Jurnal Ekonomi Malaysia 52(2) 2018 39 - 54
http://dx.doi.org/10.17576/JEM-2018-5202-4

Nexus among Carbon Emissions, Real Output and Energy Consumption in Malaysia and South Korea: New Evidence using Non-Linear Autoregressive Distributed Lag (NARDL) Analysis

(Hubungan antara Pelepasan Karbon, Output Benar dan Penggunaan Tenaga di Malaysia dan Korea Selatan: Bukti Baharu menggunakan Analisis Lat Tertabur Autoregresif Bukan Linear

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ABSTRACT

This study investigates the asymmetries in the nexus among carbon emissions, real output, and energy consumption between Malaysia and South Korea through the use of a non-linear autoregressive distributed lag (NARDL) model. The positive and negative shock of the variables indicate varying signs and magnitudes. Furthermore, the findings revealed a mixed presence of asymmetries among the nexus, as indicated in the variables for both short and long runs. The study also exemplified that the dependence of South Korea on energy consumption to generate economic growth appears to be greater than Malaysia. On the contrary, the impact of economic expansion upon the higher release of carbon emissions is greater for the case of Malaysia, in comparison to South Korea. The outcomes further displayed that higher energy consumption in both nations could lead to higher economic growth. As such, the presence of asymmetries in the relationships between the tested variables could impose significant information for future policy recommendations, particularly for these two nations.

Keywords: Energy consumption; real output; carbon emissions; Non-Linear Autoregressive Distributed Lag (NARDL)

ABSTRAK

Kajian ini meneliti asimetri dalam perhubungan antara pelepasan karbon, keluaran benar, dan penggunaan tenaga antara Malaysia dan Korea Selatan menggunakan model ARDL bukan linear. Kejutan positif dan negatif pembolehubah menunjukkan tanda dan magnitud yang berlainan. Tambahan pula, dapatan kajian menunjukkan bahawa terdapat kepelbagaian asimetri di antara neksus seperti yang ditunjukkan dalam pembolehubah untuk kedua-dua jangka pendek dan panjang. Kajian itu juga menunjukkan bahawa pergantungan Korea Selatan terhadap penggunaan tenaga untuk menjana pertumbuhan ekonomi adalah lebih besar berbanding Malaysia. Sebaliknya, kesan perkembangan ekonomi melalui pengeluaran yang tinggi oleh pelepasan karbon adalah lebih besar bagi kes Malaysia berbanding dengan Korea Selatan. Penemuan kajian ini menunjukkan bahawa penggunaan tenaga yang lebih tinggi di kedua-dua negara boleh membawa kepada pertumbuhan ekonomi yang lebih tinggi di negara-negara ini. Kehadiran asimetri dalam hubungan di antara pemboleh ubah yang diuji dapat memberikan maklumat penting untuk cadangan dasar masa depan di kedua negara.

Kata kunci: Penggunaan tenaga; keluaran hasil sebenar; karbon dioksida; ARDL bukan linear

INTRODUCTION

Global warming has turned into a serious threat to the existence of mankind. The escalating global average air and ocean temperatures, the meltdown of ice caps, and the rise of global average sea levels are the ultimately supporting evidence that global warming has detrimental effects upon Mother Earth. As a consequence of global warming, series of floods, for example, do not only harm the lives of human beings, but also the destruction of properties, such as cars, buildings, and roads, thus leading to a complete shutdown of economic activities in the affected areas. Besides, the attempt to recover from such disasters incurs millions of dollars. One of the many reasons for this occurrence of climate change is due to the escalating usage of energy consumption derived from polluted energy resources, such as coal and fossil fuels, to generate economic output. Excessive usage of such energy, although it has a significant influence upon higher economic activities, could lead to higher emission of carbon into the atmosphere, thus causing global warming. The two nations observed in this research paper are: 1) Malaysia, a developing country with a population of 31 million people, and 2) South Korea, an advanced nation with a population of 51 million people. These particular two nations have become subjects of interest as they both have been ranked as the top ten contributors for energy consumption and contributors for carbon emissions (World Energy Statistic 2016). Since its independence in 1957, Malaysia has recorded an outstanding upsurge in its energy usage, which stimulated a simultaneous intensification in the emissions of pollutants until this present moment (Islam et al. 2013). The authors added that during the period from 1990 until 2004, the carbon emissions in the country spiked by 221%, resulting Malaysia to be listed as the 26th among 30 countries with the highest emission of pollutants. Therefore, in order to address this pressing issue, Malaysia has participated in signing the Kyoto Protocol, an international treaty that extends the United Nations Framework Convention on Climate Change (UNFCCC) established in 1992, which commits to reduce greenhouse gas emissions. Recently, the Malaysian government has introduced the Green Technology Master Plan 2017-2030 to slash carbon emissions from the present eight metric tonnes (MT) per capita to six MT per capita in 2030. Similar to Malaysia, the Korean government has also initiated emission reduction plan called the First Basic Plan for Climate Change Response 2017, which aims to cut its national greenhouse gas emissions level by 37% by 2030, in line with the South Korea's pledge to the Paris Agreement.

Based on the statistical records released by the World Energy Statistics (2016), the overall level of carbon emissions, energy consumption, and real output in South Korea are almost double the amount recorded in Malaysia. Hence, in order to better understand the patterns of both energy consumption and carbon emission, the trends of these two variables had been carefully monitored in this research paper. The three diagrams as revealed in Figure 1 illustrate that the level of energy consumption, carbon emissions, and real output in both Malaysia and South Korea have increased substantially since 1971. Historically, from the beginning of 1970 up to 1990, Malaysia and South Korea were almost at par in terms of its economic development. Later, after the 1990s, the South Korean government had successfully brought the country to another level of economic stage as they had placed more focus in developing their own technology, which led to the success of their five well-known companies, namely Samsung, LG, Hyundai, SK, and Lotte. These five companies, which are also called as *chaebol*, have contributed to approximately 60% of the country's total GDP. These companies have continuously received support by the Korean government since the beginning of 1960s to 1970s so as to fasten their industrialization process, apart from centralising and efficiently using all their economic resources to achieve economies of scale in the country. Meanwhile, in Malaysia, the economy of this developing country still heavily relies on combustion of coal and fuel as the cheaper sources of energy, while selection of cleaner alternative energies, such as solar, wind, biomass, and tide energies, is still scarce in this country. Hence, in order to curb heavy reliance on fuel as the primary energy source, the government has introduced two significant policies; 1) The Four-Fuel Diversification policy in 1981, and 2) the Five-Fuel Diversification policy in 2002 (Saboori & Sulaiman 2013). Similarly, the Korean government also has established the National Energy Master Plan for every 5 years beginning in 2008, which emphasized on converting dirty energy into renewable types of energy in the attempt to address global warming. Despite of the implementation of various energy-related policies, Malaysia is still dependent on fossil fuel sources, such as natural gas, coal, and oil (Oh et al. 2010), while a similar scenario is also believed to occur in South Korea. With the escalating energy demand in sustaining the country's economic growth in the future, it is inevitable that CO_2 emission will continue to increase, as long as fossil fuels are the main contributor to the energy supply and demand. The different stages of economic development between Malaysia and South Korea may influence the nexus between carbon emissions, real output, and energy consumption in these two countries.

Given the trend portrayed in Figure 1 above, a pressing need is present to minimise energy consumption in both countries so as to cut down carbon emissions. Hence, in order to propose effective energy and environmental policies, it is necessary to examine the nexus between carbon emissions, real output, and energy consumption. The outcome of this study offers extended input for policy recommendation in both countries. For instance, if energy consumption and carbon emissions are found to have nil effect upon output, energy conservation and efficiency improvement policies can be applied to reduce energy use and carbon emissions without affecting economic growth (Al Mulali & Normee Che Sab 2013).

Although vast studies have looked into this topic, this paper proposes a new novelty by allowing asymmetry

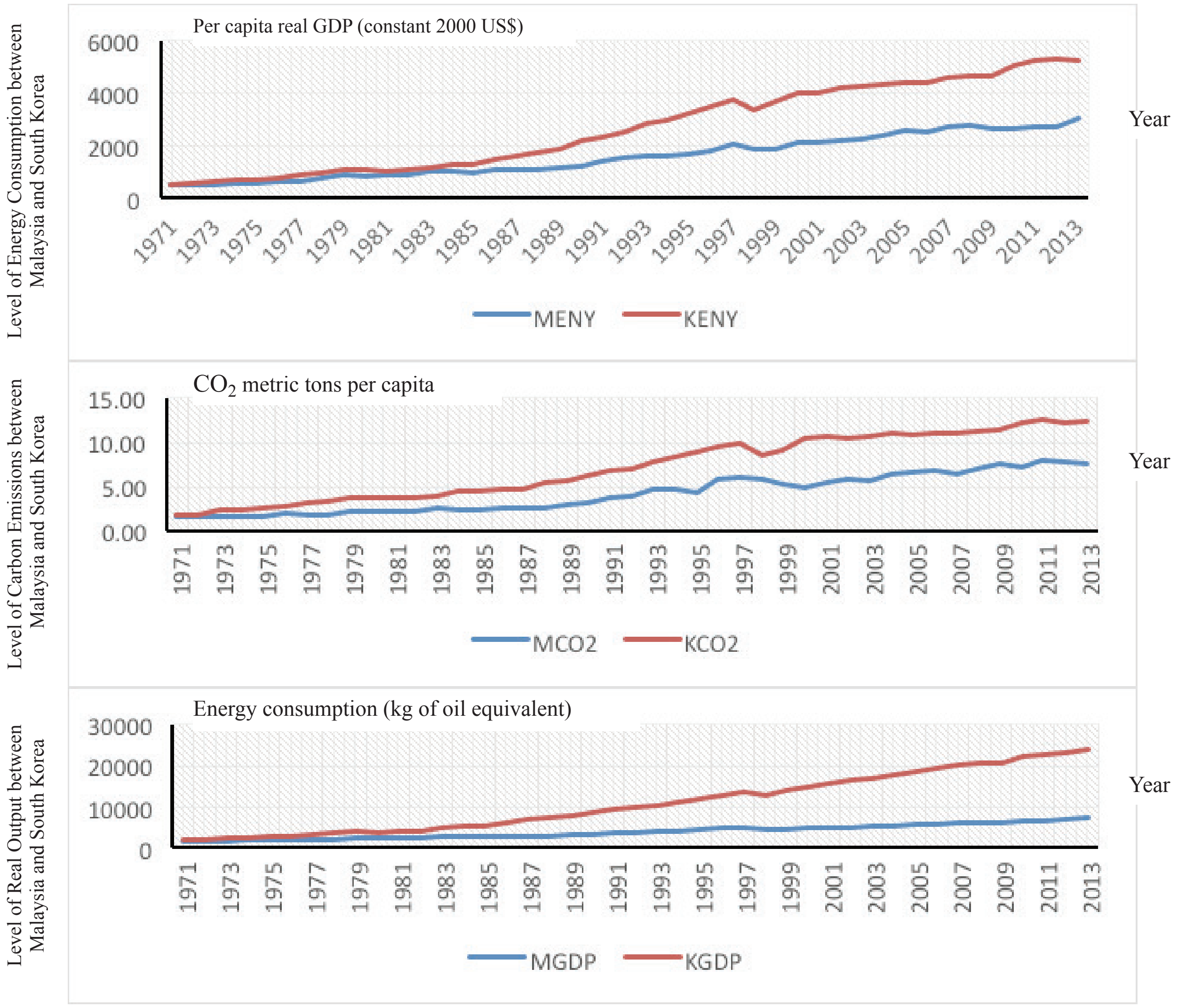

FIGURE 1. The trend of energy consumption (ENY), carbon emissions (CO_2) and real output (GDP) between Malaysia and South Korea
Note: M is refer to Malaysia, K is refer to South Korea.
**Sources:* World Development Indicator (2016).

while examining the nexus between carbon emissions, real output, and energy consumption through the use of Non-linear Autoregressive Distributed Lag (NARDL) model, which refers to a recent innovative methodology initiated by Shin et al. (2014). According to Hatemi-J and Uddin (2012), allowance of asymmetry is integral because the effects of negative shock from a variable may differ from the effect of positive shock in both sign and magnitude. In addition, the incorporation of asymmetry is made possible by the present available econometric software program that transforms data into a cumulative sum of positive and negative components for asymmetric NARDL modelling (Shin et al. 2014).

This paper is organized as follows. Section 2 focuses on selected prior studies, while Section 3 highlights the methodology. Next, Section 4 presents the analysis and discussion of the results, whereas Section 5 concludes the study.

LITERATURE REVIEW

The nexus between economic growth, energy consumption, and pollution has been the subject of concentrated research since past two decades due to the rising concern over global warming issues. Overall, studies in this area may be divided into three main research groups based on their methodologies, which are: 1) time series analysis based on a country, 2) cross-sectional, and 3) panel data-based analysis. As such, this section briefly summarizes all prior studies from the first group until the third group, in order to capture more information pertaining to this research topic.

The first research group investigates the nexus between economic growth and carbon emissions to determine the inverted U-shaped relationship between pollution and economic growth by testifying the presence of Environmental Kuznets Curve (EKC) hypothesis. The

EKC assumes that environmental degradation, initially, increases as income increases, then plateaus when income hits a certain high level, and finally, slumps. In fact, the two approaches that have been employed to test EKC are parametric and non-parametric approaches. As for the parametric approach, the authors used only income to capture the evidence of EKC. This can be achieved by comparing short run income elasticity with that of long run (Narayan & Narayan 2010). If the short run income elasticity exceeds that in the long run, then this suggests that overtime income leads to less carbon emissions. On the other hand, as for the non-parametric approach, the authors included 'income-squared' as an additional variable (Jaunky 2011; Lee & Lee 2010; Saboori et al. 2012; Tang & Tan 2015; Wang 2013), or both income-squared and income cube to testify EKC (Friedl & Getzner 2003; Onafowora & Owoye 2014). As for this approach, the EKC is detected based on the outcomes of long run elasticities. The empirical results recorded in the literatures pertaining to the inverse U-shaped relationship between CO_2 emissions and per capita income are abundant, but yet to arrive conclusively (Fodha & Zaghdoud 2010). Saboori et al. (2012), for example, reported the existence of EKC for the case of Malaysia, whereas Holtz-Eakin and Selden (1995) found a monotonic rising curve, and Friedl and Getzner (2003) discovered an N-shaped curve for the case of Austria. Meanwhile, Agras and Chapman (1999) and Richmond and Kaufman (2006) concluded an insignificant relationship between economic growth and environmental pollutants. Similar outcome was revealed by Lean and Smyth (2010), who examined the existence of EKC amongst ASEAN countries (Indonesia, Malaysia, Philippines, Singapore, and Thailand) for the period between 1980 and 2006. Although their results seemed to support the validity of EKC hypothesis for the ASEAN-5 countries as a group, they failed in determining the correlation between income and pollutant emissions in Malaysia.

Next, the second research group focuses on the nexus between energy consumption and output. The study for this classification had been initiated with the pioneering work by Kraft and Kraft (1978), who promoted the use of Granger's causality test as an instrument to investigate the correlation between energy consumption and economic growth across nations (Apergis & James 2010a; Belke et al. 2011; Lau et al. 2011; Tang & Tan 2013). In the attempt to elaborate the nexus between energy consumption and economic growth, Apergis and Payne (2010a, 2010b) addressed four hypotheses that have been commonly discussed in the literature: 1) the growth hypothesis, 2) the conservation hypothesis, 3) the feedback hypothesis, and 4) the neutrality hypothesis. The growth hypothesis implies a positive causal effect of energy consumption upon economic growth. In contrast, the conservation hypothesis claims that energy conservation policies have little or no effect on economic growth. Meanwhile, the feedback hypothesis projects that energy consumption and economic growth can affect each other simultaneously. Lastly, the neutrality hypothesis suggests an independent correlation between energy consumption and economic growth. In fact, recent studies are more focused on renewable source of energy, such as hydroelectricity, biomass, and natural gases, as compared to fossil fuel or coal-type energy consumption, which is considered as dirty energy (Al-Mulali et al. 2016; Danish et al. 2017; Shahbaz et al. 2017; Sinha & Shahbaz 2018; Yin et al. 2015;).

The conclusion that can be drawn from the first two groups is that first, the estimates research outcomes are mixed; and second, most literature suffers from the omitted variable biasness as they examine the bivariate relationship, either between energy consumption and economic growth or environmental and economic growth. This scenario leads to the third group that combines the aspects both first and second groups by examining the dynamic correlations between environmental pollutants, energy consumption, and economic growth within a single framework, as initiated by Ang (2007) and Soytas et al. (2007). The extension of this particular group of studies includes various determinants, such as foreign direct investment, trade openness, population growth, financial development (Acaravci & Ozturk 2010; Apergis & James 2010b; Azlina et al. 2014; Begum et al. 2015; Chang & Carballo 2011; Hamit-Haggar 2012; Pao & Tsai 2010, 2011; Saboori & Sulaiman 2013). Azlina et al. (2014) and Begum et al. (2015), for example, discovered the invalidity of EKC in Malaysia. Meanwhile, the outcomes of other tested variables based on these two studies are mixed. The findings retrieved by Azlina et al. (2014) showed that higher transportation energy consumption caused higher release of carbon emissions, while structural change of the economy and use of renewable energy can decrease the emissions. Begum et al. (2015), on the other hand, proved that both per capita energy consumption and per capita GDP had long term positive impacts upon pollution, but insignificant impact of population growth on carbon emission.

Although many researches have investigated this topic, the outcomes for the dynamic relationships between pollution, energy consumption, and economic growth have remained inconclusive. Several studies have focused on Malaysia, whereas the study on South Korea is still scarce in the literature. To the best of authors' knowledge, most of the existing studies have focused on linear relationship, while neglecting the presence of asymmetry relationship. By incorporating asymmetry relationship, policymakers are able to receive more input for both positive and negative impacts of each tested variable, thus giving them more ideas to construct effective policies. The adoption of NARDL estimation in this paper appears to enrich the body of knowledge, apart from providing more insights regarding the investigated area.

METHODOLOGY AND DATA ANALYSIS

This paper gathered annual data derived from years 1970 until 2013. The first variable, carbon emissions emission (CO_2), which was measured in terms of MT per capita, represented environmental quality. Next, the level economic growth in a country (GDP) was measured by using per capita real GDP (US$). Lastly, per capita as well, energy consumption (kg of oil equivalent) was employed to measure energy consumption (ENY). All the accumulated data were obtained by using the World Development Indicator (2016) that was published by the World Bank.

Next, in the attempt to evaluate asymmetries between carbon emissions (CO_2), real output (GDP), and energy consumption (ENY), this research paper had adopted the NARDL model developed by Shin et al., (2014). The non-linear econometric framework has been gaining popularity within these recent years given that the nature of correlations between the variables is not always linear. Given two variables, y_t and x_t, the equation begins with asymmetric long run regression, as portrayed in the following:

$$y_t = \alpha^+ x_t^+ + \alpha^- x_t^- + v_t, \tag{1}$$

where α^+ and α^- refer to the associated long run parameters, while x_t^+ and x_t^- denote the cumulative sum of positive and negative changes in x_t, as elaborated as follows:

$$x_t^+ \sum_{j=1}^{t} x_j^+ = \sum_{j=1}^{t} \max(\Delta x_j, 0);\ x_j^- = \sum_{j=1}^{t} x_j^- = \sum_{j=1}^{t} \max(\Delta x_j, 0) \tag{2}$$

Shin et al., (2014) combined equation (1) with the linear ARDL model initiated by Pesaran et al., (2001) in order to obtain the following non-linear ARDL (NARDL) model:

$$\begin{aligned} \Delta yt &= \beta y_{t-1} + \delta^+ x_{t-1}^- + \delta^- x_{t-1}^- + \sum_{j=1}^{p-1} \lambda_j \Delta x_{t-j} \\ &\quad + \sum_{j=0}^{q-1} (\varsigma_j^+ \Delta x_{t-j}^+ + \varsigma_j^+ \Delta x_{t-j}^+) + \varepsilon_t, \end{aligned} \tag{3}$$

for $j = 1, \ldots, q - 1$, with $\alpha^+ = -\delta^+/\beta$ and $\alpha^- = -\delta^-/\beta$.

Based on the NARDL model given in equation 3 above, an F-test, developed by Narayan (2004), was performed so as to test for asymmetric co-integration. This F-test is exemplified based on the following hypothesis:

$H_0 : \beta = \delta^+ = \delta^- = 0$.

Besides, the long run symmetry restrictions can also be tested by imposing $\delta^+ = \delta^- = 0$.

Meanwhile, restrictions of short run symmetry restrictions are tested by imposing $\varsigma_j^+ = \varsigma_j^-$ for all $j = 0, \ldots q - 1$ or $\sum_{j=0}^{q-1} \varsigma_j^+ = \sum_{j=0}^{q-1} \varsigma_j^-$. Nevertheless, both forms can be evaluated by using the standard Wald test. Similar to the proposed models adopted by Xia (2012) in China and Ndoricimpa (2017) in South Africa, the general form of the NARDL (p,q) model proposed for Malaysia and South Korea in this paper derived from three segregated models, as listed below. In fact, only three variables had been employed in this study due to a limitation in terms of the number of observations. Besides, according to Hatemi (2012), it is indeed a requirement to generate positive and negative shocks for each variable so as to address asymmetric correlation. The three econometric models were developed in this study in order to treat every single variable to function as an endogenous variable. Moreover, due to the interaction between the three variables; energy consumption, CO_2 emissions, and real output, segregating them may result in misleading outcomes, especially upon determining the correlations between them, as purported by Xia (2012). Nevertheless, the core model in this study is the first model. Both the economic growth and the energy consumption were adopted as independent variables in this particular study as it is believed that these two variables are strong indicators for carbon emissions. Furthermore, due to the shortcoming in terms of number of observations, only two indicators had been applied in this study, which had been separated into positive and negative values. Nonetheless, inclusion of additional variables may result in unreliable results due to the effect of the degree of freedom upon each model.

The three models are listed as follows:

Model 1:

$$\begin{aligned} \Delta CO_{2_t} &= c + \beta CO_{2_{t-1}} + \delta_1^+ GDP_{t-1}^+ + \delta_1^- GDP_{t-1}^- + \delta_1^+ ENY_{t-1}^+ \\ &\quad + \delta_1^+ ENY_{t-1}^- + \sum_{i=1}^{p-1} \pi_j \Delta CO_{2_{t-1}} + \sum_{i=0}^{q} \phi_{1i}^+ \Delta GDP_{t-i}^+ \\ &\quad + \sum_{i=0}^{q} \phi_{1i}^- \Delta GDP_{t-i}^- + \sum_{i=0}^{q} \phi_{2i}^+ \Delta ENY_{t-1}^+ \\ &\quad + \sum_{i=0}^{q} \phi_{2i}^- \Delta ENY_{t-1}^- + \upsilon_t \end{aligned} \tag{4}$$

Model 2:

$$\begin{aligned} \Delta GDP_{2_t} &= c + \beta GDP_{t-1} + \delta_1^+ CO_{2_{t-1}}^+ + \delta_1^- CO_{2_{t-1}}^- \\ &\quad + \delta_2^+ ENY_{t-1}^+ + \delta_2^+ ENY_{t-1}^- + \sum_{i=1}^{p-1} \phi_j \Delta GDP_{2_{t-1}} \\ &\quad + \sum_{i=0}^{q} \pi_{1i}^+ \Delta CO_{2_{t-i}}^+ + \sum_{i=0}^{q} \pi_{1i}^- \Delta CO_{2_{t-i}}^- \\ &\quad + \sum_{i=0}^{q} \pi_{2i}^+ \Delta ENY_{t-1}^+ + \sum_{i=0}^{q} \pi_{2i}^- \Delta ENY_{t-1}^- + \upsilon_t \end{aligned} \tag{5}$$

Model 3:

$$\begin{aligned} \Delta ENY_t &= c + \beta ENY_{t-1} + \delta_1^+ CO_{2_{t-1}}^+ + \delta_1^- CO_{2_{t-1}}^- + \delta_2^+ GDP_{t-1}^+ \\ &\quad + \delta_2^- GDP_{t-1}^- + \sum_{i=1}^{p-1} \pi_j \Delta ENY_{t-1} + \sum_{i=0}^{q} \omega_{1i}^+ \Delta ENY_{t-i}^+ \\ &\quad + \sum_{i=0}^{q} \omega_{1i}^- \Delta ENY_{t-i}^- + \sum_{i=0}^{q} \omega_{2i}^+ \Delta GDP_{t-1}^+ \\ &\quad + \sum_{i=0}^{q} \omega_{2i}^- \Delta GDP_{t-1}^- + \upsilon_t \end{aligned} \tag{6}$$

After estimating equations (4) until (6) by using the Stepwise Least Square, asymmetric co-integration via Wald test was tested to confirm the existence of long run co-integration in this NARDL model. Next, the asymmetries between CO_2 emissions, real output, and energy consumption were tested both in short and long runs. From the outputs derived from equations (4), (5), and (6), the asymmetric co-integration was examined by testing the null hypothesis given below:

$H_0 : \beta = \delta_1^+ = \delta_1^- = \delta_2^+ = \delta_2^-$ (using F test of Narayan, 2004).

The impacts of short run upon both positive and negative economic growths were captured respectively by δ_{1i}^+ and δ_{1i}^-, while the influences of short run on both positive and negative shocks of energy consumption had been captured by δ_{2i}^+ and δ_{2i}^-. Besides, the impacts of long run upon positive and negative economic growths were captured respectively by $-\delta_1^+/\beta$ and $-\delta_1^-/\beta$, while the impacts of long run on both positive and negative shocks of energy consumption had been captured by $-\delta_2^+/\beta$ and $-\delta_2^-/\beta$. In fact, similar short and long run impacts can be applied for both second and third models.

ANALYSIS AND DISCUSSION

All variables; CO_2 emissions, GDP, and ENY, were converted into logarithm prior to analysis. All the estimations run in this paper were carried out by employing the Eviews version 9 software program. The time plots of CO_2 emissions, GDP, and ENY, as well as their positive and negative shocks, are illustrated in Figure 2 found in the Appendix. Similar to the ARDL estimation procedure, the order of integration for each variable was tested initially by using unit root tests. The estimation could proceed as long as no variable is integrated at I (2). Moreover, the two types of unit root tests, namely Augmented Dickey-Fuller (ADF) and Philip-Perron (PP), had been applied for this purpose. The results are displayed in Table 1. Based on the outcomes recorded for Malaysia, all the variables appeared to be significant only at the first variance for both ADF and PP unit root tests. In precise, all the variables had been integrated for order one, thus fulfilling the co-integration procedures. As for the case of South Korea, a mixed stationarity of variables had been noted at a level, as well as at first variance. For instance, all the three variables; carbon emissions ($LNCO_2$), real output (LNGDP), and energy consumption (LNENY) appeared to be significant at 5% and 10% significant levels for the intercept at the levels of ADF and PP test statistics. The positive shock of these variables was found to be significant even at level. Nevertheless, given that no variable co-integrated at order two, the model may also fulfil the requirement to proceed with co-integration analysis.

After establishing the order of integration of each variable for both Malaysia and South Korea, the next empirical analysis involved three stages. The first stage estimated the NARDL model by testing for asymmetric co-integration via F statistical test that employed the standard Wald test. As for F test, the null hypothesis of no co-integration had been tested for each model for both nations. The results are as tabulated in Table 2. Based on the outcomes obtained for Malaysia and South Korea, the F statistics for all the three models was larger than the upper bound and the lower bound values of 10% significant level. Hence, the null hypothesis of no co-integration is rejected, thus verifying the presence of long run co-integration in all model.

As for the second stage, various diagnostics tests, such as serial correlation test, heteroscedasticity test, functional form, and normality test, were performed to validate each model so as to ascertain that the models do generate reliable results. The results of the diagnostics tests, which are presented in Table 3, indicate that the probability values for both Malaysia and South Korea at every test performed for every model had been greater than 10% significant level. This means; the probability values failed to reject the hypothesis of no serial correlation, correct functional form, and normal residuals for all models, as well as the absence of heteroscedasticity.

Next, the stability of each model for both nations had been evaluated by using CUSUM and CUSUMSQ tests. The stability of the models was supported for all the cases, mainly because the plots of both CUSUM and CUSUMSQ for both Malaysia and South Korea models fell within the critical bounds of 5% significance. The plotted graphs of this analysis are displayed in Figure 3.

As for stage three, the NARDL form of the models for all variables had been explored. Based on the NARDL estimation, the long run positive and negative effects were also included. In addition, both long and short runs for the asymmetric estimation are presented in the same table. The explanation begins with findings from Malaysia in Table 4a and followed by South Korea in Table 4b. The tables are further divided into several sections. Section A depicts the long run and short run NARDL estimation results, while Section B displays the long run effects calculated from NARDL output in section A. The results of both long and short run asymmetries, which were derived from Wald test, are tabulated in Section C.

Section A in Table 4A presents the results of the unrestricted NARDL estimator for Malaysia based on both long and short run asymmetric assumptions that were not offered under the ARDL estimation. As for Model 1, the long run coefficients were only significant for positive shock of real output (LNGDP) with the value of 4.15. This means; increment in real output increased carbon emissions ($LNCO_2$) by 4.15% in Malaysia.

TABLE 1. Unit Root Test

	Model	Variable Intercept	ADF test statistic		PP test statistic	
			Trend and intercept	Intercept	Trend andintercept	
Malaysia	Level	LNCO$_2$	–0.828 (0)	–2.595 (0)	–0.790 (3)	–2.584 (3)
		LNGDP	–1.589 (0)	–2.232 (0)	–1.544 (1)	–2.343 (2)
		LNENY	–1.005 (0)	–2.043 (0)	–1.559 (11)	–2.081 (1)
	First difference	LNCO$_2$	–8.147 (0)***	–8.066 (0)***	–8.310 (2)***	–8.233 (2)***
		LNGDP	–5.568 (0)***	–5.652 (0)***	–5.533 (2)***	–5.653 (1)***
		LNENY	–6.705 (0)***	–6.784 (0)***	–6.912 (6)***	–9.821 (14)***
	Level	LNCO$_2^+$	–0.622 (0)	–2.411 (0)	–0.632 (1)	–2.394 (3)
		LNGDP$^+$	–0.973 (1)	–1.505 (1)	–1.511 (3)	–1.795 (3)
		LNENY$^+$	–1.286 (0)	–1.986 (0)	–2.574 (17)	–1.849 (3)
	First difference	LNCO$_2^+$	–8.254 (0)***	–8.205 (0)***	–8.254 (4)***	–8.278 (1)***
		LNGDP$^+$	–5.378 (0)***	–5.409 (0)***	–5.401 (3)***	–5.434 (3)***
		LNENY$^+$	–6.698 (0)***	–6.967 (0)***	–6.789 (6)***	–11.183 (19)***
	Level	LNCO$_2^-$	–0.320 (0)	–2.323 (0)	–0.233 (6)	–2.399 (1)
		LNGDP$^-$	–0.431 (0)	–2.609 (0)	–0.414 (1)	–2.666 (1)
		LNENY$^-$	–0.427 (0)	–2.954 (0)	–0.146 (7)	–2.999 (1)
	First difference	LNCO$_2^-$	–6.335 (0)***	–6.266 (0)***	–6.375 (5)***	–6.346 (6)***
		LNGDP$^-$	–6.446 (0)***	–6.370 (0)***	–6.446 (1)***	–6.377 (2)***
		LNENY$^-$	–7.152 (0)***	–7.109 (0)***	–7.711 (6)***	–8.759 (8)***
South Korea	Level	LNCO$_2$	–2.608 (0)*	–1.201 (0)	–4.478 (16)***	–0.909 (9)
		LNGDP	–3.175 (0)**	–0.148 (0)	–3.247 (2)**	–0.018 (3)
		LNENY	–2.995 (0)**	–0.217 (0)	–3.018 (2)**	–0.186 (1)
	First difference	LNCO$_2$	–6.882 (0)***	–8.281 (0)***	–6.869 (1)***	–8.864 (9)***
		LNGDP	–5.020 (0)***	–6.327 (0)***	–5.033 (2)***	–6.377 (4)***
		LNENY	–5.312 (0)***	–6.433 (0)***	–5.384 (3)***	–6.433 (1)***
	Level	LNCO$_2^+$	–3.108 (0)**	–1.365 (0)	–3.302 (5)**	–1.353 (2)
		LNGDP$^+$	–4.453 (0)***	0.274 (0)	–4.184 (1)***	0.405 (4)
		LNENY$^+$	–3.476 (0)**	0.241 (0)	–3.130 (3)**	0.167 (2)
	First difference	LNCO$_2^+$	–7.731 (0)***	–8.591 (0)***	–7.603 (1)***	–8.389 (3)***
		LNGDP$^+$	–4.315 (0)***	–4.704 (1)***	–4.303 (2)***	–5.562 (4)***
		LNENY$^+$	–2.792 (1)*	–5.959 (0)***	–5.069 (3)***	–5.982 (2)***
	Level	LNCO$_2^-$	–0.389 (0)	–2.007 (0)	–0.369 (2)	–2.007 (0)
		LNGDP$^-$	–1.024 (0)	–2.402 (0)	–1.000 (2)	–2.478 (1)
		LNENY$^-$	–0.833 (0)	–2.367 (0)	–0.8335 (0)	–2.367 (0)
	First difference	LNCO$_2^-$	–6.429 (0)***	–6.430 (0)***	–6.432 (2)***	–6.434 (2)***
		LNGDP$^-$	–6.466 (0)***	–6.386 (0)***	–6.480 (3)***	–6.396 (3)***
		LNENY$^-$	–6.438 (0)***	–6.353 (0)***	–6.442 (2)***	–6.355 (2)***

Note: (*), (**), (***) indicate significance at 10%, 5% and 1% levels, respectively. Lag automatic selection for ADF test is based on Schwarz Info Criterion (SIC). PP bandwidth is set under Newey-West Bandwidth

TABLE 2. Bound test for Asymmetric Co integration

	Model	Max. lag	F Statistic
Malaysia	Model 1	4	7.065***
	Model 2	4	9.254***
	Model 3	3	4.150**
South Korea	Model 1	3	11.899***
	Model 2	4	9.203***
	Model 3	4	10.245***

Critical Values for *F*-statistics[#]	Lower I (0)	Upper I (0)
1%	3.790	5.411
5%	2.764	4.123
10%	2.327	3.541

Note: # The critical values are based on Narayan (2004) case III: restricted intercept and trend, k is the number of variables and equivalent to six; *, **, and *** represent 10%, 5% and 1% levels of significance, respectively. The F statistics is generated from Wald test of NARDL estimation

TABLE 3. Result of Diagnostic Tests

	Model	(A) Serial correlation	(B) Functional form	(C) Normality	(D) Heteroscedasticity
Malaysia	Model 1	0.837	0.282	0.754	0.530
	CO_2 = GDP, ENY	(0.448)	(0.601)	(0.685)	(0.904)
	Model 2	1.159	2.627	1.401	0.601
	GDP = CO_2, ENY	(0.296)	(0.103)	(0.496)	(0.859)
	Model 3	0.982	1.754	1.648	0.801
	ENY = CO_2, GDP	(0.386)	(0.179)	(0.438)	(0.618)
South Korea	Model 1	2.372	0.427	0.485	0.833
	CO_2 = GDP, ENY	(0.106)	(0.521)	(0.494)	(0.648)
	Model 2	0.651	1.495	3.769	0.451
	GDP = CO_2, ENY	(0.534)	(0.238)	(0.152)	(0.953)
	Model 3	2.373	0.274	1.991	0.365
	ENY = CO_2, GDP	(0.118)	(0.606)	(0.369)	(0.975)

Note. The numbers in brackets ( ) are p-values. The tests used as follows: A. Lagrange multiplier test for residual serial correlation; B. Ramsey's RESET test using the square of the fitted values; C. Based on a test of skewness and kurtosis of residuals; D. Based on the regression of squared fitted values.

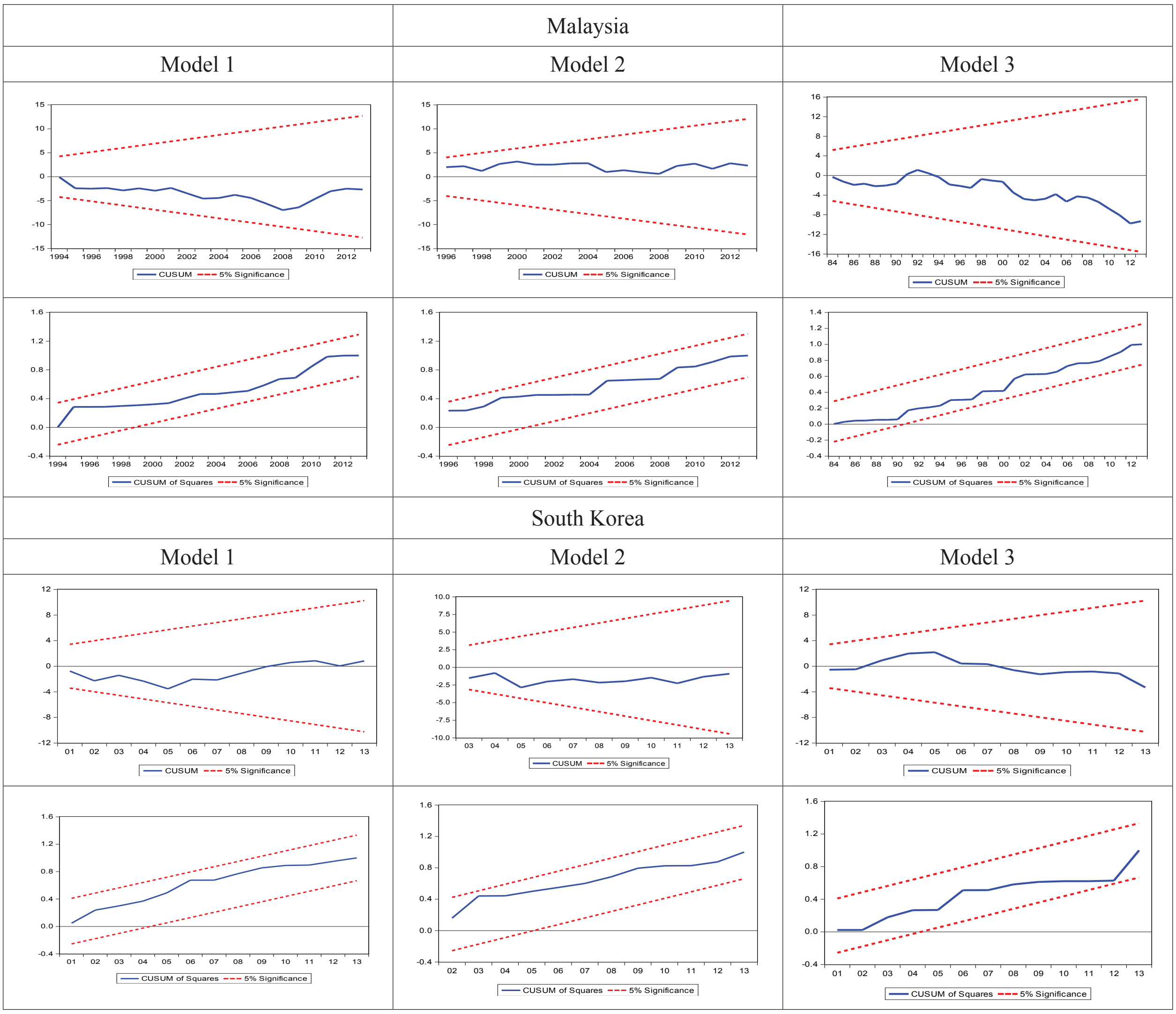

FIGURE 3. CUSUM and CUSUMSQ

This result is also supported by Azlina et al. (2014), who discovered that the real output in Malaysia did cause environmental degradation. On the other hand, the results clearly showed that the long run coefficients for both positive and negative shocks of energy consumption (LNENY) had been significant at 1% level with the coefficient values of -0.775 and 4.999, respectively. Statistically, when there is a 1% increment in positive shock of energy consumption, the level of carbon emissions decreased by 0.78%, while increment in negative shock of energy consumption by 1% resulted in an increase of carbon emissions by 5.0%. This outcome contradicts that obtained by Shahbaz et al. (2013), who revealed that increase in energy consumption leads to higher release of carbon emissions in Malaysia, regardless of short or long run. Based on the short run analysis, the level of carbon emissions was negatively influenced by both positive and negative lag first variances (Δ) of real output at 1% significant level. The 1% increase and decrease in economic growth, on the other hand, decreased the carbon emissions by 3.55% and 1.42%, respectively. The long run relationship outcomes in Section B revealed that all variables indeed significantly influenced carbon emissions, except for the negative shock of real output. Given that the negative and positive components of coefficients for size differed, the presence of an asymmetric association can be concluded. The asymmetric test, as displayed in Section C, confirms that both real outputs adjusted both long and short run contexts, while energy consumption only adjusted the long run, given that the probability value of the Wald F-stat is significant at 1% level. In precise, the positive impacts of real output on carbon emissions differed from the negative impacts of energy consumption. The short run symmetric adjustment was detected for energy consumption, thus failing to reject the null hypothesis of equality.

Next, based on the second model outcomes disclosed in Section A, the long run coefficients for both positive and negative shocks of carbon emissions ($\mathrm{LNCO_2}$), as well as energy consumption (LNENY), appeared to be statistically significant at 1% and 5% levels. In short, 1% increment in carbon emissions increased the Malaysian economic growth by 0.32%, while 1% decrease in carbon emissions increased the level of economic growth by 0.56%. In this non-linear relationship, both positive and negative shocks of carbon emissions seemed to generate greater growth to the country's output. This outcome offers some clues that the country's economic growth would continue to boost regardless of increase or decrease of environmental pollution. Next, it was found that the positive shock did exist in energy consumption in a positive manner and significantly had an impact on economic growth, while the negative shock in energy consumption decreased economic growth significantly. Technically, a 1% increase in this variable could increase the level of real output (LNGDP) by 0.28%, whereas a 1% decrease in energy consumption could decrease the country's real output by 0.55%. The outcomes imply that an increase in energy consumption has a pivotal role in generating economic growth. As such, it can be concluded that energy consumption does have a positive effect upon economic growth and this particular outcome is in line with that found in prior studies, such as Ang (2008) and Begum et al. (2015), who also reported that energy consumption in this country does enhance domestic production, thus bringing the economic to greater heights. The outcomes for short run shock, on the other hand, displayed that higher increment for positive shocks of energy consumption and carbon emissions at first lag would decrease the real output by 0.20% and 0.28%, respectively. Next, both positive and negative shocks of carbon emission and energy consumption, as depicted in Section B, were significant for at least 5% significant level. With the varying coefficient values detected, the presence of an asymmetric association is confirmed. The asymmetric adjustment, as revealed in Section C for both variables in this model, was detected in the short run as its F-statistic values were significant at 1% level, while based on the long run, asymmetry adjustment was noted for carbon emissions, and symmetry adjustment for energy consumption.

As for the third model, the significant relationship was only discovered for the positive shock of real output or economic growth (LNGDP) at 5% significant level. In short, a 1% increase in economic growth would increase the country's energy consumption (LNENY) by 0.68%. Thus, higher economic development demonstrates higher purchasing power for the Malaysian citizens. As a result, demands for local goods and services would begin to escalate, and in order to fulfil these demands, the producer would increase their production activities, thus leading to higher energy consumption. This outcome is in line with a prior study conducted by Azam et al. (2015), who confirmed that economic growth is an important determinant for energy consumption in Malaysia. The outcomes for short run shock also exhibited similar impact, where both positive and negative shocks of real output positively increased the level of energy consumption by 1.84 and 0.90%, respectively. Similar to the outcomes derived from the previous two models, it was found that the size of coefficient values for each variable differed in Section B, thus verifying the presence of asymmetric association. On the contrary, only one symmetric adjustment was detected, as displayed in Section C, for short run of carbon emissions ($\mathrm{LNCO_2}$) at 1% significant level.

Table 4B presents the findings of the unrestricted NARDL estimator based on long and short run asymmetric assumptions for South Korea. The long run coefficient shows that only positive shock of real (LNGDP) had a significantly negative relationship with carbon emissions ($\mathrm{LNCO_2}$), while the real output with

TABLE 4A. Long Run and Short Run Asymmetric based on NARDL estimation for Malaysia

Section A: Non-Linear estimation result					
Model 1		Model 2		Model 3	
Variables	Coefficient	Variables	Coefficient	Variables	Coefficient
C	0.079 [0.062]	C	5.762*** [1.082]	C	2.469*** [0.697]
$LNCO_{2(-1)}$	–2.168*** [0.382]	$LNGDP_{(-1)}$	–0.768*** [0.146]	$LNENY_{(-1)}$	–0.406*** [0.112]
$LNGDP^{+}_{(-1)}$	4.152*** [0.767]	$LNCO^{+}_{2(-1)}$	0.315*** [0.065]	$LNCO^{+}_{2(-1)}$	–0.185 [0.140]
$LNGDP^{-}_{(-1)}$	0.495 [0.777]	$LNCO^{-}_{2(-1)}$	0.552*** [0.109]	$LNCO^{-}_{2(-1)}$	–0.151 [0.224]
$LNENY^{+}_{(-1)}$	–0.775*** [0.276]	$LNENY^{+}_{(-1)}$	0.277*** [0.082]	$LNGDP^{+}_{(-1)}$	0.682** [0.266]
$LNENY^{-}_{(-1)}$	4.999*** [1.366]	$LNENY^{-}_{(-1)}$	–0.554** [0.238]	$LNGDP^{-}_{(-1)}$	0.535 [0.506]
$\Delta LNGDP^{+}_{(-1)}$	2.930*** [0.721]	$\Delta LNENY^{-}$	1.137 [0.198]	$\Delta LNGDP^{-}$	1.843** [0.682]
$\Delta LNGDP^{-}_{(-1)}$	–3.553*** [1.212]	$\Delta LNGDP_{(-1)}$	0.735*** [0.142]	$\Delta LNGDP^{+}$	0.904** [0.489]
$\Delta LNCO_{2(-1)}$	0.980*** [0.322]	$\Delta LNENY^{+}{}_{(-1)}$	–0.204** [0.084]		
$\Delta LNGDP^{+}_{(-1)}$	–1.421* [0.809]	$\Delta LNCO_{2}{}^{+}{}_{(-1)}$	–0.281*** [0.070]		
R square	0.77	R square	0.91	R square	0.62
Ad.R square	0.59	Ad.R square	0.81	Ad.R square	0.51
Section B: Long run relationship					
$LNGDP^{+}_{(-1)}$	1.915*** [0.168]	$LNCO^{+}_{2(-1)}$	0.410*** [0.179]	$LNCO^{+}_{2(-1)}$	–0.455 [0.370]
$LNGDP^{-}_{(-1)}$	0.228 [0.360]	$LNCO^{-}_{2(-1)}$	0.718*** [0.179]	$LNCO^{-}_{2(-1)}$	–0.371 [0.569]
$LNENY^{+}_{(-1)}$	–0.357*** [0.114]	$LNENY^{+}_{(-1)}$	0.360*** [0.069]	$LNGDP^{+}_{(-1)}$	1.679** [0.584]
$LNENY^{-}_{(-1)}$	2.305*** [0.547]	$LNENY^{-}_{(-1)}$	–0.721** [0.331]	$LNGDP^{-}_{(-1)}$	1.317 [1.233]
Section C: Presence of long run and short run asymmetry					
$LNGDP_{LR}$	_16.604***_ [0.413]	$LNCO_{2LR}$	_4.100*_ [0.152]	$LNCO_{2LR}$	0.011 [0.757]
$LNENY_{LR}$	_13.797***_ [0.524]	$LNENY_{LR}$	_1.160_ [0.334]	$LNGDP_{SR}$	0.053 [1.552]
$LNGDP_{SR}$	_17.254***_ [3.064]	$LNCO_{2SR}$	_19.056***_ [0.220]	$LNCO_{2SR}$	_13.108***_ [0.362]
$LNENY_{SR}$	0.026 [1.972]	$LNENY_{SR}$	_43.854***_ [0.350]	$LNGDP_{SR}$	_0.790_ [1.055]

Note: (*), (**), (***) indicate significance at 10%, 5% and 1% levels, respectively. + represent positive and – represent negative. Δ represent first difference which also capturing short run results. Ad.R refer to adjusted R-square. The test is performed using Stepwise Least Square. The number in [] represent standard error. The long-run coefficients (+ and –) as reveal in Section B are calculated as $\alpha^{+} = -\delta^{+}/\beta$ and $\alpha^{-} = -\delta^{-}/\beta$. The italic number in long run and short run asymmetry in Section C represent F-statistic value for Wald test. LR represent long run and SR represent short run.

negative shock suggested no adverse effect on the level of carbon emissions. Furthermore, based on the estimated coefficient, a 1% increase in positive shock for real output (LNGDP) decreased the level of carbon emissions ($LNCO_2$) by 0.69%. In this case, the high progress of economic development in South Korea, as an advanced nation, could lead to the advancement of cleaner technology, which aids in reducing pollution, thus presenting a contradicting scenario for the case in Malaysia that highlights greater environmental degradation, as displayed in Table 4A. Similar outcomes are also detected in other advanced countries in the Europe, such as Denmark and Italy (Acaravci & Ozturk 2010). Next, it was observed that both the positive and negative shocks of energy consumption for both short and long runs exhibited a direct relationship with the environmental quality in South Korea. Technically, a 1% increase in positive shock of energy consumption (LNENY) increased the level of carbon emissions by 1.11% for short run, but a reduction to 0.79% for the long run. Meanwhile, a 1% increase in the negative shock of energy consumption increased pollution by 0.94% in the short run, while its impact seemed higher in the long run with the estimate coefficient of 1.51%. As for Section B, all the variables displayed a long run correlation with carbon emission, except for negative shock of real output. The presence of the asymmetric association had been detected, given that the negative and positive component coefficients differed. Besides, the long run symmetric test for both LNGDP and LNENY had been verified, hence accepting the null hypothesis of equality. Therefore, the positive and negative shocks of these two variables have been considered similar in the long run. Meanwhile, both LNGDP and LNENY posited an asymmetric trend in the short run, thus signifying that the shocks of these two variables are non-linear.

Based on Model 2, both positive and negative shocks of carbon emissions ($LNCO_2$) and energy consumption (LNENY) appeared significant at 1 and 5 level, respectively. Hence, 1% increase in carbon emissions led to 0.54% decrease in real output (LNGDP), whereas 1% decrease in carbon emissions increased the country's real output by 1.11%, as compared to 1.03% in the short run. The decrease in carbon emissions could help to stabilize climate changes, apart from increasing the productivity capacity in the country (Boopen & Vinesh 2011). The long run positive shock of energy consumption showed that 1% increase in its value could increase the country's real output by 0.54%. This outcome is in line with a prior study conducted for South Korea by Oh and Lee (2004). Meanwhile, the negative shock of energy consumption revealed that 1% decrease in its value could decrease the country's real output by 2.27%, which is slightly lower, when compared to short run shock at 3.67%. Furthermore, the expected sign for the outcome of energy consumption in South Korea in this model is similar to that for Malaysia. Regardless of similar sign, it was observed that the size of magnitude for energy consumption on real output in South Korea is relatively higher than Malaysia. As an advanced nation, South Korea indeed has larger industries that demand massive amount of energy, when compared to the developing country of Malaysia. Next, all variables (both positive and negative shocks) were found to have a long run relationship with economic growth, as revealed in Section B. Hence, the presence of an asymmetric association is confirmed in this model due to the varied coefficients obtained for the tested variables. The asymmetric adjustment for both variables in this model further verified that in the short run based on the long run, asymmetry adjustment occurred for energy consumption (LNENY), while symmetry adjustment for carbon emissions ($LNCO_2$).

Lastly, based on Model 3, the short and long run positive shocks of carbon emissions ($LNCO_2$) exhibited a direct impact on energy consumption (LNENY). This indicates that 1% increase in carbon emissions increased the energy consumption by 0.48% and 0.54%, respectively. Wang (2013) asserted that the level of carbon emission in the country is directly related to the use of energy, which seems to be an essential factor in both production and consumption. The high release of carbon emissions can be the result of electricity and heat production gaseous fuel consumption, as well as liquid and solid fuel consumption, to name a few. The negative shock of carbon emission, on the other hand, posited a negative impact on energy consumption at 0.66% and this interaction only occurred for the short run. Next, the negative shock of real output suggested greater impacts upon energy consumption, as compared to positive shock for both short and long run estimates. Specifically, in the short run, a 1% increase (decrease) in positive (negative) shock of real output (LNGDP) increased the energy consumption by 0.55% and 2.61%, respectively. A similar impact was observed for long run estimates, where a 1% increase in positive shock of real output increased the energy consumption by 0.44%, while a 1% decrease in negative shock of real output increased the energy consumption by 2.09%. As the country's economic development become more rapid, it has the ability to provide better prospects for small and budding industries to expand their businesses. As a result, more energy consumption is required to produce more goods and services to both local and international markets. Nevertheless, the impact of higher usage of energy consumption appears to be greater if economy slump hits the nation. The country might decrease its import of high energy intensity product from market abroad and would eventually decide to produce on their own, which could lead to higher energy consumption. The presence of an asymmetric association had been verified in this model due to the varying sizes of coefficients for all variables. All variables displayed a significant correlation with energy consumption, except for negative shock of carbon emissions. Last but not least, based on the output depicted in Section C, both carbon emissions ($LNCO_2$) and energy consumption (LNENY) posited asymmetry adjustment for both short and long runs. This indicates that the effect of the positive shock upon these variables appears to differ from the effect of negative shock for both short and long runs. The findings of asymmetries in the nexus between energy consumption and economic growth

TABLE 4B. Long run and Short Run Asymmetric based on NARDL estimation for South Korea

Section A: Non-Linear estimation result					
Model 1		Model 2		Model 3	
Variables	Coefficient	Variables	Coefficient	Variables	Coefficient
C	0.598*** [0.088]	C	2.029** [0.706]	C	4.900*** [0.928]
$\text{LNCO}_{2(-1)}$	–0.692*** [0.121]	$\text{LNGDP}_{(-1)}$	–0.226** [0.090]	$\text{LNENY}_{(-1)}$	–0.801*** [0.151]
$\text{LNGDP}^{+}_{(-1)}$	–0.282*** [0.095]	$\text{LNCO}^{+}_{2(-1)}$	–0.536*** [0.161]	$\text{LNCO}^{+}_{2(-1)}$	0.536*** [0.162]
$\text{LNGDP}^{-}_{(-1)}$	–1.216 [0.969]	$\text{LNCO}^{-}_{2(-1)}$	1.111*** [0.222]	$\text{LNCO}^{-}_{2(-1)}$	0.202 [0.166]
$\text{LNENY}^{+}_{(-1)}$	0.794*** [0.150]	$\text{LNENY}^{+}_{(-1)}$	0.538*** [0.174]	$\text{LNGDP}^{+}_{(-1)}$	0.439*** [0.072]
$\text{LNENY}^{-}_{(-1)}$	1.511** [0.616]	$\text{LNENY}^{-}_{(-1)}$	–2.273*** [0.428]	$\text{LNGDP}^{-}_{(-1)}$	2.090*** [0.414]
ΔLNENY^{+}	0.794*** [0.118]	ΔLNENY^{+}	0.540*** [0.113]	$\Delta\text{LNCO}^{+}_{2}$	0.482*** [0.112]
ΔLNENY^{-}	0.944** [0.414]	$\Delta\text{LNCO}^{-}_{2}$	1.029*** [0.355]	$\Delta\text{LNCO}^{-}_{2}$	0.616*** [0.128]
$\Delta\text{LNGDP}^{-}_{(-1)}$	1.111** [0.444]	ΔLNENY^{-}	–0.907 [0.572]	ΔLNGDP^{+}	0.469*** [0.151]
$\Delta\text{LNGDP}^{+}_{(-1)}$	–0.283* [0.157]	$\Delta\text{LNENY}^{-}_{(-1)}$	3.666*** [0.856]	$\Delta\text{LNCO}^{-}_{2(-1)}$	–0.655*** [0.149]
ΔLNGDP^{-}	1.115* [0.613]	$\Delta\text{LNCO}^{-}_{2(-1)}$	–2.079*** [0.552]		
R square	0.95	R square	0.91	R square	0.94
Ad.R square	0.90	Ad.R square	0.81	Ad.R square	0.90
Section B: Long run relationship					
$\text{LNGDP}^{+}_{(-1)}$	–0.407*** [0.130]	$\text{LNCO}^{+}_{2(-1)}$	–2.372** [0.904]	$\text{LNCO}^{+}_{2(-1)}$	0.669*** [0.106]
$\text{LNGDP}^{-}_{(-1)}$	–1.756 [1.285]	$\text{LNCO}^{-}_{2(-1)}$	4.919** [2.241]	$\text{LNCO}^{-}_{2(-1)}$	0.252 [0.180]
$\text{LNENY}^{+}_{(-1)}$	1.146*** [0.120]	$\text{LNENY}^{+}_{(-1)}$	2.384*** [0.592]	$\text{LNGDP}^{+}_{(-1)}$	0.548*** [0.092]
$\text{LNENY}^{-}_{(-1)}$	2.181*** [0.730]	$\text{LNENY}^{-}_{(-1)}$	–10.060** [4.147]	$\text{LNGDP}^{-}_{(-1)}$	2.607*** [0.634]
Section C: Presence of long run and short run asymmetry					
LNGDP_{LR}	_1.135_ [1.265]	$\text{LNCO}_{2\text{LR}}$	_1.938_ [1.828]	$\text{LNCO}_{2\text{LR}}$	_7.237_** [0.155]
LNENY_{LR}	_1.972_ [0.737]	LNENY_{LR}	3.942* [3.865]	LNGDP_{SR}	_12.513_*** [0.582]
LNGDP_{SR}	_19.159_*** [1.550]	$\text{LNCO}_{2\text{SR}}$	_10.826_*** [1.358]	$\text{LNCO}_{2\text{SR}}$	10.379*** [0.232]
LNENY_{SR}	_23.141_*** [0.894]	LNENY_{SR}	_18.595_*** [2.353]	LNGDP_{SR}	18.808*** [0.722]

Note: (*), (**), (***) indicate significance at 10%, 5% and 1% levels, respectively. + represent positive and – represent negative. Δ represent first difference which also capturing short run results. Ad.R refer to adjusted R-square. The test is performed using Stepwise Least Square. The number in [] represent standard error. The long-run coefficients (+ and –) as reveal in Section B are calculated as $\alpha^{+} = -\delta^{+}/\beta$ and $\alpha^{-} = -\delta^{-}/\beta$. The italic number in long run and short run asymmetry in Section C represent F-statistic value for Wald test. LR represent long run and SR represent short run.

revealed in this country is in line with the prior studies carried out by Araç and Hasanov (2014) and Hatemi-J and Uddin (2012).

CONCLUSION AND POLICY RECOMMENDATIONS

This study investigated the asymmetries in the nexus between carbon emissions, real output, and energy consumption in Malaysia and South Korea via NARDL estimation. The analysis began by detecting the order of integration for each variable via ADF and PP unit root tests. Similar to ARDL estimation, the NARDL estimation could only be used if no variable is co-integrated at the order two. Upon confirming the unit root, the analysis was preceded by conducting a bound test for asymmetric co-integration. This test ascertained the existence of long run co-integration within the three proposed models, which had been performed by comparing the F-statistics values generated from the Wald test with the critical value table suggested by Pesaran (2001). This test had further confirmed the presence of long run co-integration in all models. Next, prior to NARDL estimation, several diagnostic tests were conducted. The results from these tests indicated that the three models for both Malaysia and South Korea had passed all the diagnostic tests, including stability test (CUSUM and CUSUMSQ), thus portraying reliable results. As for the last analysis, the focus was placed on long run positive and negative shocks for every variable, as well as the confirmation of long and short run asymmetries. Based on the first model, a significant relationship was displayed between positive real output and carbon emission for both Malaysia and South Korea. As for energy consumption, the results revealed that both its positive and negative shocks significantly influenced carbon emissions in these two countries. Next, as for the second model, both carbon emissions and energy consumption for Malaysia and South Korea significantly influenced real output. Meanwhile, as for the third model, a significant relationship was exemplified between positive shock of real output and carbon emission for the case of Malaysia. Meanwhile, significant correlations were illustrated for all variables, except for the negative shock of carbon emissions for the case of South Korea. Lastly, mixed significant outcomes had been detected for long and short run asymmetries in both nations.

The main outcome of this paper, which is based on the first model, sheds some ideas on the different implications of the tested variables for the cases of Malaysia and South Korea. The impact of increment in income or economics growth has created awareness for South Korean consumers to support and to demand for greener products, as more producers in the country have taken the initiative to invent more products in the light of being environmental-friendly, thus supporting the government's missions to protect the environmental quality. This scenario is opposite for the case of Malaysia, where greater economic growth is linked to greater environmental degradation. Thus, the policymakers in this country should take an initiative to organise more awareness campaigns to the society to support green products, while the government can impose lower tax rates for businesses that implement clean technologies in their production. Next, the challenge faced by both countries in this study is to curb the negative impact of using the existing energy consumption on environment. It is important for the policymakers of both countries to take into consideration the above implication by drafting an effective energy conversation plan that should emphasize on the use of renewable types of energy, as well as effective environmental policies to combat global warming, while stimulating economic growth at the same time. The countries need to be more cautious in preparing policies that involve energy and environmental impacts by taking into account the presence of asymmetries in the relationship between these variables. As such, further studies are needed to explore the asymmetric in the nexus among these variables.

ACKNOWLEDGEMENT

This research project is fully funded by IRMI, Universiti Teknologi MARA (600 IRMI/Dana 5/3/GOT (003/2018).

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APPENDIX

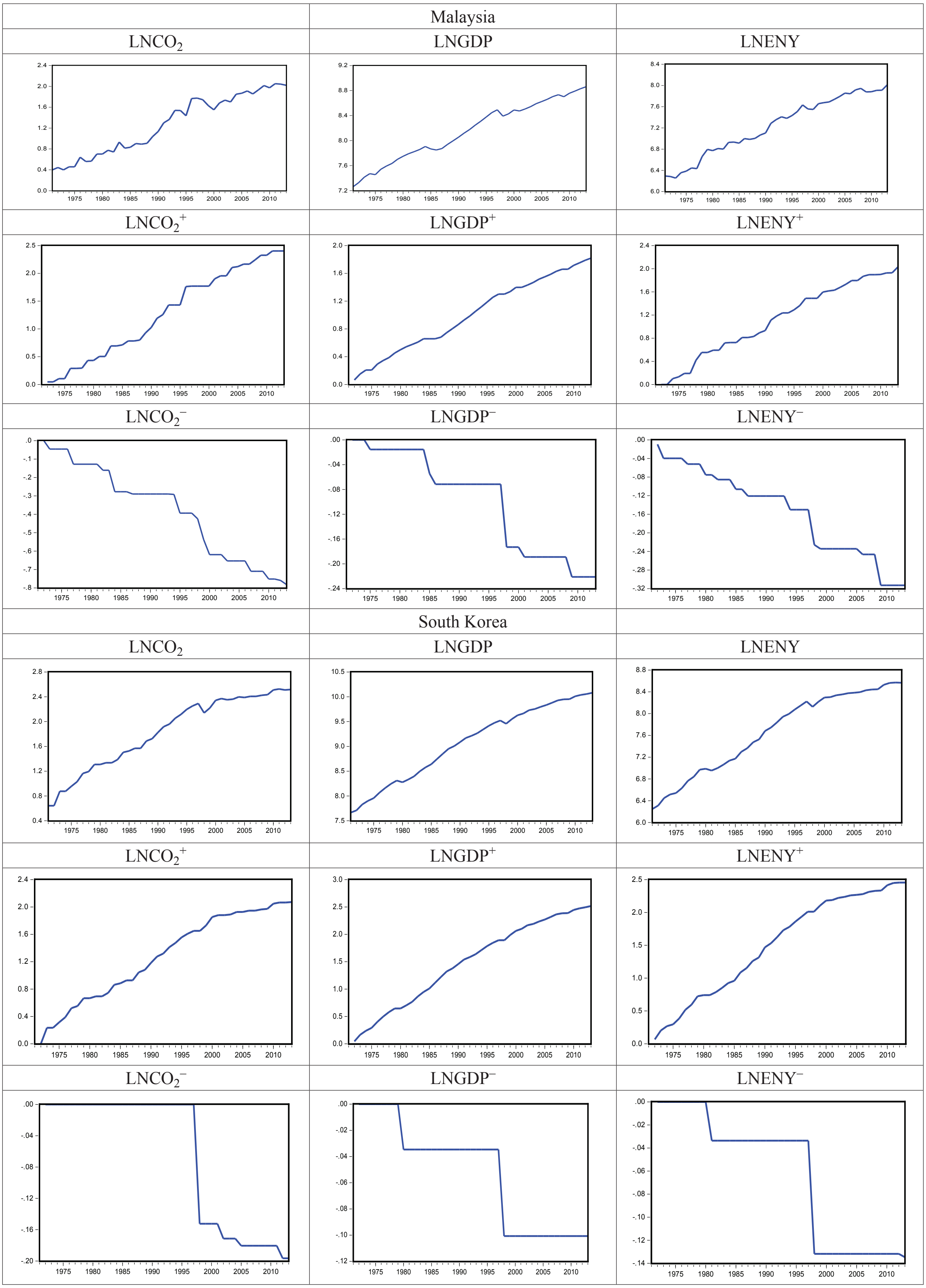

FIGURE 2. Plot of carbon emissions, real output and energy consumption as well as their cumulative sum of positive and negative components