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The Role of Renewable, Non-renewable Energy Consumption and Technology Innovation in Testing Environmental Kuznets Curve in Malaysia

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ABSTRACT

This current paper investigates the role of renewable energy, non-renewable energy and technology innovation in testing the environmental Kuznets Curve in Malaysia by using the annual data over the time from 1980 to 2017. We applied the advance econometrics to serve the purpose of investigation and therefore used the auto regressive distributed lags (ARDLs) bound testing approach for assessing the presence of long-run relationship between the variables. The results of ARDL bound testing approach confirm the valid long run relationship between renewable energy, non-renewable energy, technology innovation and economic growth with carbon dioxide emission in Malaysia. The empirical results indicate that renewable energy consumption and technology innovation have significant and negative impact on carbon dioxide emission whereas, the non-renewable energy consumption and economic growth have a significant and positive impact on carbon dioxide emission. Furthermore, results also confirm the existence of inverted U-shape curve in Malaysia.

Keywords: Sustainable Energy, Green Technology, Renewable Energy, Technological Innovation, Environmental Kuznets Curve, Malaysia
JEL Classifications: Q20, Q56, O31

1. INTRODUCTION

The rising change in the climate condition has increased the concerns of people all around the globe as it entails the tendency to influence human, social and economic development of the countries. The orthodox practices of certain businesses are also a contributing factor of witnessing increasing environmental degradation (Jebli and Youssef, 2015). On the other hand, energy is considered as a vital element of economic progress by being a critical catalyst of economic activities (Shahbaz et al., 2018). However, the excessive dependence of economies on fossil fuels and other non-renewable sources of energy has enhanced the adversity of the existing climate situation. In addition, the harmful emissions from industrial processes not only increases the level of pollution but also cause permanent damages to the atmospheric condition.

As a result, economies have started to give the supreme attention to the notion of sustainability in ensuring economic development. In this regard, the conception of non-renewable sources of energy play a substantial role in curtailing the negative effects of environmental degradation. Non-renewable energy is defined as the form of energy that is obtained from environmental friendly sources and bring minimum damage to the environment (Kobayashi et al., 2013; Apergis and Payne, 2014; Henry, 2014; Ekpung, 2014; Zomorrodi and Zhou, 2016; Danbaba et al., 2016; Zomorrodi and Zhou, 2017; Chen et al., 2018). These include the energy attained from sources such as solar, wind, bio-fuels etc. In addition, the progressions in energy efficiencies alongside the advancement of green sources of energy are also recognized as the highly effective way of abridging the decline in environmental condition and achieving sustainable growth. Therefore, on the macro-economic level, in order to curtail the adverse changes in the ecological condition, countries from various parts of the world are striving hard to convert their carbon intensive brown economy to the eco-friendly green economy.

In the process of becoming green economy, the importance of technological innovation cannot ignored. With the rapid advancements in information and communication technologies, the concept of green innovation is considered crucial in ensuring sustainable development. Acknowledging the hostile effects of carbon emissions on the environment (Chidoko, 2014; Gideon, 2014; Luong et al., 2017; Zhang, 2017; Al-Fatlawi, 2018; Fernández et al., 2018) and the similar harmful emissions, countries have diverted their concentration towards innovative types of business operations that can abridge the negative impact on such emissions on ecological deterioration as well as brings the profitability and improved effectiveness. In this regard, the contribution of innovation is considered exceptionally by the researchers, financial specialists and government organizations. The focus is to ensure the sustainable solutions by complimenting the business missions with environmental sustainability (Adebambo et al., 2014; Ekpung, 2014; Chidoko, 2014; Zhang et al., 2017; Wireko-Manu and Amamoo, 2017; Zhu and Chen, 2018; Anowor and Nwanji, 2018). Therefore, the organizations in present times are more engaged in improving the capabilities of workforce, encouraging knowledge sharing culture, green organizational practices and augmented co-ordination among businesses and governments to adjust, nurture and improve the innovative methods for industry functioning that equate the objective of sustainable progress. For that reason, the focal point of countries is redirected towards using dynamic strategies and inventive machineries that conforms to the objective of green economy.

In the domain of environmental degradation, the framework of environmental Kuznets curve (EKC) is renowned to measure the impact of economic development on environment. Over the years, many studies have examined the validity of EKC curve with the inclusion of numerous variables including trade (Cole, 2004), financial development (Javid and Sharif, 2016), inequality (Torras and Boyce, 1998), de-forestation (Ehrhardt-Martinez et al., 2002) and tourism (Ozturk et al., 2016). Recognizing the critical role of energy in environment, many studies have started to analyze the inclusion of energy consumption (Jebli et al., 2016; Dogan and Seker, 2016; Jebli and Youssef, 2015; Jabarullah et al., 2015) followed by the more recent emphasis in identifying the contribution of non-renewable energy consumption in influencing environmental degradation (Dong et al., 2018; Liu et al., 2017; Zoundi, 2017). In recent literature, very few studies have also included the vital role of innovation in examining EKC hypothesis (Fernández et al., 2018; Zhang et al., 2017). However, to the best of our knowledge, none of the existing studies have analyzed the role of renewable and non-renewable energies along with innovation in investigating EKC approach, especially in developing countries including Malaysia.

In compliance, the objective of the present study is to investigate the crucial relationship of renewable energy consumption, non-renewable energy consumption and innovation with environmental degradation measured by carbon emission in Malaysia. In addition, a general observation of the innovation literature has witnessed the excessive use of investments in research and development as the indicator of innovation (Álvarez-Herránz et al., 2017; Kang and Hwang, 2016; Baiardi, 2014). The uniqueness of the present study also lies in the distinctive examination of innovation in EKC by utilizing the novel measure of high technology exports as an indicator of innovation. In addition, the present study is also inventive in applying the refined methodology of auto regressive distributed lag (ARDL) as opposed to depending on the conventional procedures, such as the traditional OLS methodology (Qazi et al., 2017a and b).

2. LITERATURE REVIEW

The studies examining the connection between renewable and non-renewable sources of energies with economic development can be seen extensively in literature. In recent time, the association of green and non-green energy consumption in discussing environmental degradation, have started to capture the attention of researcher (Jebli et al., 2016; Dogan and Seker, 2016; Jebli and Youssef, 2015). However, the review of literature in this regard, beheld a highly scant literature that investigate the role of innovation along with green and non-green energies in EKC (Álvarez-Herránz et al., 2017; Jabarullah et al., 2017).

In European region, Al-Mulali et al. (2015) examined the impact of economic development and renewable production on the pollution of twenty-three European countries. The study utilized data from the period of 1990 to 2013. In order to measure pollution, the authors utilized the proxy of carbon-di-oxide emissions of the sampled countries. The outcome of the empirical analysis applying the Pedroni co-integration concluded that all the three variables are co-integrated by source. Furthermore, the results of FMOLS revealed that the level of economic development enhanced carbon emissions, however, renewable production have the tendency to reduce carbon emissions in long run. In order to check the causal effects, the study applied vector error correction model (ECM) granger causality, which indicated that economic growth have causal connection with carbon emission however, renewables production has failed to show the causal effects on the level of carbon emission in majority of the analyzed models. As for the Group of Seven (G-7) countries, Ajmi et al. (2015) investigated the association among energy consumption and carbon emission. The findings of the causal effects from the time varying granger causality suggested the presence of uni-directional causality from power consumption to carbon emissions in France, however, for united states, the results confirmed the existence of feedback effect between energy consumption and carbon emission. As in Vietnam, Tang and Tan (2015) analyzed the relationship between energy usage and carbon-di-oxide emission in between 1976 and 2009. The study applied Granger causality to identify the presence of causal effect among the variables. The findings of the investigation established the existence of uni-directional causality running from energy to carbon emissions in the country.

In a group of nineteen emerging and developed economies, Menyah and Rufael (2010) investigated the causal effect of renewable energy consumption on carbon emissions. The study utilized the data from the period of 1984 to 2007. The empirical findings of the study concluded that in Long-run, renewable energy consumption has found to exert a significant positive effect on CO_2 emissions. However, in short run, the study failed to find any relationship between renewable energy and carbon emission. For new EU member countries, Alper and Oguz (2016) investigated the presence of asymmetric causality between renewable and economic development during the period of 1990–2009. In order to find the long term relationship, the authors also applied ARDL analysis that established that the levels of renewable energy consumption have significant positive impact on economic development of Estonia, Slovenia, Poland and Bulgaria. On the other hand, the causal investigation performed in the study showed mixed results. The findings of Bulgaria supported the presence of uni-directional causality running from renewables from GDP, however the opposite is found in the case of Czech Republic suggesting that the direction of causal effects run from GDP to renewables. Furthermore, the results from asymmetric causality conclude the absence of causal connections between renewable energy consumption and economic development in the countries of Cyprus, Slovenia, Hungary, Estonia and Poland.

Utilizing the non-stationary Panel analysis, Al-Mulali et al. (2016) examined the inclusion of renewable energy in the EKC Framework using annual data from 1980 to 2010. The authors measure environmental degradation in terms of carbon emission in the selected seven regions of the world. The study applied the techniques of DOLS to measure long-term association among the variables. The findings of the study confirmed the presence of the long-run negative influence of renewable consumption on environmental degradation in the regions of Central and Eastern Europe, Americas, East Asia and Pacific, Western Europe and South Asia. However, the study failed the association between renewables and environmental degradation in Sub-Saharan Africa and Middle East and North Africa. Similarly, Dogan and Seker (2016) also analyzed the contribution of economic growth, renewable consumption and non-renewable consumption on the environmental degradation of fifteen European countries. The study utilized data from the period of 1980 to 2012. In order to measure environmental degradation, the authors utilized the proxy of carbon-di-oxide emissions of the sampled countries. The outcome of the empirical analysis applying the Panel dynamic ordinary least squares concluded that non-renewable energy consumption increases environmental degradation. On the other hand, the results confirmed the significant negative association of renewable consumption with carbon emission. In order to check the causal effects the study applied Dumitrescu-Hurlin non-causality techniques (Ali et al., 2018). The results of causality supported the presence of the uni-directional causal association between non-renewable energy and environmental degradation, where the direction of causality runs from carbon emission to the energy consumption through non-renewables. Furthermore, the results also concluded the presence of bi-directional causality between renewable energy consumption and environmental degradation (Abidin et al., 2015; Haseeb and Azam, 2015; Haseeb et al., 2014).

Furthermore, For United States, Menyah and Rufael (2010) investigated the relationship among renewable energy consumption and carbon emission utilizing the annual data from the period of 1960 to 2007. Similar to Tang and Tan (2015), the authors also applied Granger causality to identify the existence of causal connections among the variables. However, the study failed to find the presence of any causal connections between renewables energy and carbon emissions. The results therefore suggested that renewable consumption has not touched a level where it could create an essential reduction in carbon emission of the country. Similarly, Soytas et al. (2007) also analyze the state of carbon emission in United States. The authors examined the association among energy consumption and carbon emission utilizing the annual data from the period of 1960 to 2004 of the country. Similar to Menyah and Rufael (2010), the study applied granger causality to assess the causal effects among the variables. However, the results of the study, unlike to Menyah and Rufael (2010) established the presence of unidirectional association among energy consumption and carbon emissions. Furthermore, the direction of the causality is found to run from energy consumption to carbon emission in Unites States. More recently, Fernández et al. (2018) also inspect the influence of innovations measured by research and development on environmental degradation. The study utilized the measures of carbon emission to reflect environmental degradation in a sample of seventeen countries from the period of 1990 to 2013. The empirical investigations of the study is carried out by applying the technique of Ordinary Least Square in the panel estimation. The results of the study conclude that investments in research and development reduce the effects of carbon emission and is considered crucial for curtailing the adverse effects on the climate (Abidin et al., 2014; Haseeb et al., 2014; Haseeb et al., 2017).

For Central America, Apergis and Payne (2015) inspected the relationship between renewable, GDP per capita and carbon-di-oxide emissions. In order to assess the long-run association, the study used the data of the seven Central American countries from the period of 1980 to 2010. Similar to Apergis and Payne (2014), the results of the study established the long-run association between renewable energy, economic growth and carbon emissions in the sampled countries. Likewise, Bilgili et al. (2016) also analyzed the inclusion of renewable energy consumption in the EKC framework. In doing so, the authors used the data from the period of 1977 to 2010 for a sample of seventeen OECD countries. The empirical investigations employing the econometrics of DOLS and FMOLS suggested that renewable energy consumption reduces the environmental degradation in long-run. Similarly, In Turkey, Bölük and Mert (2015) also investigated the inclusion of renewables in the conventional EKC methodology. Using the data from the period of 1961 to 2010, the study aimed to find the relationship of economic growth and renewable electricity consumption with carbon emission. The study applied the technique of ARDL to investigate the long-run association among the studied variables. The results of the empirical investigations confirmed the existence of the U-shaped association between economic growth and environmental degradation reflected by carbon emissions. Moreover, the study also concluded the negative influence of renewable consumption with environmental degradation of Turkey.

Studying the role of innovation in EKC framework, Álvarez-Herránz et al. (2017) investigate the connection between innovations and environmental degradation. The investigation tests the EKC in twenty-eight OECD nations and utilized yearly data from 1990 to 2004. Using the measure of research development and demonstration to reflect level of innovation and green house gas emissions as environmental degradation, the findings of the study aim to reflect how energy innovation contributes to reducing energy intensity and environmental pollution. However, the empirical results conclude that energy efficient technology has insignificant effects in improving environmental quality. Applying the similar methods, Andreoni and Levinson (1998) also inspec the association between innovations in technologies, energy consumptions, growth and environmental degradation depends on the technical effect. The study thus suggested that expanded interest in innovation helps in diminishing level of contaminations in atmosphere. Furthermore, the study recommended that more elevated amount of investment in economies brought about higher energy utilization and decreases the level of degradation through the level of innovations (Abidin and Haseeb, 2015; 2018; Azam et al., 2016; Azam et al., 2016).

Similarly, Apergis and Payne (2014) also examined the association between economic growth, renewable energy and carbon emission. The study utilized data from the period of 1980 to 2011 for a panel of twenty five OECD economies. The empirical results supported the presence of the long-run association between renewables, economic development and carbon emission of the sampled countries. Furthermore, the results also concluded the presence of bi-directional causality among the studied variables. In Tunisia, Jebli and Youssef (2015) examined the EKC framework by including the variables of renewable and non-renewable energy consumption. The study utilized data from the period of 1980 to 2009. In order to measure environmental degradation, the authors utilized the proxy of carbon-di-oxide emissions of the Tunisia. The outcome of the empirical analysis applying the ARDL bounds testing approach concluded that non-renewable energy consumption increased carbon emission. On the other hand, the results confirmed the significant negative association of renewable consumption with environmental degradation reflected from carbon emission of the country (Jabarullah et al., 2014; Othman et al., 2017).

In another panel investigation, Zhang et al. (2017) discover the influence of innovation in affecting environmental degradation. In doing so, the authors utilized the data from the period of 2000 to 2013 in thirty provinces of China. The study applied the empirical technique of SGMM methodology to explore the effect of technological innovation in reducing environmental degradation in the provinces of China. The outcomes of the investigation suggested that innovation is substantial in decreasing the negative effects of carbon emissions in the environment and therefore recommend the policymakers should considered innovations as the efficient tool of minimizing environmental degradation. In a panel investigation of thirty eight countries, Bhattacharya et al. (2016) inspected the relationship between renewable consumption and economic development. Utilizing the data from the period of 1991 to 2012, the study confirmed the presence of cross-sectional dependency and heterogeneity among the sample. In addition, the empirical investigation of the study concluded that renewable energy consumption exert a significant positive influence on the development of fifty seven percent of the sampled economies.

In OECD region, Jebli et al. (2016) examine the relationship of economic development and renewable consumption and non-renewable consumption in influencing environmental degradation of twenty five OECD countries. The study utilized data from the period of 1980 to 2010. In order to measure environmental degradation, the authors utilized the proxy of carbon-di-oxide emissions of the sampled countries. The outcome of the empirical analysis applying the DOLS and FMOLS revealed that the validity of U-shaped curve. Furthermore, the results established that non-renewable energy consumption enhanced carbon emissions, however, renewable energy have the tendency to reduce carbon emissions in long run. The findings of long-run Granger causality indicated the feedback effects of renewables energy, non-renewable energy and economic growth with carbon-di-oxide emission in the studied countries. In a panel investigation of European countries, Bölük and Mert (2014) investigate the role of fossil fuel and renewable energy consumption in influencing environmental degradation of sixteen European countries. The study utilized data from the period of 1990 to 2008. In order to measure environmental degradation, the authors utilized the proxy of carbon-di-oxide emissions of the sampled countries. The outcome of the empirical analysis failed to find the presence of the inverted U-shaped curve. However, the study concludes the presence of a negative significant relationship between renewable energy and carbon-di-oxide emission suggesting that increasing level of renewables sources of energy underlie the tendency to curtail the adverse effects of carbon emission on the environment.

Therefore, the majority of the existing studies focus on the panel estimations forming the need of performing the time series analysis to overcome the gap of country specific analysis with improved methodology. In addition, the inclusion of innovation utilizing the measures of high technology export, despite of the conventional proxy of research and development, has also strengthen the uniqueness of the current study and therefore enhanced its contribution.

3. METHODOLOGY

The present study examines the connection between carbon dioxide emission, economic growth, innovation, renewable and non-renewable energy by using EKC model and the framework is given below:

$$CE=\beta_0+\beta_1(Y)+\beta_2(Y^2)+\beta_3(RENE)+\beta_4(ENC)+\beta_5(INO)+\varepsilon_t$$

Where, ε_t is the error term, Y represents the economic growth which is calculated by the total finished goods and services (in Local Currency Unit, LCU), Y^2 is the square of economic growth, *RENE* explains the renewable energy consumption which is explained by portion of renewable energy consumption out of total energy consumption (in Local Currency Unit), *ENC* represents total energy consumption which is calculated in LCU. High technology exports are used as a proxy of innovation and it is also in the form of LCU. However, *CE* represents the carbon dioxide emission which is measured in metric kilotons. The data is collected from the period of 1980 to 2017. All data are gathered from World Development Indicators (World Bank).

3.1. Stationarity Approaches

In order to check the stationary features for long-term linking of considered time series data, the current study apply Augmented Dickey-Fuller (ADF) and Philip Perron (PP) unit root tests. We examine the data initially on level and then on first differential series (Hussain et al., 2018; Abdul et al., 2018).

3.2. Long Run Co-integration Analysis

In order to inspect the role of renewable, non-renewable energy consumption and technology innovation in EKC in Malaysia, we consider the ARDL technique of long run relationship which was proposed by Pesaran et al. (2001; 2000), Pesaran and Shin (1999), Pesaran and Pesaran (1997) is utilized with the support of unobstructed vector error correction framework to examine the long-term association among social Islamic finance and economic development. The ARDL method has several benefits on former long run relationship analyses (like J.J Cointegration and others). The ARDL method could be useful nevertheless of whether considered series are completely *I(0)*, *I(1)* or equally co-integrated.[1] The ARDL framework is proposed for above examination is as follow:

$$
CE = \begin{aligned}
&\varphi_0 + \varphi_1 \sum_{i=1}^{p} \mathrm{CE}_{t-1} + \varphi_2 \sum_{i=1}^{p} \mathrm{Y}_{t-1} + \varphi_3 \sum_{i=1}^{p} \mathrm{Y}^2_{t-1} + \\
&\varphi_4 \sum_{i=1}^{p} \mathrm{RENE}_{t-1} + \varphi_5 \sum_{i=1}^{p} \mathrm{ENC}_{t-1} + \\
&\varphi_6 \sum_{i=1}^{p} \mathrm{INO}_{t-1} + \gamma_1 \mathrm{CE}_{t-1} + \gamma_2 \mathrm{Y}_{t-1} + \gamma_3 Y^2_{t-1} + \\
&\gamma_4 RENE_{t-1} + \gamma_5 ENC_{t-1} + \gamma_6 INO_{t-1} + \mu_t
\end{aligned}
$$

Where, φ_0 is constant term and μ_t is white noise error term, the error correction boundary is represented by the sign of summation whereas the other measure of the equation relates to long-term connection. The Schwarz Bayesian criteria (SBC) is utilized to examine the maximum lag length selection for each variable. In ARDL method, initially the current study calculates the *F*-statistics significance by applying the suitable ARDL frameworks. Next, the Wald (*F*-stats) test is applied to study the long-term association among the variables. If long-term bonding between carbon dioxide emission, RENE, ENC, Y and INO are established, then the present study calculated the long run parameter measurements by using following model.

$$
\mathrm{CE}_t = \begin{aligned}
&\zeta_0 + \zeta_1 \sum_{i=1}^{p} \mathrm{CE}_{t-1} + \zeta_2 \sum_{i=1}^{p} \mathrm{Y}_{t-1} + \zeta_3 \sum_{i=1}^{p} \mathrm{Y}^2_{t-1} + \\
&\zeta_4 \sum_{i=1}^{p} \mathrm{RENE}_{t-1} + \zeta_5 \sum_{i=1}^{p} \mathrm{ENC}_{t-1} + \\
&\zeta_6 \sum_{i=1}^{p} \mathrm{INO}_{t-1} + \mu_t
\end{aligned}
$$

If the long-term connection among CO_2, RENE, ENC, Y and INO are presented with indication then we calculate the beta value of the short run coefficients by utilizing the below equation:

$$
CE_t = \begin{aligned}
&\delta_0 + \delta_1 \sum_{i=1}^{p} \mathrm{CE}_{t-1} + \delta_2 \sum_{i=1}^{p} \mathrm{Y}_{t-1} + \delta_3 \sum_{i=1}^{p} \mathrm{Y}^2_{t-1} + \\
&\delta_4 \sum_{i=1}^{p} \mathrm{RENE}_{t-1} + \delta_5 \sum_{i=1}^{p} \mathrm{ENC}_{t-1} + \\
&\delta_6 \sum_{i=1}^{p} \mathrm{INO}_{t-1} + n\mathrm{ECT}_{t-1} + \mu_t
\end{aligned}
$$

The ECM show the speed of adjustment allow to measure the long-run symmetry due to a short-term fluctuation (Shawtari et al., 2016). The *n* is the value of ECT in the framework that explain the speed of change.

3.3. Variance Decomposition Method (VDM)

Generalized forecast error variance decomposition approach is applied under vector autoregressive (VAR) system to investigate the causal relationship between RENE, CO_2, ENC, Y and INO. The VDM gives the scale of the forecasted error variance for a data responsible for novelties by every predictor over various time domain (Sharif and Raza, 2016; Sharif et al., 2018; Sharif et al., 2017).

4. DATA ANALYSIS AND DISCUSSION

The current section discusses about the data analysis. Primarily, we used stationary test to confirm the stationary property of the considered variables. The results of unit root test are reported in Table 1. We utilized two-unit root tests namely ADF and PP test to check the stationary properties of the variables. The findings confirm that CO_2, RENE, ENC, Y and INO initially are not stationary at level and becomes stationary at first differential series. In simple words, from the outcomes of unit root test, we can conclude that series of all the variables reflect the stationary properties and allow for proceeding towards the long run estimations (Zainudin et al., 2017).

Furthermore, to study the long-term connection between CO_2, RENE, ENC, Y and INO in Malaysia, the current study applied the technique of (ARDL). In doing so, the first stage is to identify the optimum lag-length of the all the variables. The sequence of this optimum lag-length is chosen by taking criteria of SBC. Therefore, the outcome of the ARDL long-term relationship results are displayed in Table 2.

The results of Table 2 confirm the null hypothesis claiming that not cointegration between the variables is rejected. This is due to the coefficient of the *F*-stats is larger than UBC coefficient at 1% significance level. So, it is in the favor of acceptance of the alternative hypothesis which suggest that there is an effective long-term connection occur among CO_2, ENC, RENE, Y and INO in Malaysia.

1 Sharif et al. (2017); Sharif and Afshan, (2017).

Table 1: Results of unit root test

Variables	ADF unit root test				PP unit root test			
	I(0)		I(1)		I(0)		I(1)	
	C	C&T	C	C&T	C	C&T	C	C&T
CE	1.254	1.291	−4.864	−4.87	1.102	1.128	−4.832	−4.164
Y	0.325	0.401	−3.924	−3.80	0.317	0.403	−4.190	−4.130
ENC	−0.201	−0.198	−4.163	−4.535	−0.189	−0.220	−4.425	−4.408
RENE	−1.323	−1.224	−4.125	−4.180	−1.239	−1.218	−4.133	−4.160
INO	−1.212	−1.281	−5.356	−5.019	−1.412	−1.382	−5.284	−5.201

The critical values for ADF and PP tests with constant (C) and with constant and trend (C&T) 1%, 5% and 10% level of significance are−3.711, −2.981, −2.629 and−4.394, −3.612 and −3.243 respectively. Source: Authors' estimations. ADF: Augmented Dickey-Fuller, PP: Philip Perron

Table 2: Results of bound testing for cointegration

Lags order	AIC	HQ	SBC	F-test statistics
0	−5.321	−5.871	−5.923	49.541*
1	−6.231	−6.168	−6.237	
2	−7.745*	−7.542*	−7.632*	
3	−7.215	−7.102	−7.495	

*1% level of significant. Source: Authors' estimation. SBC: Schwarz Bayesian criteria

The results of ARDL bound testing cointegration test, therefore, establish the robustness of achieved results. It is indicated that a significant long-term association presents among CO_2, ENC, RENE, Y and INO in Malaysia (Table 3). Moreover, after confirming the evidence of long-term connection between the considered variables, the further step of the examination is to apply the ARDL method with the aim of finding the beta value of long-short run time. In doing so, the present study measures the lag length order of all the considered variables through the minimum value of SBC.

The long run results of ARDL method of estimation is displayed in Table 4. The findings therefore establish that non-renewable, renewable energy consumption and technology innovations are valid determinants of carbon emission in Malaysia. Also, the results confirm that economic growth and non-renewable energy have a positive effect of carbon emission in Malaysia which means that the energy consume from non-renewable source and economic progression also increase the level of carbon dioxide emission in Malaysia (Jabarullah et al., 2016). Also, it can be argued that all variables including technology innovation, renewable energy consumption and square of economic growth play a significant role to reduce the carbon dioxide emission in Malaysia which means that invert U-Shape EKC curve exists in Malaysia. The results of EKC curve and technology innovation highlights that in the starting the growth of economy increases the carbon emission in the country but after getting the substantial growth it helps to reduce the environmental degradation in the case of Malaysia.

The short run results of ARDL method of estimation is displayed in Table 5. The findings reported a valid short run relationship between RENE, ENC, Y, INO and CO_2 in Malaysia. The value of error term is displaying around −0.35 suggest that around 35% of instability is adjusted in the current year. Furthermore, the findings also confirm the significant impact of non-renewable, renewable energy consumption, economic growth and technology innovation on carbon dioxide emission in Malaysia in short run as well.

The results of Table 6 show the causal connection between RENE, ENC, Y, INO and CO_2 in Malaysia. The outcomes of

Table 3: Results of lag length selection

Lag	0	1	2	Nominated lags
	SBC	SBC	SBC	SBC
Y	1.671	−2.132*	−1.324	1
ENC	1.213	−3.921*	−2.432	1
RENE	2.765	−3.043*	−2.189	1
INO	1.343	−3.932	−4.477*	2

*Indicate minimum SBC values. Source: Authors' estimation.
SBC: Schwarz Bayesian criteria

Table 4: Results using ARDL approach (long run)

Variables	Coeff.	t-stats	Prob.
C	0.224	2.957	0.000
CE (−1)	0.112	5.909	0.000
Y	0.294	5.321	0.000
Y (−1)	0.021	3.529	0.000
Y^2	−0.292	−4.505	0.000
Y^2 (−1)	−0.114	−0.936	0.350
ENC	0.535	7.679	0.000
ENC (−1)	0.204	1.452	0.148
RENE	−0.321	−4.491	0.000
RENE (−1)	−0.201	−1.182	0.238
INO	−0.432	−2.643	0.009
INO (−1)	−0.201	−1.965	0.050
INO (−2)	−0.022	−1.612	0.108
Adj. R^2		0.889	
D.W stats		2.179	
F-stats (Prob.)		1023.281 (0.000)	

Source: Authors' estimation. ARDL: Auto regressive distributed lags

CO_2 framework explain that in first stage, the variation in CO_2 is described 100% completely by its progresses. In the next level, 98.634% show by own progresses, 0.004% by economic growth, 0.608% by ENC, 0.753% by RENE and 0.000% by technology innovation. In third year, period the variation in CO_2 explain 97.155% by its own enhancement, 0.032% by economic growth, 1.163% by ENC, 0.816% by RENE and 0.068% by INO. In the fifth year, the variation in CO_2 explain 96.527% by its own improvement, 0.034% by economic growth, 2.322% by non-renewable energy consumption, 0.886% by renewable energy consumption and 0.231% by technology innovation. The results of Table 6 propose the bi-directional causal relationship among all the variables but the tendency of the causality is very low.

5. CONCLUSION AND RECOMMENDATION

This current paper investigates the role of RENE, ENC and INO in testing the EKC in Malaysia by using the annual data over the time from 1980 to 2017. The study uses RENE (% of renewable

Table 5: Results using ARDL approach (short run)

Variables	Coeff.	t-stats	Prob.
C	0.277	2.512	0.012
ΔCE (−1)	0.051	1.801	0.074
ΔY	0.292	3.947	0.000
ΔY (−1)	0.039	1.375	0.170
ΔY^2	−0.292	−6.627	0.000
ΔY^2 (−1)	−0.114	1.598	0.112
ΔENC	0.451	7.679	0.000
ΔENC (−1)	0.204	0.287	0.774
ΔRENE	−0.129	−4.221	0.000
ΔRENE (−1)	−0.201	−1.182	0.238
ΔINO	−0.216	−2.560	0.011
ΔINO (−1)	−0.201	−2.135	0.034
ΔINO (−2)	−0.032	−0.094	0.924
ECM (1)	−0.351	−5.313	0.000
Adj. R^2		0.859	
D.W stats		2.016	
F-stats (Prob.)		871.220 (0.000)	

Source: Authors' estimation ARDL: Auto regressive distributed lags

Table 6: Results of variance decomposition approach

Period	CE	Y	ENC	RENE	INO
Variance decomposition of CE					
Period	**CE**	**Y**	**ENC**	**RENE**	**INO**
1	100.000	0.000	0.000	0.000	0.000
2	98.634	0.004	0.608	0.753	0.000
3	97.922	0.032	1.163	0.816	0.068
4	97.155	0.034	1.803	0.872	0.136
5	96.527	0.034	2.322	0.886	0.231
Variance decomposition of Y					
Period	**CE**	**Y**	**ENC**	**RENE**	**INO**
1	4.597	95.403	0.000	0.000	0.000
2	11.392	87.362	0.858	0.072	0.316
3	11.377	87.012	0.674	0.643	0.294
4	11.715	86.355	0.605	0.955	0.370
5	11.556	86.054	0.547	1.339	0.504
Variance decomposition of ENC					
Period	**CE**	**Y**	**ENC**	**RENE**	**INO**
1	13.014	0.465	86.521	0.000	0.000
2	19.214	1.549	79.081	0.119	0.037
3	24.829	1.327	73.592	0.118	0.134
4	28.087	1.219	70.284	0.108	0.302
5	30.713	1.225	67.470	0.111	0.482
Variance decomposition of RENE					
Period	**CE**	**Y**	**ENC**	**RENE**	**INO**
1	22.667	4.861	7.277	65.194	0.000
2	32.802	6.170	5.353	55.551	0.124
3	36.640	5.819	4.961	52.435	0.145
4	38.897	5.773	4.676	50.426	0.228
5	40.456	5.667	4.574	49.012	0.291
Variance decomposition of INO					
Period	**CE**	**Y**	**ENC**	**RENE**	**INO**
1	14.031	0.553	0.291	0.006	85.120
2	16.421	0.709	0.519	0.005	82.346
3	16.000	0.643	0.695	0.048	82.614
4	15.667	0.623	0.849	0.061	82.800
5	15.358	0.611	1.003	0.079	82.950

Source: Authors' estimation

energy consumption to total energy consumption), energy consumption, high technology exports are used as a proxy of innovation. However, *CE* represents the carbon dioxide emission which is measured in metric kilotons. We applied the advance econometrics to serve the purpose of investigation and therefore used the ARDL bound testing approach for assessing the presence of long-run relationship between the variables. Utilizing the framework of EKC, the results of ARDL bound testing approach confirm the valid long run relationship between RENE, ENC, Y, INO and CO_2 in Malaysia.

The empirical results indicate that renewable energy consumption and technology innovation have significant and negative impact on carbon dioxide emission whereas, the non-renewable energy consumption and economic growth have a significant and positive impact on carbon dioxide emission. Furthermore, results also confirm the existence of inverted U-Shape curve in Malaysia.

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