERENCES

- Al-Mulali, U., B. Saboori and I. Ozturk, 2015. Investigating the environmental Kuznets curve hypothesis in Vietnam. *Energy Policy*, 76: 123-131. Available at: <https://doi.org/10.1016/j.enpol.2014.11.019>.
- Alam, M.J., I.A. Begum, J. Buysse, S. Rahman and G. Van Huylenbroeck, 2011. Dynamic modeling of causal relationship between energy consumption, CO<sub>2</sub> emissions and economic growth in India. *Renewable and Sustainable Energy Reviews*, 15(6): 3243-3251. Available at: <https://doi.org/10.1016/j.rser.2011.04.029>.
- Ang, J.B., 2007. CO<sub>2</sub> emissions, energy consumption, and output in France. *Energy Policy*, 35(10): 4772-4778. Available at: <https://doi.org/10.1016/j.enpol.2007.03.032>.
- Antonakakis, N., I. Chatziantoniou and G. Filis, 2017. Energy consumption, CO<sub>2</sub> emissions and economic growth: An ethical dilemma. *Renewable & Sustainable Energy Reviews*, 68(Part 1): 808-824. Available at: <https://doi.org/10.1016/j.rser.2016.09.105>.
- Apergis, N. and I. Ozturk, 2014. Testing environmental Kuznets curve hypothesis in Asian countries. *Ecological Indicators*, 52: 16-22. Available at: <https://doi.org/10.1016/j.ecolind.2014.11.026>.
- Asghari, M., 2013. Does FDI promote MENA region's environment quality? Pollution halo or pollution haven hypothesis. *International Journal of Scientific Research in Environmental Sciences*, 1(6): 92-100. Available at: <https://doi.org/10.12983/ijrsres-2013-p092-100>.
- Atici, C., 2012. Carbon emissions, trade liberalization, and the Japan-ASEAN interaction: A group-wise examination. *Journal of the Japanese and International Economies*, 26(1): 167-178. Available at: <https://doi.org/10.1016/j.jjie.2011.07.006>.
- Begum, R.A., K. Sohag, S.M.S. Abdullah and M. Jaafar, 2015. CO<sub>2</sub> emissions, energy consumption, economic and population growth in Malaysia. *Renewable and Sustainable Energy Reviews*, 41(C): 594-601.
- Behera, S.R. and D.P. Dash, 2017. The effect of urbanization, energy consumption, and foreign direct investment on the carbon dioxide emission in the SSEA (South and Southeast Asian) region. *Renewable and Sustainable Energy Reviews*, 70(C): 96-106. Available at: <https://doi.org/10.1016/j.rser.2016.11.201>.
- Brown, R., J. Durbin and J. Evans, 1975. Techniques for testing the constancy of regression relationships over time. *Journal of the Royal Statistical Society. Series B (Methodological)*, 37(2): 149-192. Available at: <https://doi.org/10.2307/2986299>.
- Dasgupta, S., B. Laplante, H. Wang and D. Wheeler, 2002. Confronting the environmental Kuznets curve. *Journal of Economic Perspectives*, 16(1): 147-168. Available at: <https://doi.org/10.1257/0895330027157>.

- Dean, J.M., 2004. Trade and the environment: A survey of the literature. Policy Research Working Paper, 68: 103-116.
- Dickey, D.A. and W.A. Fuller, 1979. Distribution of the estimators for autoregressive time series with a unit root. Journal of the American Statistical Association, 74(366a): 427-431.
- Dinda, S., 2004. Environmental Kuznets curve hypothesis: A survey. Ecological Economics, 49(4): 431-455. Available at: <https://doi.org/10.1016/j.ecolecon.2004.02.011>.
- Du, L., C. Wei and S. Cai, 2012. Economic development and carbon dioxide emissions in China: Provincial panel data analysis. China Economic Review, 23(2): 371-384. Available at: <https://doi.org/10.1016/j.chieco.2012.02.004>.
- Fawcett, T. and Y. Parag, 2017. An introduction to personal carbon trading. In Personal Carbon Trading, 10(4): 329-338.
- IPCC, 2013. Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Paris.
- Jalil, A. and M. Feridun, 2011. The impact of growth, energy and financial development on the environment in China: A cointegration analysis. Energy Economics, 33(2): 284-291. Available at: <https://doi.org/10.1016/j.eneco.2010.10.003>.
- Jaunkly, V.C., 2011. The CO<sub>2</sub> emissions-income nexus: Evidence from rich countries. Energy Policy, 39(3): 1228-1240. Available at: <https://doi.org/10.1016/j.enpol.2010.11.050>.
- Johansen, S., 1988. Statistical analysis of cointegration vectors. Journal of Economic Dynamics and Control, 12(2-3): 231-254. Available at: [https://doi.org/10.1016/0165-1889\(88\)90041-3](https://doi.org/10.1016/0165-1889(88)90041-3).
- Johansen, S., 1991. Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. Econometrica, 59(6): 1551-1580. Available at: <https://doi.org/10.2307/2938278>.
- Johansen, S., 1992. Determination of cointegration rank in the presence of a linear trend. Oxford Bulletin of Economics and Statistics, 54(3): 383-397. Available at: <https://doi.org/10.1111/j.1468-0084.1992.tb00008.x>.
- Johansen, S. and K. Juselius, 1990. Maximum likelihood estimation and inference on cointegration—with applications to the demand for money. Oxford Bulletin of Economics and Statistics, 52(2): 169-210. Available at: <https://doi.org/10.1111/j.1468-0084.1990.mp52002003.x>.
- Kasman, A. and Y. Duman, 2015. CO<sub>2</sub> emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: A panel data analysis. Economic Modelling, 44(C): 97-103. Available at: <https://doi.org/10.1016/j.econmod.2014.10.022>.
- Koçak, E. and A. Şarkgüneş, 2017. The renewable energy and economic growth nexus in black sea and Balkan countries. Energy Policy, 100(C): 51-57. Available at: <https://doi.org/10.1016/j.enpol.2016.10.007>.
- Lee, C.-C. and C.-P. Chang, 2008. Energy consumption and economic growth in Asian economies: A more comprehensive analysis using panel data. Resource and Energy Economics, 30(1): 50-65. Available at: <https://doi.org/10.1016/j.reseneeco.2007.03.003>.
- Maddala, G.S. and I.M. Kim, 1998. Unit roots, cointegration, and structural change (No. 4). Cambridge University Press.
- Mousavi, B., N.S.A. Lopez, J.B.M. Biona, A.S. Chiu and M. Blesl, 2017. Driving forces of Iran's CO<sub>2</sub> emissions from energy consumption: An LMDI decomposition approach. Applied Energy, 206(C): 804-814. Available at: <https://doi.org/10.1016/j.apenergy.2017.08.199>.
- Narayan, P.K. and S. Narayan, 2010. Carbon dioxide emissions and economic growth: Panel data evidence from developing countries. Energy Policy, 38(1): 661-666. Available at: <https://doi.org/10.1016/j.enpol.2009.09.005>.
- Narayan, P.K. and R. Smyth, 2005. Electricity consumption, employment and real income in Australia evidence from multivariate Granger causality tests. Energy Policy, 33(9): 1109-1116. Available at: <https://doi.org/10.1016/j.enpol.2003.11.010>.
- Nasir, M. and F.U. Rehman, 2011. Environmental Kuznets curve for carbon emissions in Pakistan: An empirical investigation. Energy Policy, 39(3): 1857-1864. Available at: <https://doi.org/10.1016/j.enpol.2011.01.025>.
- Nejat, P., F. Jomehzadeh, M.M. Taheri, M. Gohari, A. Majid and M. Zaimi, 2015. A global review of energy consumption, CO<sub>2</sub> emissions and policy in the residential sector (with an overview of the top ten CO<sub>2</sub> emitting countries). Renewable and Sustainable Energy Reviews, 43(C): 843-862. Available at: <https://doi.org/10.1016/j.rser.2014.11.066>.

- Ottelin, J., J. Heinonen and S. Junnila, 2018. Carbon and material footprints of a welfare state: Why and how governments should enhance green investments. *Environmental Science and Policy*, 86: 1-10. Available at: <https://doi.org/10.1016/j.envsci.2018.04.011>.
- Ozturk, I. and A. Acaravci, 2010. CO<sub>2</sub> emissions, energy consumption and economic growth in Turkey. *Renewable and Sustainable Energy Reviews*, 14(9): 3220-3225. Available at: <https://doi.org/10.1016/j.rser.2010.07.005>.
- Ozturk, I., A. Aslan and H. Kalyoncu, 2010. Energy consumption and economic growth relationship: Evidence from panel data for low and middle income countries. *Energy Policy*, 38(8): 4422-4428. Available at: <https://doi.org/10.1016/j.enpol.2010.03.071>.
- Panayotou, T., 2016. Economic growth and the environment. *The Environment in Anthropology*, 3(8): 140-148.
- Perkins, R. and E. Neumayer, 2009. Transnational linkages and the spillover of environment-efficiency into developing countries. *Global Environmental Change*, 19(3): 375-383. Available at: <https://doi.org/10.1016/j.gloenvcha.2009.05.003>.
- Pesaran, H.M. and B. Pesaran, 1997. Microfit 4.0. Oxford: Oxford University Press.
- Pesaran, M.H., Y. Shin and R.J. Smith, 2001. Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(3): 289-326. Available at: <https://doi.org/10.1002/jae.616>.
- Phillips, P.C. and P. Perron, 1988. Testing for a unit root in time series regression. *Biometrika*, 75(2): 335-346. Available at: <https://doi.org/10.2307/2336182>.
- Riahi, K., D.P. van Vuuren, E. Kriegler, J. Edmonds, B.C. O'Neill, S. Fujimori, N. Bauer, K. Calvin, R. Dellink, O. Fricko and W. Lutz, 2017. The shared socioeconomic pathways and their energy, land use, and greenhouse gas emissions implications: An overview. *Global Environmental Change*, 42: 153-168.
- Shiu, A. and P.-L. Lam, 2004. Electricity consumption and economic growth in China. *Energy Policy*, 32(1): 47-54. Available at: [https://doi.org/10.1016/s0301-4215\(02\)00250-1](https://doi.org/10.1016/s0301-4215(02)00250-1).
- Solarin, S.A., U. Al-Mulali, I. Musah and I. Ozturk, 2017. Investigating the pollution haven hypothesis in Ghana: An empirical investigation. *Energy*, 124(C): 706-719. Available at: <https://doi.org/10.1016/j.energy.2017.02.089>.
- Soytas, U. and R. Sari, 2009. Energy consumption, economic growth, and carbon emissions: Challenges faced by an EU candidate member. *Ecological Economics*, 68(6): 1667-1675. Available at: <https://doi.org/10.1016/j.ecolecon.2007.06.014>.
- Soytas, U., R. Sari and B.T. Ewing, 2007. Energy consumption, income, and carbon emissions in the United States. *Ecological Economics*, 62(3-4): 482-489. Available at: <https://doi.org/10.1016/j.ecolecon.2006.07.009>.
- Sun, C., F. Zhang and M. Xu, 2017. Investigation of pollution haven hypothesis for China: An ARDL approach with breakpoint unit root tests. *Journal of Cleaner Production*, 161: 153-164. Available at: <https://doi.org/10.1016/j.jclepro.2017.05.119>.
- Tang, C.F. and B.W. Tan, 2015. The impact of energy consumption, income and foreign direct investment on carbon dioxide emissions in Vietnam. *Energy*, 79(C): 447-454. Available at: <https://doi.org/10.1016/j.energy.2014.11.033>.
- UNCC, 2015. United nations framework convention on climate change. 12 December 2015.
- Wang, C., F. Wang, X. Zhang, Y. Yang, Y. Su, Y. Ye and H. Zhang, 2017. Examining the driving factors of energy related carbon emissions using the extended STIRPAT model based on IPAT identity in Xinjiang. *Renewable and Sustainable Energy Reviews*, 67(C): 51-61. Available at: <https://doi.org/10.1016/j.rser.2016.09.006>.
- WDI, 2018. World development indicators databank. Available from <https://databank.worldbank.org/data/reports.aspx>.
- Yeh, J.-C. and C.-H. Liao, 2017. Impact of population and economic growth on carbon emissions in Taiwan using an analytic tool STIRPAT. *Sustainable Environment Research*, 27(1): 41-48. Available at: <https://doi.org/10.1016/j.serj.2016.10.001>.
- Zakarya, G.Y., B. Mostefa, S.M. Abbes and G.M. Seghir, 2015. Factors affecting CO<sub>2</sub> emissions in the BRICS countries: A panel data analysis. *Procedia Economics and Finance*, 26: 114-125. Available at: [https://doi.org/10.1016/s2212-5671\(15\)00890-4](https://doi.org/10.1016/s2212-5671(15)00890-4).

- Zhang, C. and X. Zhou, 2016. Does foreign direct investment lead to lower CO<sub>2</sub> emissions? Evidence from a regional analysis in China. *Renewable and Sustainable Energy Reviews*, 58: 943-951. Available at: <https://doi.org/10.1016/j.rser.2015.12.226>.
- Zhang, Q., S. Zhang, Z. Ding and Y. Hao, 2017. Does government expenditure affect environmental quality? Empirical evidence using Chinese city-level data. *Journal of Cleaner Production*, 161: 143e152. Available at: <https://doi.org/10.1016/j.jclepro.2017.05.096>.
- Zhang, X.-P. and X.-M. Cheng, 2009. Energy consumption, carbon emissions, and economic growth in China. *Ecological Economics*, 68(10): 2706-2712. Available at: <https://doi.org/10.1016/j.ecolecon.2009.05.011>.
- Zhu, H., L. Duan, Y. Guo and K. Yu, 2016. The effects of FDI, economic growth and energy consumption on carbon emissions in ASEAN-5: Evidence from panel quantile regression. *Economic Modelling*, 58(C): 237-248. Available at: <https://doi.org/10.1016/j.econmod.2016.05.003>.

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