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The Impact of Energy Consumption, Economic Growth, and Non-Renewable Energy on Carbon Dioxide Emission in Malaysia

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ABSTRACT

Human activities such as burning fossil fuels, deforestation, and economic growth are increasingly affecting the climate and temperature of the earth. Large amounts of greenhouse gases in the atmosphere have increased the greenhouse effect and global warming. By 2020, the concentration of greenhouse gases in the atmosphere has increased to 48% above its pre-industrial level. The main objectives of this study are to determine the level and the pattern of the relationship between dependent and independent variables. Also, this study examines the long-term and short-term impacts of energy consumption, economic growth, and non-renewable energy on carbon dioxide (CO_2) emissions in Malaysia. Due to increased industrialization, Malaysia faces significant problems, such as environmental pollution. This study uses annual time series data from 1986 to 2021 and is analyzed using the Autoregressive Distributed Lag approach. The study suggests that energy consumption, economic growth, and non-renewable energy positively impact carbon dioxide (CO_2) emissions. The results through dynamic ARDL indicate that energy consumption, economic growth, and non-renewable energy positively impact Malaysia's carbon dioxide (CO_2) emissions in the short-run and long run. The error correction model (ECM) provides short-run shocks in these variables and establishes equilibrium relations in the long run. Therefore, policymakers should consider implementing a carbon tax to be enforced on polluters to prevent ecological pollution at a minimum for the short-term regulation of carbon dioxide (CO_2) emissions.

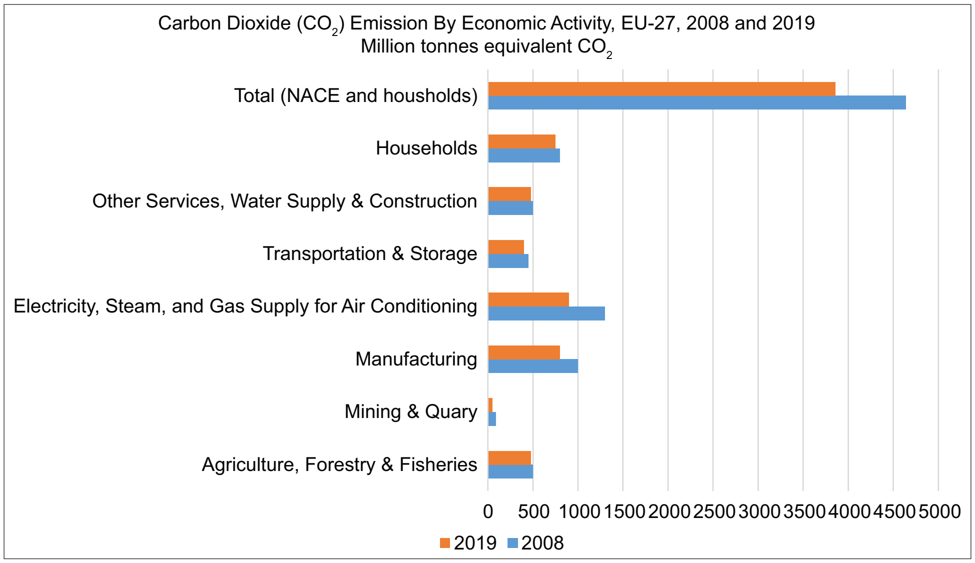
Keywords: Carbon Dioxide Emission, Energy Consumption, Economic Growth, Non-Renewable Energy, Malaysia
JEL Classifications: Q54, Q41, O40, Q42, O53

1. INTRODUCTION

Malaysia is a growing Asian country. Malaysia's economy is quickly expanding, and this trend is projected to continue in the future, with the agriculture sector playing a key role. Furthermore, rapid population growth has resulted in deforestation, with Malaysia ranking first in Asia. Economic growth and the industrial sector consume more energy, producing environmental damage. Malaysia has a high energy demand and traditional energy sources are being employed to supply it. While energy generation and transportation are significant emitters, coal-fired power plants account for 20% of worldwide GHG emissions. According to Wolde-Rufael and Menyah (2015), energy consumption produces carbon dioxide (CO_2) emissions, contributing to environmental degradation. Large volumes of greenhouse gas emissions, such as carbon dioxide, nitrous oxide, and methane, degrade the environment. Carbon dioxide (CO_2) emissions are increased by energy consumption, such as using fossil fuels in daily life, enormous smoke emissions from factories, and using wood as an energy source. Carbon dioxide (CO_2) emissions harm other sectors, such as agriculture and forestry.

Carbon dioxide (CO_2) emissions are emitted using solid, liquid, and gaseous fuels and gas combustion. Figure 1 shows carbon dioxide (CO_2) emissions by economic activity for the EU-27 countries between 2008 and 2019. Compared to 2008, greenhouse gas emissions by all economic activities in the European Community (NACE) and households were reduced by 20% in

Figure 1: Carbon Dioxide (CO_2) Emission by Economic Activity for the EU-27 Countries



2019. Between 2008 and 2019, households in the EU-27 reduced greenhouse gas emissions by 93 million metric tonnes of carbon dioxide (CO_2), equivalent to an 11% reduction. Meanwhile, carbon dioxide (CO_2) emissions from electricity, steam, and gas supply for air conditioning declined by 381 million tonnes of carbon dioxide (CO_2) equivalent in 2019, a 31% decrease from 2008. Manufacturing emissions decreased by −220 million tonnes of carbon dioxide (CO_2) equivalent in 2019 compared to 2008. In 2019, mining and quarrying emissions were reduced by 30%.

Malaysia is Southeast Asia's second-largest oil and gas producer and the world's fifth-largest LNG exporter in 2019. For marine energy trading, Malaysia is strategically located (refer to Figure 2). Malaysia's energy sector is a source of economic development or growth. So, the Malaysian government has prioritized upstream investment and exploration to grow hydrocarbon production.

The study aimed to determine the level and the pattern of the relationship between a dependent variable and independent variables. Although empirical studies found a long-term and short-term impact of energy consumption, economic growth, and non-renewable energy on carbon dioxide (CO_2) emissions, no study using time series data was still done using Malaysia data. Therefore, this research aims to see how energy consumption, economic growth, and non-renewable energy affect carbon dioxide (CO_2) emissions in Malaysia. Furthermore, the study's findings have some implications for Malaysia's carbon dioxide (CO_2) emissions. Additionally, multiple tests were done to determine all the variables' coefficients before comparing the results to the anticipated effects. The diagnostic test, unit root test, correlation test, DOLS test, and ARDL test are among the tests performed.

2. LITERATURE REVIEW

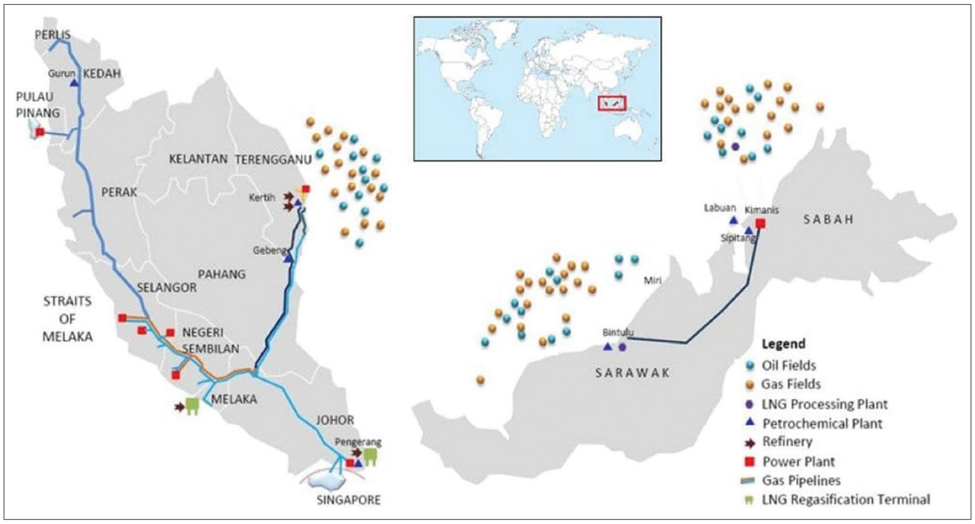
Many studies have examined the relationship between energy consumption, economic growth, and non-renewable energy on carbon dioxide (CO_2) emissions. This section will explain the impact of energy consumption, economic growth, and non-renewable energy on a country's carbon dioxide (CO2) emissions.

2.1. Energy Consumption, Economic Growth, Non-Renewable Energy, and Carbon Dioxide Emission

Aeknarajindawat et al. (2019) have discovered that natural resources, renewable energy, and economic growth raise the emission of carbon dioxide (CO_2) emission in Malaysia using the ARIMA method. A similar study was conducted by Baloch et al. (2019) but using a different method, the Panel Mean Group. His research findings also show a positive effect of natural resource variables on carbon dioxide (CO_2) emissions, except in Russia. Meanwhile, a study by Nazirah (2016) has examined the cause-and-effect relationship between energy consumption, economic growth, carbon dioxide (CO_2) emissions, and renewable energy sources using the Vector Error Correction Model (VECM) method and Environmental Kuznets Curve (EKC) against three ASEAN countries namely Malaysia, Indonesia, and Singapore. There is a one-way relationship between energy consumption and economic growth to renewable energy sources and carbon dioxide (CO_2) emissions in all three countries. Still, the Environmental Kuznets Curve (EKC) hypothesis also does not exist for all three countries.

However, Hasnisah et al. (2019) have investigated the relationship between economic growth. Energy consumption had a positive effect on carbon dioxide (CO_2) emissions, while the renewable energy source hurt carbon dioxide (CO_2) emissions using the least squares method (OLS) and Environmental Kuznets Curve (EKC), which assumes inverted U-shaped relationships in 13 developing countries in Asia. Liu et al. (2017) have studied the effects of energy consumption, economic growth, and non-renewable energy sources on carbon dioxide (CO_2) emissions using ARIMA, Granger Causality, and Environmental Kuznets Curve (EKC) methods in four selected countries Association of Southeast Asian Countries namely Indonesia, Malaysia, Philippines, and Thailand. He found that the variables of energy consumption and economic growth have a negative effect on carbon dioxide (CO_2) emissions. In contrast, the non-renewable energy source positively affects carbon

Figure 2: Oil and Gas Infrastructure in Malaysia



dioxide (CO_2) emissions. These results support the Environmental Kuznets Curve (EKC) hypothesis, which assumes an inverted U-shaped relationship in selected countries: Indonesia, Malaysia, the Philippines, and Thailand.

2.2. Energy Consumption, Economic Growth, and Carbon Dioxide Emission

Jeremiah and Hinaunye (2020) examined how urban population, energy consumption, and economic growth positively affected carbon dioxide (CO_2) emissions. The hypothesized results of the inverted U-shaped Environmental Kuznets Curve (EKC) in this study. In addition, researcher Murat Ertugrul et al. (2015) have studied that the variables of carbon dioxide (CO_2) emissions, trade openness, real income, and energy consumption are integrated against Thailand, Turkey, India, Brazil, China, Indonesia, and South Korea while the variables of real income, energy consumption, and trade openness is a major determinant of carbon dioxide (CO_2) emissions in the long run against Turkey, India, China, and South Africa. In addition, the possibility of an inverted U-shaped Kuznets Environmental Curve (EKC) hypothesis exists in the studied country. Kahia et al. (2019) have studied that economic growth variables have a positive effect on carbon dioxide (CO_2) emissions, while the variables of energy consumption, international trade, and foreign direct investment have a negative impact on carbon dioxide (CO_2) emissions. A similar study was conducted by Tang and Tan (2015) in Vietnam using the same method, which showed that the variables of energy consumption, FDI (Foreign Direct Investment), and income have a positive effect on carbon dioxide (CO_2) emissions in the short and long term. These results support the Environmental Kuznets Curve (EKC) hypothesis, which assumes an inverted U-shaped relationship between carbon dioxide (CO_2) emissions and economic growth in Vietnam.

Subsequent studies by Naz et al. (2018) investigated that the variables of Foreign Direct Investment (FDI) and economic growth have a positive effect on carbon dioxide (CO_2) emissions. Meanwhile, energy consumption variables have a negative impact on carbon dioxide (CO_2) emissions. Environmental Kuznets Curve (EKC) hypothesis is for the variables of Foreign Direct Investment (FDI) inflows, economic growth, and carbon dioxide (CO_2) emissions in Pakistan. A similar study was conducted by Khan et al. (2020) with a similar method to discover that the results of the ARDL study showed that the variables of energy consumption and economic growth have a positive effect on carbon dioxide (CO_2) emissions in Pakistan in the short and long term. A study by Khobai and Le Roux (2017) examined the existence of a two-way causality between energy consumption and economic growth in the long run. He also found that one-way causality flows from the variables of carbon dioxide (CO_2) emissions, economic growth, trade openness, and urbanization variables to energy consumption. From energy consumption, carbon dioxide (CO_2) emissions, trade openness, and urbanization variables to economic growth, the VECM method results in South Africa. Alshehry and Belloumi (2015) studied the results of Johansen's multivariate cointegration approach. They showed that there was at least a long-term relationship between energy consumption, energy prices, carbon dioxide (CO_2) emissions, and economic growth. Furthermore, the results of Granger Causality show that long-term one-way causality is from energy consumption variables to economic growth and carbon dioxide (CO_2) emissions, two-way causality between carbon dioxide (CO_2) emissions variables and economic growth, and one-way causality long-term from energy price variables to economic growth and carbon dioxide (CO_2) emissions. In the short-run, there is a one-way causality from the carbon dioxide (CO_2) emission variable to energy consumption and economic growth and from the energy price variable to carbon dioxide (CO_2) emissions.

Cheng Lu (2018) has studied the fact that both energy consumption and economic growth variables have a positive effect on carbon dioxide (CO_2) emissions, while information and communication technology (ICT) variables have a negative impact on carbon dioxide (CO_2) emissions. The cointegration test results show that energy consumption, economic growth, and financial development positively affect carbon dioxide (CO_2) emissions. Mohamad Ridzuan, Lang Tseng, Marwan, and Khalid (2020) have studied that the relationship between agricultural sub-sector variables and energy consumption had a negative effect on carbon dioxide (CO_2) emissions, while the relationship between economic growth and urbanization variables had a positive effect on carbon dioxide (CO_2) emissions. These results support the Environmental Kuznets Curve (EKC) hypothesis, which assumes an inverted U-shaped relationship between carbon dioxide (CO_2) emissions and economic growth in Malaysia. Ching Tan and Tan Shi (2018) have studied that both energy consumption and economic growth variables have a positive effect on carbon dioxide (CO_2) emissions and show one direction from economic growth, energy consumption to carbon dioxide (CO_2) emissions in the short and long term in Malaysia. Whereas Alberto Fuinhas et al. (2017) have studied that energy consumption variables have a positive effect on carbon dioxide (CO_2) emissions in the short and long term by using the use of Autoregressive Distributed Lag test in 10 Latin American Countries.

2.3. Energy Consumption, Non-Renewable Energy and Carbon Dioxide Emission

The study by El Araby et al. (2019) showed that the results showed a significant positive effect on economic growth variables and non-renewable energy sources on carbon dioxide (CO_2) emissions. In contrast, energy consumption variables negatively affect carbon dioxide (CO_2) emissions using the Hausman test and panel unit root test in the Euro Mediterranean, which is 25 countries. According to Dogan and Seker (2016) have studied that the variables of energy consumption and real income, and trade openness have a positive effect on carbon dioxide (CO_2) emissions, while the non-renewable energy source variables have a negative impact on carbon dioxide (CO_2) emissions. The author also found that the Granger Causality results show a two-way causality between the energy consumption variable and carbon dioxide (CO_2) emissions. One-way causality runs from the actual income variable to carbon dioxide (CO_2) emissions, from the carbon dioxide (CO_2) emission variable to non-renewable energy sources, as well as from trade openness variables to carbon dioxide (CO_2) emissions. These results support the Environmental Kuznets Curve (EKC) hypothesis, which assumes an inverted U-shaped relationship in European Union countries. In addition, a study by Ahmad and Majeed (2019) examined that the variables of energy consumption and trade openness had a negative effect on carbon dioxide (CO_2) emissions, while the variables of non-renewable energy sources and urbanization had a positive effect on carbon dioxide (CO_2) emissions by using the Fully Modified Ordinary Least Square Panel (FMOLS) method in selected South Asian countries.

2.4. Economic Growth, and Carbon Dioxide Emission

According to Aisah (2019) has studied the variable of Foreign Direct Investment (FDI), economic growth has a significant positive effect on carbon dioxide (CO_2) emissions. A similar study was conducted by Ara Begum et al. (2020), but in the deforestation area variable in Malaysia. The researchers found the results of the DOLS study that the economic growth variable has a significant positive effect on carbon dioxide (CO_2) emissions. In contrast, the deforestation area variable significantly negatively affects carbon dioxide (CO_2) emissions. A study by Baah Boamah et al. (2017) examined the fact that economic growth variables significantly negatively affect carbon dioxide (CO_2) emissions. These results confirm the Environmental Kuznets Curve (EKC) hypothesis, which assumes an N-shaped relationship between economic growth and long-run carbon dioxide (CO_2) emissions in Malaysia. Jardon et al. (2017) have studied the fact that economic growth variables significantly negatively affect carbon dioxide (CO_2) emissions. These results support the Environmental Kuznets Curve (EKC) hypothesis, which assumes an inverted U-shaped relationship between carbon dioxide (CO_2) emissions and economic growth in 20 Latin American and Caribbean countries. A study by Naminse and Zhuang (2017) examined the fact that economic growth variables significantly affect carbon dioxide (CO_2) emissions. Furthermore, economic growth has a two-way relationship with carbon dioxide (CO_2) emissions. These results support the Environmental Kuznets Curve (EKC) hypothesis, which assumes an inverted U-shaped relationship between carbon dioxide (CO_2) emissions and economic growth in China.

3. MATERIALS AND METHODS

This study uses a secondary data source obtained from three major reports. Firstly, the energy consumption and non-renewable energy data are obtained from the Energy Commission Report, which included Malaysia data from 1986 to 2021 (Energy Commission Report, 2022). Secondly, economic growth in real GDP is sourced from the Malaysia Economic Report, published from 1986 to 2021 (Ministry Finance of Malaysia, 1995, 1999, 2003, 2006, 2010, 2012, 2013, 2017, 2021). Lastly, carbon dioxide (CO_2) emissions data is sourced from Malaysia's Carbon (CO_2) Emissions from 1986 to 2021 (Macrotrents.net, 2021). The measurements of the variables are shown in Table 1 in detail. This study uses E-views software to analyze the data and various tests in this study, such as the correlation test, unit root test, DOLS test, and the ARDL test. This research is based on a quantitative method. The measurement of the variables is shown in Table 1 in detail.

The statistical criteria used in this study were the t-test, R-squared test (R^2), and F test. The t-test was used to test the parameters at the 1% and 5% levels. This test aims to determine whether or not three independent variables influence the dependent variables studied. At the same time, the econometric criteria aim to determine the econometric equation based on the diagnostic test, unit root test, correlation test, DOLS test, and ARDL test.

Estimation model diagnostics is a test to identify whether the model used is the best model or not from a statistical point of view. Diagnostic testing of the estimation model in this study will prove whether it is a good model or not. First, the author identified the independent variables PTit1, PEit2, and STDit3 to determine whether this model is good. The model is good if most of the independent variables are significant. This is indicated by the P value for the variable less than 5%.

Second, the match of R^2 must be 90% and if the match of R^2 is low but statistically F is significant, it is also considered a good model. If statistic F is significant, all independent variables are together with the dependent variable, match R^2 is the model in the sample, and statistic F is the model in the population. In addition, residual analyses are performed in diagnostic tests, including normality, autocorrelation, multicollinearity, and heteroskedasticity tests.

Table 1: Measurement of the variables

Variable	Definition	Source of Data
Energy Consumption	Final energy consumption by sector includes industry, transportation, residential and commercial, non-energy consumption, and agriculture.	Energy Commission Report (2022)
Economic Growth (Real GDP)	A component in National Accounting has been widely used worldwide as a benchmark for measuring a country's size and rate of economic growth.	Ministry Finance of Malaysia (1995 - 2021)
Non-Renewable Energy	Final energy consumption for petroleum products includes petrol, diesel, fuel oil, LPG, kerosene, ATF and AVGAS, non-energy, and refining gas.	Energy Commission Report (2022)
Carbon Dioxide (CO_2) Emissions	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced from solid, liquid, and gas fuels and gas flaring.	Macrotrents.net. (2021)

To determine whether this model is good from a statistical point of view, the researcher should use residual analysis such as the Normality test. If the value of P is more than 5%, this means the remainder of the normal distribution. Like normality tests, the autocorrelation, multicollinearity, and heteroskedasticity hypotheses are if the P value is more than 5%, where it cannot reject the null hypothesis. In comparison, if the P value is less than 5%, it can reject the null hypothesis. No autocorrelation problems, multicollinearity problems, and heteroskedasticity problems exist if the null hypothesis is not rejected. Based on the above four diagnostic test steps, it is possible to identify whether the model is good or not.

3.1. Econometric Model

Based on the study's theoretical framework, the linear model is the best model for determining the relationship between dependent and independent variables. The linear model used in this study is as follows:

$$CO_{2it} = \beta_0 + \beta_1 EC_{it1} + \beta_2 EG_{it2} + \beta_3 R_{it3} + \varepsilon_i$$

While carbon dioxide (CO^2) emissions are the dependent variable, which is measured with proxy as a kilo tan, β_0 is constant, β_1 is the energy consumption (EC) as total energy usage in a year in ktoe, β_2 is the economic growth as GDP growth (EG) in a year in RM million, β_3 is non-renewable energy (RWE) which is measured with final consumption in a year in ktoe, and ε_i is the error term.

The method used is *Ordinary Least Square* (OLS) through *Eviews 12 Student Version Lite* software. A regression equation is an equation that shows a linear relationship between 2 variables. This simple regression analysis estimates one variable against another variable. The variables estimated were the dependent variables (CO_{2it}) and those used to estimate the independent variables (EC_{it1}, EG_{it2}, RWE_{it3}). In this regression analysis, the relationship between these two variables must be linear, i.e., directly proportional. In addition, the researcher also used Dynamic Ordinary Least Squares (DOLS) and Autoregressive Distributed Lag (ARDL) model analysis to determine whether the results of this model are good or bad.

Comparing the probability value of each variable DOLS test result with a significant value is a technique for determining the long-run relationship between the variables in the model (1%, 5%, or 10%) and vice versa. According to Stock-Watson (1983), Dynamic Ordinary Least Square (DOLS) analysis is used to construct a single cointegration vector that characterizes long-run connections between variables in a model. Cointegration regression with lag and lead from ΔXt was used in this DOLS approach. The DOLS Stock-Watson equation model is defined as equation (1)

$$Y_t = \beta_0 + \beta X_{-} + \sum_{j=-q}^{p} d_j \Delta X_{t-j} + u_t \qquad (1)$$

Y_t is the dependent variable, X is the matrix of the independent variable, βX is the cointegration vector indicating the long-run connection or effect, p is the lag length, and q is the lead length.

In DOLS regression, the terms lag and length indicate a stochastic error or the random nature of a variable that does not depend on the complete history of previous stochastic regression. Based on the hypothesis, all long-run correlations between error variables will be absorbed by combining different lags and regressor leads. The ARDL model is relatively more efficient for small and finite sample data sizes. Using the ARDL technique, unbiased long-term estimates were obtained. The general ARDL model (p, q) is expressed as in equation (2)

$$Y_t = \gamma_{0i} + \sum\nolimits_{i=1}^{p} \delta Y_{t-i} + \sum\nolimits_{i=1}^{q} \beta'_i X_{t-i} + \varepsilon_t \qquad (2)$$

Where Y't is a vector and the variable in (X't) 'is allowed only I(0) or I(1) or integrated; β and δ are coefficients; γ is a constant; i = 1,… k; p, q is the optimal lagging order; Ɛt is the vector for the non-observable error term zero mean white noise vector process (serially uncorrelated or independent variable). The dependent variable is a function of the model's lagging value, current value, and other exogenous variables. The lag lengths for p, and q may not be the same. Indication p refers to the dependent variable's previous lag, while q refers to the exogenous variable's previous lag. To perform a bound test for cointegration, the ARDL model is conditional with βij variable coefficient previous lag expressed as in equation (3).

Hypothesis is;
H_0: There is no cointegration ($\beta ij = 0$),
H_1: There is cointegration ($\beta ij \neq 0$)

$$\Delta CO_{2\,t} = \alpha_1 + \beta_{11} CO_{2\,t-1} + \beta_{21} EC_{t-1} + \beta_{31} EG_{t-1} + \beta_{41} RWE_{t-1} + \sum_{i=1}^{p} \alpha_{1i} \Delta CO_{2\,t-i} + \sum_{i=1}^{q} \alpha_{2i} \Delta EC_{t-i} + \sum_{i=1}^{r} \alpha_{3i} \Delta EG_{t-i} + \sum_{i=1}^{s} \alpha_{4i} \Delta RWE_{t-i} + \varepsilon_{1t} \quad (3)$$

Based on the study's objectives, the ARDL model is a better model to employ than others because it is more reliable and performs better with small samples of data, which is appropriate for this research. Identifying the short-run and long-run effects of independent variables on carbon dioxide (CO_2) emissions is also preferable, which is why the ARDL model was used to find the study's findings. Most of the past researchers used the ARIMA model to conduct their studies. Using the ARIMA approach, Aeknarajindawat et al. (2019) found that Malaysia's natural resources, renewable energy, and economic growth all cause an increase in carbon dioxide (CO_2) emissions. However, the findings of this study indicate that renewable energy has a negative impact on carbon dioxide (CO_2) emissions, while natural resources and economic growth have a positive impact. By applying the ARIMA model to determine the short-run and long-run effects of independent variables on carbon dioxide (CO_2) emissions, this research cannot provide a precise conclusion.

4. RESULTS AND DISCUSSION

Table 2 shows the two variables' descriptive statistics and Pearson correlation analysis. The mean and standard deviation indicate no isolated values in the data. All series displayed an excess of kurtosis, while the skewness for each variable was negative. Next, the Jarque-Bera normality test showed that the data analysis was normal. Table 2 shows the Pearson correlation analysis between study variables. The study results found that the Pearson correlation value is a strong positive relationship between the carbon dioxide (CO_2) emissions variable and the energy consumption (EC) is r = 0.9943, close to 1 at a significant level of 0.01. In addition, the Pearson correlation value is a strong positive relationship between the carbon dioxide (CO_2) emissions variable and economic growth (EG), which is r = 0.9939, which is close to 1 at a significant level of 0.01. The third Pearson correlation value is a strong positive relationship between the carbon dioxide (CO_2) emission variable and non-renewable energy (RWE) that is r = 0.9860, close to 1 at a significance level of 0.01.

In addition, the Pearson correlation value is a strong positive relationship between energy consumption (EC) variables and economic growth (EG), which is r = 0.9912, close to 1 at the significance level of 0.01. The fifth Pearson correlation value is a strong positive relationship between the energy consumption (EC) variable and non-renewable energy (RWE), r = 0.9918, close to 1 at the significance level of 0.01. Next, the Pearson correlation value is a strong positive relationship between the economic growth (EG) variable and non-renewable energy (RWE), r = 0.9751, close to 1 at the significance level 0.01.

Figure 3 shows carbon dioxide (CO_2) emissions, energy consumption, economic growth, and non-renewable energy in Malaysia from 1986 to 2021 (Ritchie and Roser, 2021). Increasing trends in carbon dioxide (CO_2) emissions, energy consumption, economic growth, and non-renewable energy were shown from 1986 to 2008 and decreased in 2009. This is because, in the transport sector, initiatives have been taken to control smoke emissions from motor vehicles through the increased use of energy-efficient vehicles and biofuels. At the same time, there was a financial crisis in Malaysia. The rising transport sector has led to a widening service deficit. For non-renewable energy, the use of fossil fuels, namely crude oil and gas, and coal has decreased while the use of hydro has increased. These changes reflect a reduction in dependence on fossil fuel sources.

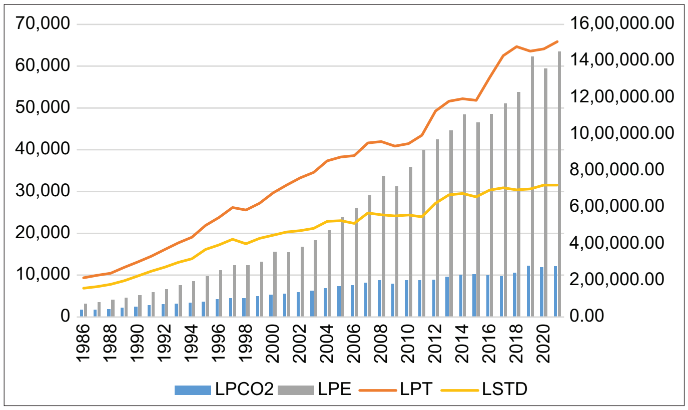
From 2010 to 2014, energy consumption, economic growth, and non-renewable energy showed an increasing trend due to the industrial sector burning fossil fuels such as gas and coal to power machines and machinery. In addition, electricity generation capacity has been increased by operating 10 power plants to ensure a secure electricity supply. Carbon dioxide (CO_2) emissions increased from 2010 to 2013. However, in 2014, carbon dioxide (CO_2) emissions decreased as the government implemented the B7 program and reduced greenhouse gas

Table 2: Results of descriptive statistics and pearson correlation

	$lnCO^2$	lnEC	lnEG	lnRWE
Mean	11.7694	10.3342	12.9481	9.8585
Standard deviation	0.5953	0.5856	0.9172	0.4514
Skewness	−0.5660	−0.5700	−0.3574	−0.8948
Kurtosis	2.1006	2.2233	1.9082	2.7133
Jarque-Bera	3.1353	2.8544	2.5545	4.9281
Probability	0.2085*	0.2399*	0.2787*	0.0850*
Pearson Correlation Analysis				
	$lnCO^2$	lnEC	lnEG	lnRWE
$lnCO^2$	1.0000			
lnEC	0.9943 (0.00)***	1.0000		
lnEG	0.9939 (0.00)***	0.9912 (0.00)***	1.0000	
logRWE	0.9860 (0.00)***	0.9918 (0.00)***	0.9751 (0.00)***	1.0000

The signs *,**, and *** are significant at 10%, 5% and 1%. The value of "( )" is probability

Figure 3: Dynamics of Carbon Dioxide (CO_2) Emissions, Energy Consumption, Economic Growth, and Non-Renewable Energy in Malaysia



emissions (GHGs) by 1.7 million tons of carbon dioxide equivalent (tCO2eq).

In 2015, energy consumption, economic growth, and non-renewable energy declined due to rising building material prices and high inflationary pressures in the residential sub-sector. From 2016 to 2018, there was an increase in energy consumption, economic growth, and non-renewable energy. Meanwhile, carbon dioxide (CO_2) emissions increased in 2015 and decreased from 2016 to 2017. This is due to major downstream oil and gas sub-sector developments, such as PETRONAS's implementation of the Pengerang Integrated Petroleum Complex (PIPC) project to ensure sustainable economic growth and energy supply security.

There has been an increasing trend in carbon dioxide (CO2) emissions, energy consumption, economic growth, and non-renewable energy from 2018 to 2019, and it has declined in 2020 due to the COVID-19 pandemic crisis. When the Malaysian government tightened the Movement Control Order (MCO), all sectors of the economy, namely manufacturing, industry, development, and others, were laid off. Therefore, carbon dioxide (CO_2) emissions in Malaysia can be reduced. Meanwhile, economic growth in Malaysia contracted due to the COVID-19 pandemic crisis in the global economy. Developments with the COVID-19 pandemic crisis and policy responses have never been taken before to mitigate the economic shocks.

In 2021, carbon dioxide (CO_2) emissions, energy consumption, economic growth, and non-renewable energy will increase as the government implements the Recovery Movement Control Order (RMCO) by allowing some economic sectors to re-operate and be subject to Standard Operating Procedures (SOPs). Meanwhile, the economy grew slowly due to some initiatives taken, such as working from home to pursue the economy, except international trade. The Malaysian government focuses on producing non-renewable energy by considering them as the backbone of the economy. When there is an increase in energy consumption, economic growth, and non-renewable energy, carbon dioxide (CO_2) emissions will also increase in Malaysia and vice versa.

The unit root test is a prerequisite and assumption of secondary data where the data for each variable should be placed at the level I (0) or 1st difference I(1). Two different unit root tests, namely Augmented Dickey-Fuller (ADF) and Phillip Perron (PP), were used to check the stationary from the data (Table 3). As noted earlier in the analysis graph (Table 2), most variables are stationary at level, ADF and PP test results show all variables and stationery at 1st difference, which qualifies ARDL analysis. However, results also show that some variables are stationary on the level as well. Therefore, ARDL testing can be continued.

Table 4 shows the results of OLS, DOLS, and ARDL (1,1,1,1). The OLS results show that the relationship between the variables of carbon dioxide (CO_2) emissions and the three variables, namely energy consumption, economic growth, and non-renewable energy, is positive and significant. Meanwhile, the DOLS results show a long-run demand relationship by predicting the same sign as the ARDL model in Table 4. Still, it is insignificant except for variable EG (significant in 10%). The regression diagnostic tests for OLS and ARDL showed that residues from the regression estimates did not display heteroscedasticity, serial correlation, and normality problems in the OLS and ARDL model estimates analysis. The adjusted R^2 and R^2 values obtained improve from the OLS model to the ARDL model. The estimated coefficients for the variables of carbon dioxide (CO_2) emissions, energy consumption (EC), economic growth (EG), and non-renewable energy (RWE) are statistically significant at the 0.10 significance level in the ARDL model as well.

Table 5 shows the results of the cointegration test and the ARDL bound test. Hypothesis H_0 is rejected for the cointegration test, and there is a cointegration in all variables. Therefore, bound tests with the ARDL model (1,1,1,1) were performed to decide on cointegration through F-statistics. Thus, the calculated F-statistic value is smaller than the value above the value of I(1) Bound at the 10% significance level. This indicates that cointegration does not exist among the study variables. Therefore, these results provide conclusive evidence of the long-run relationship between the variables of carbon dioxide (CO_2) emissions, energy consumption, economic growth, and non-renewable energy in Malaysia.

Table 6 shows the results of short-run coefficient estimation from the error correction model (ECM) with the ARDL model (1,1,1,1) and the diagnostic tests for the ARDL-ECM model. ECM values should be statistically significant and negative. The ECM value is - 0.7487, meaning that almost 75% of the discrepancies between long-run and short-run are corrected within a year. In the model, the ECM coefficient implies that the model corrects for the 75% imbalance in the previous period and tends towards long-run equilibrium at a speed of 75% in the current period.

Hypothesis H_0 failed to reject the serial correlation LM test, indicating no autocorrelation in the analysis of the ARDL-ECM model. Similarly, hypothesis H_0 failed to push for a heteroscedasticity test using the Breusch-Pagan-Godfrey test, indicating that the analysis of the ARDL-ECM model

Figure 4: Plot of the CUSUM and CUSUM of Square

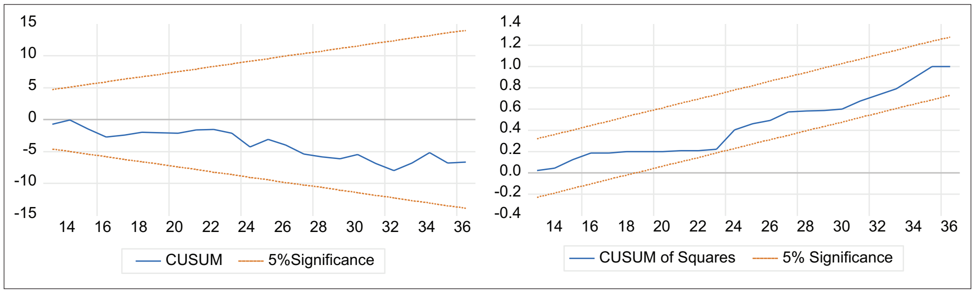


Table 3: Result of unit root test

Variables	Augmented Dickey-Fuller		Phillip-Perron	
	Level I (0)	1st Difference I (1)	Level I (0)	1st Difference I (1)
$lnCO^2$	−1.1103	−5.1132	−0.6211	−5.0944
lnEC	−1.3264	−3.8998	−1.6474	−3.9349
lnEG	−1.1630	−5.9943	−0.9845	−6.0268
lnRWE	−1.7393	−4.5106	−2.1513	−4.5322

The signs * is significant at the level of Mac Kinnon 5% (1996)

Table 4: Results of OLS, DOLS, and ARDL

Variables	OLS	DOLS	ARDL (1,1,1,1)
C	1.7996 (0.0000)***	1.3628 (0.5553)	0.4763 (0.1508)
$lnCO_2$ (-1)	-	-	0.5827 (0.0000)***
lnEC	0.0934 (0.6636)	0.3386 (0.3434)	−0.5061 (0.0640)*
lnEC (-1)	-	-	0.6608 (0.0192)**
lnEG	0.3993 (0.0000)***	0.2443 (0.0660)*	0.5807 (0.0000)***
lnEG (-1)	-	-	−0.4961 (0.0002)***
lnRWE	0.3887 (0.0244)**	0.3825 (0.1637)	0.5757 (0.0175)**
lnRWE (-1)	-	-	−0.3983 (0.0891)*
F-statistic	1707.532		1565.653
Durbin-Watson statistic	0.6918		1.8635
Long variance		0.0032	
Diagnostic Test			
R^2	0.9937	0.9961	0.9975
Adjusted R^2	0.9932	0.9937	0.9969
χ^2 BPG	0.1740		0.3050
χ^2 LM	0.0005		0.6905
χ^2 normality	1.1971		0.1360

*,**, and *** are significant at 10%, 5%, and 1%. The value of "( )" is probability

Table 5: Results of cointegration test and bound test

ARDL (1,1,1,1) Bound test		
Statistics test	Value	k
F-statistics	3.5928	3
Bound critical value		
Significant	I (0) Bound	I (I) Bound
10%	2.618	3.532
5%	3.164	4.194
1%	4.428	5.816

*,**, and *** are significant at the level of 10%, 5% and 1%

is homoscedasticity. Meanwhile, the Jarque-Bera normality test showed that the analysis of the ARDL-ECM model was normal. The results of diagnostic tests indicate that this model is independent of problem econometrics.

Figure 4 shows the plot of the CUSUM and CUSUM square. Both are used to study if the coefficients are stable or not. The results show that the coefficient is stable at the 5% significance level because the blue line of both graphs is below the red line, indicating the coefficient's stability, so the model used is stable.

Table 6: Results of short-run coefficient estimation from error correction model (ECM) with ARDL model (1,1,1,1)

Variables	Model	
	Short-Run	Prob
C	1.1418	0.0000***
Δ $lnPT_{t-i}$	0.3708	0.1765
Δ $lnPE_{t-i}$	0.2027	0.0002***
Δ $lnSTD_{t-i}$	0.4251	0.8147
ECT_{t-1}	- 0.7487	0.0000***
Diagnostic test ARDL-ECM		
Heteroscedasticity test result		
Breusch-Pagan-Godfrey	0.3050	
Serial correlation LM test result		
Breusch-Godfrey	0.4939	
Normality test result		
Normaliti Jarque-Bera	0.9891	

*,**, and *** are significant at the level of 10%, 5% and 1%

5. CONCLUSION

Human activities such as burning fossil fuels, deforestation, and economic growth are increasingly affecting the climate and temperature of the earth. Large amounts of greenhouse gases in the atmosphere have increased the greenhouse effect and global warming. By 2020, the concentration of greenhouse gases in the atmosphere has increased to 48% above its pre-industrial level. Due to increased industrialization, Malaysia faces significant problems, such as environmental pollution. This research aims to see how energy consumption, economic growth, and non-renewable energy affect carbon dioxide (CO_2) emissions in Malaysia. Due to increased industrialization, Malaysia faces significant problems, such as environmental pollution.

The first hypothesis of this paper is consistent with the researchers' investigations (Aeknarajindawat et al., 2019; Jeremiah and Hinaunye, 2020). When the energy consumption in the state increases, carbon dioxide (CO_2) emissions will increase. Moreover, the outcomes of this article demonstrate that energy consumption's effect on carbon dioxide (CO_2) emission is positive. The second hypothesis is by the study's results (Nazirah, 2016). When there is an increase in economic growth, there will be an increase in carbon dioxide (CO_2) emissions. But, the outcomes of this paper reveal the positive effect of economic growth on carbon dioxide (CO_2) emission. The third hypothesis is supported by Dogan and Seker (2016). When there is an increase in non-renewable energy, there will be an increase in carbon dioxide (CO_2) emissions. Additionally, the outcomes of this study indicate that the influence of non-renewable energy on carbon dioxide (CO_2) emission is a negative relationship. In short, energy consumption, economic growth, and non-renewable energy positively affect carbon dioxide (CO_2) emissions in Malaysia.

Energy consumption is hazardous to the environment, and the rapid increase in domestic oil demand could intensify the degradation of environmental quality through carbon dioxide (CO_2) emissions. Policymakers in Malaysia should establish policies on energy diversification because of the significant impact of energy consumption on carbon dioxide (CO_2) emissions. In addition, the Malaysian government should enhance the energy system, increase energy efficiency, and promote renewable energy growth. As a result, Malaysia should implement policies such as increasing energy efficiency and minimizing energy consumption. These initiatives should focus on sectors that rely substantially on fossil fuels, such as construction, transportation, and industry, which account for more than 90% of Malaysia's total energy consumption. Building a public transportation network within cities, driving fuel-efficient cars, enhancing building isolation methods, and encouraging the adoption of efficient energy technologies are all examples of policies that may be implemented.

With these actions, Malaysia could reduce its non-renewable energy and carbon dioxide (CO_2) emissions. Renewable energy sources, such as solar, wind, geothermal, and waste-to-energy, are also key medium and long-term alternatives for Malaysia in reducing carbon dioxide (CO_2) emissions. Malaysia has a large potential for renewable energy sources like wind and solar, which can contribute significantly to the country's energy supply (Lee et al., 2022). However, any policy adopted should consider the competitiveness of renewable energy sources compared to fossil fuels (Kabeyi and Olanrewaju, 2022). For example, Malaysia's extremely high energy price subsidies may discourage energy consumers, particularly in energy-intensive industries, from making significant investments that would allow them to shift to renewable energy sources. Additionally, the decision-makers should consider implementing a carbon tax to enforce it on polluters to prevent ecological pollution at a minimum for the short-term regulation of carbon dioxide (CO_2) emissions.

REFERENCES

Aeknarajindawat, N., Suteerachai, B., Suksod, P. (2019), The impact of natural resources, renewable energy, economic growth on carbon dioxide emission in Malaysia. International Journal of Energy Economics and Policy, 10(3), 211-218.

Ahmad, W., Majeed, M.T. (2019), The impact of renewable energy on carbon dioxide emission: An empirical analysis of selected South Asian countries. Ukrainian Journal of Ecology, 9(4), 527-534.

Aisah, S. (2019), Influence of Foreign Direct Investment (FDI) dan economic growth on carbon dioxide emission in Indonesia. Journal of Social Economics, 2019, 1-110.

Alberto Fuinhas, J., Cardoso Marques, A., Koengkan, M. (2017), Are renewable energy policies upsetting carbon dioxide emission? The case of Latin America countries. Environmental Science and Pollution Research, 24, 15044-15054.

Alshehry, A.S., Belloumi, M. (2015), Energy consumption, carbon dioxide emissions and economic growth: The case of Saudi Arabia. Renewable and Sustainable Energy Reviews, 41, 237-247.

Ara Begum, R., Raihan, A., dan Mohd Said, M.N. (2020), Dynamic impacts of economic growth and forested area on carbon dioxide emissions in Malaysia. Renewable and Sustainability Energy Reviews, 12, 9375.

Baah Boamah, K., Jianguo, D., Asare Bediako, I., Jacinta Boamah, A., Abdul-Rasheed, A.A., Mensah Owusu, S. (2017), Carbon dioxide emission and economic growth of China - The role of international trade. Environmental Science and Pollution Research, 24, 13049-13067.

Baloch, M.A., Mahmood, N., Zhang, J.W. (2019), Effect of natural resources, renewable energy and economic development on CO_2 emissions in BRICS countries. Science of the Total Environment, 678, 632-638.

Cheng Lu, W. (2018), The impacts of information and communication technology, energy consumption, financial development, and economic growth on carbon dioxide emissions in 12 Asian countries. Mitigation and Adaptation Strategies for Global Change, 23(8), 1351-1365.

Ching Tan, C., Tan, S. (2018), Energy consumption, Co_2 emissions and economic growth: A causality analysis for Malaysian industrial sector. International Journal of Energy Economics and Policy, 8(4), 254-258.

Dogan, E., Seker, F. (2016), Determinants of Co_2 emissions in the european union: The role of renewable and non-renewable energy. Energy, 94, 429-439.

El Araby, L., Sawak, N., Ibrahiem, D.M. (2019), The impact of renewable and non-renewable energy on carbon dioxide Emission: An empirical analysis for euro Mediterranean countries. International Journal of Energy Economics and Policy, 9(6), 103-108.

Energy Commission Report (2022). Malaysia Energy Statistics Handbook 2022. https://www.st.gov.my/contents/files/download/116/

Malaysia%20Energy%20Statistics%20Handbook%202022%20%28Updated%29.pdf

Hasnisah, A., Azlina, A.A., Che Taib, C.M.I. (2019), The impact of renewable energy consumption on carbon dioxide emissions: Empirical evidence from developing countries in Asia. International Journal of Energy Economics and Policy, 9(3), 135-143.

Jardon, A., Kuik, O., Tol, R.S.J (2017), Economic growth and carbon dioxide emissions: An analysis of Latin America and the Caribbean. Atmosfera, 30(2), 87-100.

Jeremiah Mosikari, T., Hinaunye Eita, J. (2020), Co_2 emissions, urban population, energy consumption and economic growth in selected African countries: A Panel Smooth Transition Regression (PSTR). OPEC Energy Review, 44, 319-333.

Kabeyi, M. J. B., & Olenwaraju, O. A. (2022). Sustainability in the energy transition to renewable and low carbon grid electricity generation and supply. Frontiers in Energy Research, 9, 1-45.

Kahia, M., Ben Jebli, M., Belloumi, M. (2019), Analysis of the impact of renewable energy consumption and economic growth on carbon dioxide emissions in 12 MENA countries. Clean Technologies and Environmental Policy, 21, 871-885.

Khan, M.K., Khan, M.I., Rehan, M. (2020), The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan. Financial Innovation, 6(1), 1.

Khobai, H., Le Roux, P. (2017), The relationship between energy consumption, economic growth and carbon dioxide emission: The case of South Africa. International Journal of Energy Economics and Policy, 7(3), 102-109.

Lee, C.C., & Wang, F. (2022). How does digital inclusive finance affect carbon intensity? Economic Analysis and Policy, 75, 174-190.

Liu, X., Zhang, S., Bae, J. (2017), The impact of renewable energy and agriculture on carbon dioxide emissions: Investigating the environmental Kuznets curve in four selected ASEAN countries. Journal of Cleaner Production, 164, 1239-1247.

Macrotrents.net. (2021), Malaysia Carbon (CO_2) Emissions 1960-2021. Available from: https://www.macrotrends.net/countries/MYS/malaysia/carbon-co2-emissions

Ministry Finance of Malaysia. (1995), Economic Report 1994/95, (1985-1995). Available from: https://s.docworkspace.com/d/ajkmltqf_vuxmu_i2junfa

Ministry Finance of Malaysia. (1999), Economic Report 1998/99, (1992-1999). Available from: https://s.docworkspace.com/d/ap0jzyaf_vuxkolk2junfa

Ministry Finance of Malaysia. (2003), Economic Report 2002/03, (1999-2003). Available from: https://s.docworkspace.com/d/amcjhc-f_vux-pzh2junfa

Ministry Finance of Malaysia. (2006), Economic Report 2005/06, (2002-2006). Available from: https://s.docworkspace.com/d/ademnyaf_vux-slf2junfa

Ministry Finance of Malaysia. (2010), Economic Report 2009/10, (2007-2010). Available from: https://s.docworkspace.com/d/acv0mwmf_vux4qlg2junfa

Ministry Finance of Malaysia. (2012), Economic Report 2012, (2009-2012). Available from: https://www.treasury.gov.my/arkib/2013/le/jp3_4.pdf

Ministry Finance of Malaysia. (2013), Economic Report 2012/13,(2010-2013). Available from: https://s.docworkspace.com/d/afjme_ef_vuxkrze2junfa

Ministry Finance of Malaysia. (2017), Economic Report 2016/17, (2013-2017). Available from: https://s.docworkspace.com/d/apcoee6f_vuxipjd2junfa

Ministry Finance of Malaysia. (2021), Economic Report 2020/21, (2015-2021). Available from: https://s.docworkspace.com/d/alc7cdaf_vuxsqln8p2nfa

Mohamad Ridzuan, N.H.A., Marwan, N.F., Khalid, N., Ali, M.H., Tseng, M.L. (2020), Effects of agriculture, renewable energy, and economic growth on carbon dioxide emissions: Evidence of the environmental Kuznets curve. Resources, Conservation and Recycling, 160, 104879.

Murat Ertugrul, H., Cetin, M., Seker, F., Dogan, E. (2015), The impact of trade openness on global carbon dioxide emissions: Evidence from The top ten emitters among developing countries. Munich Personal RePEc Archive, 67, 543-555.

Naminse, E.Y., Zhuang, J. (2017), Economic growth, energy intensity, and carbon dioxide emissions in China. Policy Journal Environmental Study, 5(27), 2193-2201.

Naz, S., Sultan, R., Zaman, K., Aldakhil, A.M., Nassani, A.A., Qazi Abro, M.M. (2018), Moderating and mediating role of renewable energy consumption, FDI inflows, and economic growth on carbon dioxide emissions: Evidence from robust least square estimator. Environmental Science and Pollution Research, 26, 2806-2819.

Nazirah, I. (2016), Effects of energy consumption, renewable energy and economic growth on carbon dioxide Emissions in three selected Asean countries. International Journal of Energy Economics, 1(1), 1-181.

Ritchie, H., Roser, M**.** (2021), Malaysia: CO_2 Country Profile. Our World in Data. Available from: https://ourworldindata.org/co2/country/malaysia

Sasana, H., Aminata, J. (2018), Energy subsidy, energy consumption, economic growth, and carbon dioxide emission: Indonesian case studies. International Journal of Energy Economics and Policy, 9(2), 117-122.

Tang, C.F., Tan, B.W. (2015), The impact of energy consumption, income and foreign direct investment on carbon dioxide emissions in Vietnam. Energy, 79, 447-454.