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A COINTEGRATION ANALYSIS OF ECONOMIC GROWTH AND CO2 EMISSIONS: CASE STUDY ON MALAYSIA

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ABSTRACT: *The paper aims to establish a long-run and causal relationship between economic growth, CO2 emissions, international trade, energy consumption, and population density in Malaysia. The study will use annual data from 1970 to 2014. A unique cointegrating relationship between our variables was identified, and the Environmental Kuznets Curve (EKC) hypothesis was analyzed using the Auto Regressive Distributed Lag (ARDL) methodology. Our empirical results suggest the existence of a long-run relationship between per capita CO2 emissions and our explanatory variables. The Vector Error Correction Model (VECM) methodology was used to analyze the Granger Causality, and the results show the absence of causality between CO2 emissions and economic growth in the short-run while demonstrating uni-directional causality from economic growth to CO2 emissions in the long-run.*

KEYWORDS: Economic growth, CO2 emissions (dependent variable), Environmental Kuznets Curve (EKC) Auto-Regressive Distributed Lag (ARDL)

INTRODUCTION

Since the early 1800s, scientists have labored day and night to understand Earth's climate and how it changes over time through direct and indirect causes. With high investment in research and development, scientists have discovered that many factors influence and affect our climate, and global warming is one of the several factors. In 1824, a French scientist, Joseph Fourier, explained that Earth's temperature would drop significantly, if the planet lacked adequate atmospheric replacement tools, and in 1859 an English scientist, John Tyndall, discovered that the chief gases that trapped heat were water vapor and carbon dioxide (Steve Graham, 1999). In early 1896, the Swedish scientist Svante Arrhenius argued that burning fossil fuels such as coal will lead to additional CO2 emission in Earth's atmosphere, and will result in a total rise in Earth’s average temperature.

In recent years, the issues of emissions reduction policies have garnered profound attention from both policymakers and academic researchers, with the highest per capita greenhouse gas (GHG) emitter among the Annex I parties[1]. The United Nations (UN) Framework Convention on Climate

[1] http://unfccc.int/parties_and_observers/parties/annex_i/items/2774.php

Change (UNFCCC)[2], has led to many countries pledging and aiming to reduce GHG emission at a considerable rate. This greenhouse effect is one of many speculations about climate change and global warming. Since the late 2000s, climate change, alternative sources of energy, going green, and global warming has been at the center of an intense world debate. The current foundation for affirmative action and policies rest on the Paris Agreement of 2016, which builds upon the framework convention on climate change.

Table 1:
A Comparison of per capita CO2 Emissions measured in Metric tons:

Years	World	Malaysia
1970 - 1979	42.29790256	16.63678457
1980 - 1989	41.32007651	23.80456687
1990 - 1999	40.65329456	47.79754709
2000 - 2009	48.09206881	69.24034046
2010 - 2014	24.75732999	38.96063517

Source: World Bank (2017).

Recently, the effectiveness of environmental regulations in emerging markets has become more of a critical issue when it comes to climate change, both on a national and global level. As their production and economic activities increases, it eventually leads to pollution. Malaysia is an excellent example of an emerging market with local air and water pollution that has shown substantial health cost and issues to its locals.With a population size of 31.19 million people as of 2016, Malaysia CO2 emissions per capita have increased from 4.63 metric tons in 1996 to 8.09 metric tons in 2015, which is a 74.73% increase in CO2 emissions into the environment. In 2009, the Malaysian government established the National Green Technology Policy (NGTP), which is responsible for many policies and programs[3], and the Malaysian government has engaged with several international accords.The study will investigate the long-run and causal relationship between economic growth and carbon dioxide emissions based on the EKC hypothesis for Malaysia during the period 1970 – 2014. The Cointegration analysis was conducted using the ARDL approach, and causality analysis tested the stability.

LITERATURE REVIEW

The Saboori and Sulaiman (2013) paper, *Environmental degradation, economic growth, and energy consumption: evidence of the environmental Kuznets curve in Malaysia*, used the EKC to test the short and long-run relationship between economic growth, CO2 emissions, and energy consumption in Malaysia. The authors used the aggregated and disaggregated energy consumption data in Malaysia for the period 1980–2009 for their study. The ARDL methodology and Johansen–

[2] http://unfccc.int/files/national_reports/non-annex_i_parties/biennial_update_reports/application/pdf/malbur1.pdf
[3] Source: Iopscience.iop.org/article/10.1088/1755-1315/16/1/012121/pdf

Juselius maximum likelihood approach was used to test our cointegration relationship, and the Granger causality test, based on the VECM, was used to test for causality.

The results found no evidence of an inverted U-shaped relationship (EKC) when aggregated energy consumption data was used. When the data was disaggregated based on different energy sources such as oil, coal, gas, and electricity, the study showed evidence of the EKC hypothesis. The long-run Granger causality test exhibited a bi-directional causality between economic growth and CO2 emissions with coal, gas, electricity, and oil consumption. This suggests that decreasing energy consumption such as coal, gas, electricity, and oil appears to be an effective way to control CO2 emissions but will simultaneously hinder economic growth (Behnaz Saboori 2012). The authors' conclude that suitable policies are required when it relates to efficient consumption of energy resources and the use of renewable sources are necessary.

The EKC hypothesis has been tested using the Ordinary Least Square (OLS) time series methodology for studying individual countries. Studies that have used this method for different countries include:

Table 2:

Authors	**Date**	**Area of Study**
Dijkgraaf and Vollebergh	1998	Individual OECD countries
De Bruyn et al.	1998	Netherlands, West Germany, the UK, and the USA
Roca et al.	2001	Spain
Day and Grafton	2003	Canada
Friedl and Getzner	2003	Austria
Akbostanic et al.	2009	Turkey
Fodha and Zaghdoud	2010	Greece, Malta, Oman, Portugal, and the UK
Saboor and Sulaiman	2013	Malaysia
Marie-Sophie Hervieux and Olivier Darne	2013	Chile and Uruguay
Brantely Liddle	2015	OECD countries

There isn't implicit evidence in support of the declining CO2 emissions and economic growth compared to air and water pollutants. The (Behnaz Saboori 2012) article, found a linear relationship between CO2 emissions and per capita income was supported by (Shafik and Bandyopadhyay,1992; Shafik, 1994; Azomahou et al., 2006). Others reported an inverted U-shaped or N-shaped relationship (Roberts and Grimes, 1997; Cole et al., 1997; Schmalensee et al., 1998; Galeotti and Lanza, 1999; Apergis and Payne, 2009; Lean and Smyth, 2010; Shafik, 1994; Grossman and Krueger,1995).

Fodha and Zaghdoud (2010) wrote on economic growth and pollutant emissions in Tunisia and investigated the relationship between the CO2, SO2, and GDP growth within the period of 1961 to 2004. The EKC hypothesis was applied using time series data and cointegration analysis. Their results show that there is a long-run cointegrating relationship between the per capita emissions of the two pollutants and per capita GDP. An inverted U relationship between SO2 emissions and

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GDP was found, with income turning point approximately equal to \$1200 (constant 2000 USD pricing) or \$3700 (in PPP, constant 2000 USD pricing) (Fodha and Zaghdoud, 2010). The results exhibited a relationship between income and pollution in Tunisia is one of uni-directional causality with income and environmental changes and not vice-versa both in the short and long-run. This implies that emission reduction policies and more investment in pollution abatement expenses will not hurt economic growth in Tunisia (Fodha and Zaghdoud, 2010).

The purpose of Arouri et al. (2012) was to expand on the works of Liu (2005), Ang (2007), Apergis et al. (2009) and Payne (2010) by implementing recent bootstrap panel unit root tests and cointegration techniques to investigate the relationship between carbon dioxide emissions, energy consumption, and real GDP for twelve Middle East and North African Countries (MENA) over the period 1981 to 2005. Their findings suggest that in the long-run, energy consumption has] a significant positive impact on CO2 emissions. Although the estimated long-run coefficients of income and its square satisfy the EKC hypothesis in most studied countries, the turning points are meager in some cases and very high in other cases, hence providing poor evidence in support of the EKC hypothesis. CO2 emission reductions per capita have been achieved in the MENA region, even while the region exhibited economic growth over the period 1981 to 2005 (Arouri et al.; 2012).

Muhammad et al. (2013) examines the linkages between economic growth, energy consumption, financial development, trade openness and CO2 emissions over the period of 1975(Q1) to 2011(Q4) in Indonesia. (Muhammad et al., 2013) used the Zivot-Andrews structural break unit root test was carried out to test the stasis of the dataset; the ARDL bounds test was used to test the long-run relationship between their variables; the causal relationship between the concerned variable was examined using the VECM Granger causality technique; and the robustness of causal analysis was tested by the innovative accounting approach (IAA). The study found that the variables are cointegrated, which means that a long-run relationship exists in the presence of a structural break. The findings indicate that economic growth and energy consumption increases CO2 emissions, while financial development and trade openness" decreases it. Most studies on the EKC use panel or cross-sectional data. For groups such as developed or emerging market countries, these methods are appropriate in establishing a link between economic growth and environmental degradation (Behnaz et al., 2012). Some studies (Ang, 2008; Stern et al., 1996; Carson et al., 1997; Lindmark, 2002; Friedl and Getzner, 2003) provide a general understanding of various variables and how they relate with CO2 and SO2 emissions in the environment.

These studies were selected because individual countries don't possess the same pollution path as assumed in the panel, cross-sectional, and multiple countries analysis. The primary advantage of a single country analysis is that it brings the report closer to home; that is, the researcher can spot the exogenous and endogenous variables and the dynamics in the area of study (Lindmark, 2002). Earlier empirical studies consider testing causality along with testing cointegration to see if the long-run relationship between environmental degradation and economic growth appears to be uni-directional, as the EKC model assumes, or if a reverse causal relationship exists. Their findings are summarized in Table 3.

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Table 3:
The summaries of the CO2 emission-economic growth causality results of recent studies:

Authors	Countries	Economic Techniques	Causality results
Ang (2008)	Malaysia	Granger causality based on VECM	CO2 → GDP
Halicioglu (2009)	Turkey	Granger causality based on VECM	CO2 ↔ GDP
Jalil and Mahmud (2009)	China	Pairwise Granger causality	GDP → CO2
Soytas and Sari (2009)	Turkey	Toda and Yamamoto (1995)	CO2 ↔ GDP
Fodha and Zaghdoud (2010)	Tunisia	Granger causality based on ECM	GDP → CO2
Ghosh (2010)	India	Granger causality based on VECM	CO2 ↔ GDP
Iwata et al. (2010)	France	Pair-wise Granger causality	GDP → CO2
Lotfalipour et al. (2010)	Iran	Toda and Yamamoto (1995)	GDP → CO2
Menyah and Wolde-Rufael (2010)	S. Africa	Toda and Yamamota (1995)	CO2 → GDP
Nasir and Rehman (2011)	Pakistan	Granger causality based on VECM	GDP → CO2
Pao and Tsai (2011)	Brazil	Granger causality based ECM	GDP → CO2
Saboori et al. (2012)	Malaysia	ARDL & Granger causality based VECM	CO2 → GDP

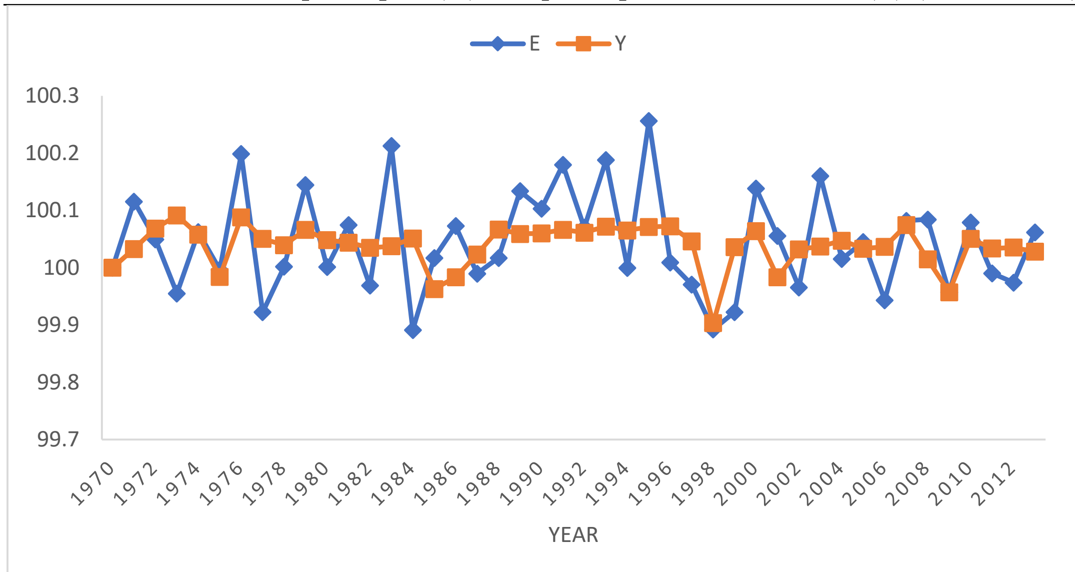
Table 4:
Keys for table 1

Symbol or Abbreviation	Meaning
→	Unidirectional Causality
↔	Bilateral Causality & No Causality
VECM	Vector Error Correction Model
ECM	Error Correction Model

Data

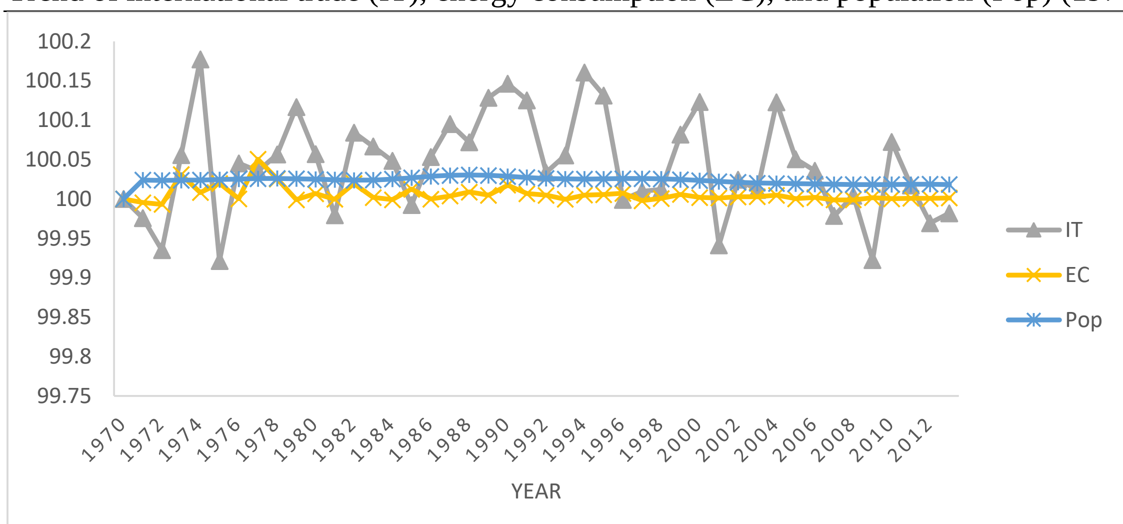
This study uses annual data from 1970 – 2014. The per capita carbon dioxide (CO2) emissions is our dependent variable, measured in metric tons. Our independent variables are: real per capita GDP, measured in constant 2010 USD; international trade, measured by the sum of imported and exported goods and services, then divided by real GDP in constant 2010 USD; energy consumption, measured by the quantity of fossil fuel energy consumption and alternative and nuclear energy; and demography, measured in total population. The time-series data of all our variables were collected from respected sources (see table 12 – 13).

Figure 1:
The trend of real GDP per capita (Y) and per capita CO2 emission (E) (1970 = 100)



Source: World Bank (2017).

Figure 2:
Trend of international trade (IT), energy consumption (EC), and population (Pop) (1970 = 100)



Source: World Bank (2017).

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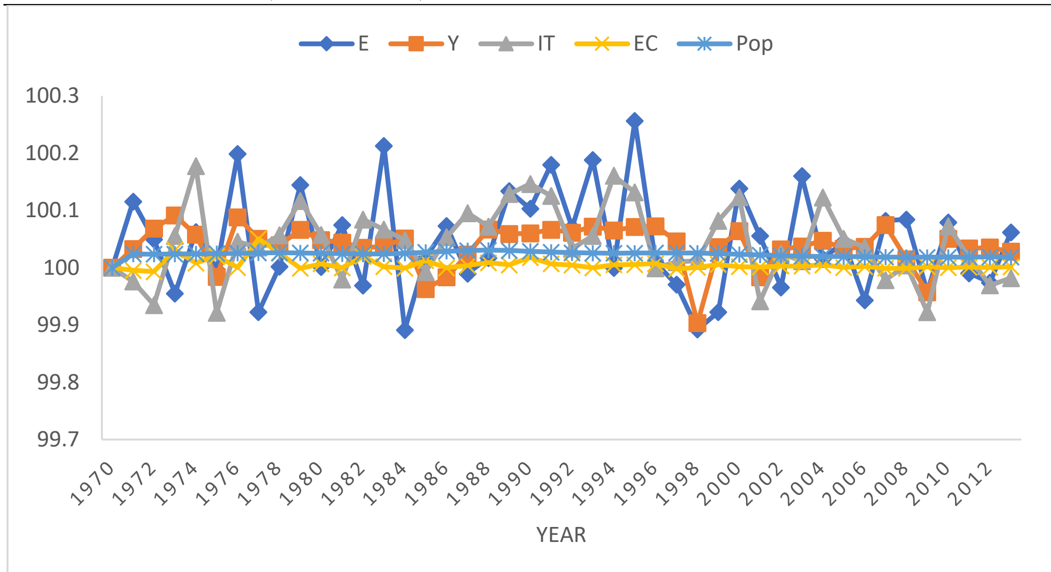
Figure 3:
Trends of variables (1970 = 100).



Source: World Bank (2017).
Reliable sources, such as the World Bank (WB) database, and our figures correspond with the Energy Information Administration (EIA) and World Development Indicator (WDI) for the study time frame. The long-run and causal relationship between CO2 emissions, real per capita GDP, international trade, energy consumption, and population were created in two steps; first testing the long-run relationship among the variables using the ARDL bounds test of cointegration, and second testing the causal relationship between variables using the Granger causality test.

MODEL AND METHODOLOGY

4.1. Model Specification:
Building on the work of Saboori et al. (2012), the economic model for the EKC hypothesis and the ARDL is specified as

$E = f(Y, Y^2, Z)$

$E = f(Y, Y^2, IT, EC, Pop)$……………………………(1)

Where E is an environmental indicator, Y is income, and Z are other explanatory variables which may influence environmental degradation. For this study, we used international trade (IT), energy consumption (EC), and total population (Pop) for our analysis. The main objective of this study is to test the cointegration and causal relationship between income, international trade, energy consumption, total population, and CO2 emissions. The estimation model in logarithm form is as follows:

$\ln(E)t = \alpha_0 + \alpha_1 \ln Yt + \alpha_2 (\ln Yt)^2 + \alpha_3 \ln Zt + \varepsilon t$

$\ln(E)t = \alpha_0 + \alpha_1 \ln Yt + \alpha_2 (\ln Yt)^2 + \alpha_3 \ln ITt + \alpha_4 \ln ECt + \alpha_5 \ln Popt + \varepsilon t$……………….(2)

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where the coefficients α_1, α_2, α_3, α_4, and α_5 are the coefficients of our variables, α_0 is the constant term (drift), t denotes time, and ξ is the error term. The following will be expected: $\alpha_1>0$, $\alpha_2 < 0$, $\alpha_3 > 0$, $\alpha_4 >0$, $\alpha_5 > 0$.

Variables in the model:

(*E*) CO2 Emissions (Metric Tons Per Capita):

In Malaysia, the average value of CO2 emissions between 1970 and 2014 was 4.173 metric ton per capita, with a minimum of 1.351 metric tons per capita and a maximum of 7.961 metric tons per capita. According to the WB, CO2 emissions stem from the burning of fossil fuels and the manufacturing of cement. Examples are carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.[4]

(*Y*) Income:

The GDP per capita in Malaysia is about 144% of the world's average when adjusted to Purchasing Power Parity (PPP)[5]. The GDP per capita is calculated by dividing Malaysia's gross domestic product, adjusted by PPP by the midyear population. According to the WB, GDP is the sum of gross value added of final products in the economy[6].

(*IT*) International Trade:

For the last three decades, Malaysia's international trade has exceeded the world's expectations[7]. After the Malaysian government expanded on its primary industries, it created a very productive environment for businesses in the country. As a result, it fostered close relationships between the Malaysian government, private businesses, and fostered international relations with enterprises and governments worldwide[8],[9].

(*EC*) Energy Consumption:

Malaysia is an independent country that can produce more than enough energy to supply its citizens. EC in our study is a combination of fossil fuel energy sources and alternatives. Fossil fuel comprises coal, oil, petroleum, and natural gas products[10]. Alternative Clean energy consists of non-carbon energy that does not produce carbon dioxide when generated. It includes hydropower and nuclear, geothermal, and solar power, among others WB[11].

(*Pop*) Total Population:

[4] Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.

[5] https://tradingeconomics.com/malaysia/gdp-per-capita-ppp

[6] World Bank national accounts data, and OECD National Accounts data files.

[7] http://www.miti.gov.my/index.php/pages/view/1771

[8] http://www.nationsencyclopedia.com/economies/Asia-and-the-Pacific/Malaysia-INTERNATIONAL-TRADE.html

[9] World Bank national accounts data, and OECD National Accounts data files.

[10] IEA Statistics © OECD/IEA 2014 (http://www.iea.org/stats/index.asp), subject to https://www.iea.org/t&c/termsandconditions/

[11] IEA Statistics © OECD/IEA 2014 (http://www.iea.org/stats/index.asp), subject to https://www.iea.org/t&c/termsandconditions/

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The entire population is all the inhabitants of a town, area, or country. For this study, it is based on all residents regardless of legal status or citizenship working in Malaysia within the working-age bracket (15 to 64), that is, the proportion of the working-age population who are employed WB[12].

Descriptive Statistic Table:
Table 5: (1970 – 2014)

Variable	Observation	Mean	Std. Dev	Median	Min (Max)	Total
E	44	4.173	2.236	3.831	1.351 (7.961)	183.64
Y	44	5429.15	2441.81	4983.91	1993.45 (9981.15)	238882.6
Y^2	44	35302602	28640259	24861255	3973841 (99623447)	1.55E+09
IT	44	24145389	14503478	21922091	6578800 (45679054)	1.06E+09
EC	44	91.114	6.891	93.92531	75.841 (97.933)	40009.04
Pop	44	19282669	5872532	18771089	10803978 (29706724)	8.48E+08

Source: World Bank (2017).

This study employs the ARDL bounds testing approach as an estimation technique. The reason for selecting this method is it has many attractive features over alternatives. The main advantage of the ARDL approach is that it doesn't require establishing the order of integration of the unit-root test. The method is applicable regardless of whether the underlying regressor is I(0) or I(1).

Table 6: The critical values

	***l*(0) Lower bounds (LCB)**	***l*(1) Upper bounds (UCB)**	**Cointegration**	**Inconclusive**
10%	2.08	3	”	’
5%	2.39	3.38	‘‘	‘
2.5%	2.7	3.73	[illegible]	[illegible]
1%	3.06	4.15	**	*

A fractional integration can also be applied, while the other standard cointegration approaches such as Engle-Granger (1987) and Johansen-Juselius (1990) can also be used. The ARDL approach

[12] : (1) United Nations Population Division. World Population Prospects, (2) Census reports and other statistical publications from national statistical offices, (3) Eurostat: Demographic Statistics, (4) United Nations Statistical Division. Population and Vital Statistics Report (various years), (5) U.S. Census Bureau: International Database, and (6) Secretariat of the Pacific Community: Statistics and Demography Programmed.

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is free of pretesting problems associated with the order of integration of variables, the short-run, as well as the long-run effects of the independent variables on the dependent variable, are assessed at the same time, so it allows the researcher to distinguish between the variables which are essential in economic analysis. Finally, the ARDL approach has better properties for small samples as well as large. The Pesaran and Shin (1999) paper, showed that with the ARDL framework, the estimators of the short-run parameters are consistent and the ARDL based estimators of the long-run coefficients are consistent in small and large sample sizes.

Estimation Procedure:

Cointegration Test:

For this study, the ARDL approach to the cointegration relationship between CO2 emissions and economic growth is estimated using the following unrestricted error correction regression. For the bounds test to be implemented in the cointegration model, the following restricted conditional version of the ARDL model is estimated to test the long-run relationship between CO2 emissions and its explanatory variables. The conditional ARDL model is

$$\Delta \ln E_t = \alpha_0 + \sum_{k=1}^{n} a1k\Delta \ln E_{t-k} + \sum_{k=0}^{n} a2k\Delta \ln Y_{t-k} + \sum_{k=0}^{n} a3k\Delta(\ln Y_{t-k})^2 + \sum_{k=0}^{n} a4k\Delta \ln IT_t + \sum_{k=0}^{n} a5k\Delta \ln EC_t + \sum_{k=0}^{n} a6k\Delta \ln Pop_t + \Delta 1E \ln E_{t-1} + \Delta 2E \ln Y_{t-1} + \Delta 3E \ln(Y_{t-1})^2 + \Delta 4E \ln IT_{t-1} + \Delta 5E \ln EC_{t-1} + \Delta 6E \ln Pop_{t-1} + \varepsilon 1t \quad (3)$$

$$\Delta \ln Y_t = \beta_0 + \sum_{k=1}^{n} \beta 1k\Delta \ln Y_{t-k} + \sum_{k=0}^{n} \beta 2k\Delta \ln E_{t-k} + \sum_{k=0}^{n} \beta 3k\Delta(\ln Y_{t-k})^2 + \sum_{k=0}^{n} \beta 4k\Delta \ln IT_t + \sum_{k=0}^{n} \beta 5k\Delta \ln EC_t + \sum_{k=0}^{n} \beta 6k\Delta \ln Pop_t + \Delta 1E \ln E_{t-1} + \Delta 2E \ln Y_{t-1} + \Delta 3E \ln(Y_{t-1})^2 + \Delta 4E \ln IT_{t-1} + \Delta 5E \ln EC_{t-1} + \Delta 6E \ln Pop_{t-1} + \varepsilon 2t \quad (4)$$

$$\Delta(\ln Y_t)^2 = \delta_0 + \sum_{k=1}^{n} \delta 1k\Delta(\ln Y_{t-k})^2 + \sum_{k=0}^{n} \delta 2k\Delta \ln Y_{t-k} + \sum_{k=0}^{n} \delta 3k\Delta \ln E_{t-k} + \sum_{k=0}^{n} \delta 4k\Delta \ln IT_t + \sum_{k=0}^{n} \delta 5k\Delta \ln EC_t + \sum_{k=0}^{n} \delta 6k\Delta \ln Pop_t + \Delta 1E \ln E_{t-1} + \Delta 2E \ln Y_{t-1} + \Delta 3E \ln(Y_{t-1})^2 + \Delta 4E \ln IT_{t-1} + \Delta 5E \ln EC_{t-1} + \Delta 6E \ln Pop_{t-1} + \varepsilon 3t \quad (5)$$

$$\Delta \ln IT_t = \Phi_0 + \sum_{k=1}^{n} \Phi 1k\Delta \ln IT_{t-k} + \sum_{k=0}^{n} \Phi 2k\Delta \ln Y_{t-k} + \sum_{k=0}^{n} \Phi 3k\Delta(\ln Y_{t-k})^2 + \sum_{k=0}^{n} \Phi 4k\Delta \ln E_t + \sum_{k=0}^{n} \Phi 5k\Delta \ln EC_t + \sum_{k=0}^{n} \Phi 6k\Delta \ln Pop_t + \Delta 1E \ln E_{t-1} + \Delta 2E \ln Y_{t-1} + \Delta 3E \ln(Y_{t-1})^2 + \Delta 4E \ln IT_{t-1} + \Delta 5E \ln EC_{t-1} + \Delta 6E \ln Pop_{t-1} + \varepsilon 4t \quad (6)$$

$$\Delta \ln EC_t = \gamma_0 + \sum_{k=1}^{n} \gamma 1k\Delta \ln EC_{t-k} + \sum_{k=0}^{n} \gamma 2k\Delta \ln Y_{t-k} + \sum_{k=0}^{n} \gamma 3k\Delta(\ln Y_{t-k})^2 + \sum_{k=0}^{n} \gamma 4k\Delta \ln IT_t + \sum_{k=0}^{n} \gamma 5k\Delta \ln E_t + \sum_{k=0}^{n} \gamma 6k\Delta \ln Pop_t + \Delta 1E \ln E_{t-1} + \Delta 2E \ln Y_{t-1} + \Delta 3E \ln(Y_{t-1})^2 + \Delta 4E \ln IT_{t-1} + \Delta 5E \ln EC_{t-1} + \Delta 6E \ln Pop_{t-1} +$$

Ƹ5t………………………………………………………………………………………………(7)

ΔlnPopt = θ_0 +$\sum_{k=1}^{n} \theta 1k$$\Delta$lnPopt-k + $\sum_{k=0}^{n} \theta 2k$$\Delta$lnYt-k +$\sum_{k=0}^{n} \theta 3k$$\Delta$(lnYt-k)^2 + $\sum_{k=0}^{n} \theta 4k$$\Delta$lnITt + $\sum_{k=0}^{n} \theta 5k$$\Delta$lnECt + $\sum_{k=0}^{n} \theta 6k$$\Delta$ln$E$t + $\Delta 1E$ln$E$t-1 + $\Delta 2E$lnYt-1 + $\Delta 3E$ln(Yt-1)^2 + $\Delta 4E$lnITt-1 + $\Delta 5E$lnECt-1 + $\Delta 6E$lnPopt-1 + Ƹ6t…………………………………………………………………………………(8)

The null hypothesis, testing no long-run relationship among the variables in *eqn2* is tested against the alternative hypothesis of the presence of long-run relationships among the variables denoted by: CO2(E, Y, (Y)^2, IT, EC, Pop). This is specified as:
Ho: α1 = α2 = α3 = α4 = α5 = 0
H1: α1 ≠ α2 ≠ α3 ≠ α4 ≠ α5 ≠ 0

Long-run and Short-run Dynamics

Once the cointegration is established, the next step is to estimate the following *ARDL* (Behnaz Saboori 2012) *(p, eqn3, eqn4, eqn5, eqn6, eqn7, eqn8*) model to obtain the long-run coefficients. Next, the estimation of the short-run parameters of the variables with the error correction representation of the ARDL model. Two different set(s) of critical values are given, with or without a time trend, for *I*(0) lower bounders (LCB) and *I*(1) upper bounders (UCB) critical values, respectively. If the computed F-stat is higher than the UCB, the null hypothesis of no cointegration is rejected, and if it is below the LCB we fail to reject the null hypothesis of no cointegration, and if it lies between the LCB and the UCB, the result will be inconclusive.

At this stage, the long-run relationship among variables is estimated after the selection of the ARDL model by using the AIC and SBC criterion. The next step is to apply the error correction version of ARDL. The velocity of the equilibrium is determined if there is a long-run relationship between the variables. Once a long-run relationship has been established, the ECM is estimated; that is, a general ECM model of *eqn3 - 8* is replicated/formulated into *eqn9 – 14*, which is the unrestricted ARDL error correction model.

Δln$E$t = α_0 +$\sum_{k=1}^{n} a1k$$\Delta$ln$E$t-k + $\sum_{k=0}^{n} a2k$$\Delta$lnYt-k +$\sum_{k=0}^{n} a3k$$\Delta$(lnYt-k)^2 + $\sum_{k=0}^{n} a4k$$\Delta$lnITt + $\sum_{k=0}^{n} a5k$$\Delta$lnECt + $\sum_{k=0}^{n} a6k$$\Delta$lnPopt + θECTt-1 + Ƹ1t…………………………………………………………………..(9)

ΔlnYt = β_0 +$\sum_{k=1}^{n} \beta 1k$$\Delta$lnYt-k + $\sum_{k=0}^{n} \beta 2k$$\Delta$ln$E$t-k +$\sum_{k=0}^{n} \beta 3k$$\Delta$(lnYt-k)^2 + $\sum_{k=0}^{n} \beta 4k$$\Delta$lnITt + $\sum_{k=0}^{n} \beta 5k$$\Delta$lnECt + $\sum_{k=0}^{n} \beta 6k$$\Delta$lnPopt + θECTt-1 + Ƹ2t……………………………………………………………(10)

Δ(lnYt)^2= δ_0 +$\sum_{k=1}^{n} \delta 1k$$\Delta$(lnYt-k)^2 + $\sum_{k=0}^{n} \delta 2k$$\Delta$lnYt-k +$\sum_{k=0}^{n} \delta 3k$$\Delta$ln$E$t-k + $\sum_{k=0}^{n} \delta 4k$$\Delta$lnITt + $\sum_{k=0}^{n} \delta 5k$$\Delta$lnECt + $\sum_{k=0}^{n} \delta 6k$$\Delta$lnPopt + θECTt-1 + Ƹ3t…………………………………………………...(11)

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ΔlnITt = Φ_0 +$\sum_{k=1}^{n} \Phi 1k$ΔlnITt-k + $\sum_{k=0}^{n} \Phi 2k$ΔlnYt-k +$\sum_{k=0}^{n} \Phi 3k$Δ(lnYt-k) ² + $\sum_{k=0}^{n} \Phi 4k$Δln$E$t + $\sum_{k=0}^{n} \Phi 5k$ΔlnECt + $\sum_{k=0}^{n} \Phi 6k$ΔlnPopt + θECTt-1 + Ƹ4t……………………………………………………..(12)

ΔlnECt = γ_0 +$\sum_{k=1}^{n} \gamma 1k$ΔlnECt-k + $\sum_{k=0}^{n} \gamma 2k$ΔlnYt-k +$\sum_{k=0}^{n} \gamma 3k$Δ(lnYt-k) ² + $\sum_{k=0}^{n} \gamma 4k$ΔlnITt + $\sum_{k=0}^{n} \gamma 5k$Δln$E$t + $\sum_{k=0}^{n} \gamma 6k$ΔlnPopt + θECTt-1 + Ƹ5t…………………………………………………………..(13)

ΔlnPopt = θ_0 +$\sum_{k=1}^{n} \theta 1k$ΔlnPopt-k + $\sum_{k=0}^{n} \theta 2k$ΔlnYt-k +$\sum_{k=0}^{n} \theta 3k$Δ(lnYt-k) ² + $\sum_{k=0}^{n} \theta 4k$ΔlnITt + $\sum_{k=0}^{n} \theta 5k$ΔlnECt + $\sum_{k=0}^{n} \theta 6k$Δln$E$t + θECTt-1 + Ƹ6t……………………………(14)

The ARDL method tests the existence or absence of cointegration relationships between our variables, but not the direction of causality. If there is no cointegration between the variable in the model, the Vector Autoregressive (VAR) model will be employed to examine the causality between the variables. Thus, in the presence of cointegration between our variables, we obtain the lagged error correction term (ECTt-1) from the long-run cointegration relationship and include it in the equation as an additional independent variable. The enhanced form of the Granger causality test with ECM is formulated in a multivariate pth order of "VECM" model as follows:

$$(1-\mathrm{B})\begin{bmatrix} lnEt \\ lnYt \\ lnY^2t \\ lnITt \\ lnECt \\ lnPopt \end{bmatrix} = \begin{bmatrix} C1 \\ C2 \\ C3 \\ C4 \\ C5 \\ C6 \end{bmatrix} + \sum_{i=1}^{p}(1-B)\begin{bmatrix} d11,i & d12,i & d13,i & d14,i & d15,i & d16,i \\ d21,i & d22,i & d23,i & d24,i & d25,i & d26,i \\ d31,i & d32,i & d33,i & d34,i & d35,i & d36,i \\ d41,i & d42,i & d43,i & d44,i & d45,i & d46,i \\ d51,i & d52,i & d53,i & d54,i & d55,i & d56,i \\ d61,i & d62,i & d63,i & d64,i & d65,i & d66,i \end{bmatrix}\begin{bmatrix} lnEt-i \\ lnYt-i \\ lnY^2t-i \\ lnITt-i \\ linECt-i \\ lnPopt-i \end{bmatrix}$$
$$+\begin{bmatrix} \lambda 1 \\ \lambda 2 \\ \lambda 3 \\ \lambda 4 \\ \lambda 5 \\ \lambda 6 \end{bmatrix}\{ECTt-1\} + \begin{bmatrix} \gamma 1 \\ \gamma 2 \\ \gamma 3 \\ \gamma 4 \\ \gamma 5 \\ \gamma 6 \end{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots (15)$$

Where (1-B) is the lag operator, and ECTt-1 is the lagged error correction term. The residual terms "γt's" are uncorrected random disturbance terms with zero mean, and the d's are parameters to be estimated. The direction of causality can be detected through the VECM of long-run cointegration. The VECM allows us to capture both the short-run and long-run relationship. The long-run causal correlation can be established through the significance of the lagged ECTs in the VECM, based on the t-test. The short-run Granger causality is detected through the significance of F-stat of the Wald test for the lagged independent variables. The model employs criteria such as AIC and SBC to choose the appropriate lag length.

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EMPIRICAL RESULTS

Unit Root Test

The unit root test, including the trend and intercept, was done to check the stasis of our variables, though it's not needed when using the ARDL approach. The ARDL approach is free of pretesting problems associated with the order integration of variables. The short-run and long-run effects of the independent variables on the explanatory variables are assessed at the same time, so it allows for distinguishing between the two, which are essential in economic analysis.

Table 7:

Unit Root test results

Variable	Level (P-Val)	1st Diff. (P-Val)
E	0.2983	0.00*
Y	0.600	0.00*
Y^2	0.9603	0.00*
IT	0.6180	0.0002*
EC	0.9439	0.0019*
Pop	0.0019*	

Where * means we reject the null hypothesis

To determine the integration order of the variables, the F-test was carried out to confirm any long-run or cointegration relationships between the variables. As the F-test is sensitive to the lag imposed on each of the first-differenced variables, it is, therefore, vital to set a different order of lags for the variables of *eqns 3 – 8*. Lag 1 was first set for all first differenced variables before the order of the lags was changed to 2, 3, 4, and 5.

Bahmani-Oskooee and Kantipong (2001) argued that there might be evidence of cointegration when variables in the model are replaced by the other independent variables in the model, so the F-statistics for the joint significance of lagged levels of variables were calculated when the dependent variables are lnE, lnY, $\ln(Y)^2$, lnIT, lnEC, and lnPop". The results are reported in Table 8. The results confirmed that the F-test is indeed sensitive to the lag lengths. The bounds test indicates that in all chosen lag lengths the calculated F-statistic is less than the upper bound critical value, supporting the null hypothesis of no cointegration or, in some cases, were inconclusive; see Table 7 for the key(s). The evidence of no cointegration in this stage was attributed to the fact that the same number of lags was imposed on each of the first-differenced variables.

At this stage, the optimum number of lags on the first-differenced variables is usually obtained from the unrestricted VAR using AIC and SBC. Given the number of variables and sample size in our study, we conducted optimal lag selection by setting the maximum lag lengths up to 5. SBC is preferred to other criteria because it tends to define more parsimonious specifications as it selects the smallest possible lag length and minimizes the loss of the degree(s) of freedom as well (Pesaran and Shin, 1999). SBC criteria implied that the order is 2 for all models; given this, SBC-based ARDL suggest ARDL (1,0,0,0,0,0) model, in which lnE is the dependent variable, and ARDL (1,0,0,0,0,0) model, in which lnY, $\ln(Y)^2$, lnIT, lnEC, lnPop are the dependent variables.

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Table 8:
The results of F test for cointegration

Equation	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5
3	8.557**	7.808**	4.083**	5.235**	2.998’’
4	10.509**	11.080**	13.592**	8.418**	6.385**
5	6.845**	9.184**	9.915**	6.732**	11.749**
6	4.150**	6.849**	6.698**	8.064**	9.142**
7	8.482**	7.690**	4.285**	3.533‘‘	8.011**
8	1182.1**	6.712**	12.466**	5.305**	11.805**

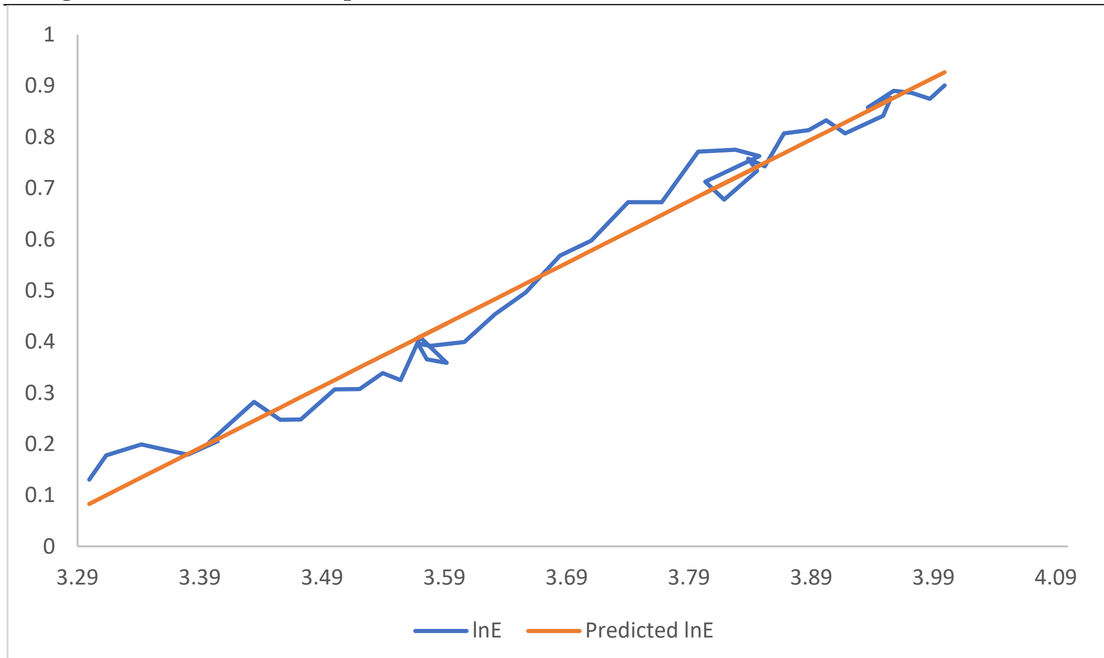
After finding the integrating order of our variables and determining the optimal order of lag, the next stage is to carry out the bound test by imposing the optimum lags on each of the first-differenced variables.

Table 9:
Long run estimation result:
ARDL (1,0,0,0,0,0) selected based on Schwarz Bayesian Criterion

Regressors	Coefficient	T- values/Ratio [P-Value]	Standard Error
lnY	0.001146	2.9483 [0.006] **	0.3889E-3
$(\ln Y)^2$	-0.1046E-7	-0.51749 [0.608]	0.2021E-7
lnIT	0.4991E-7	1.6670 [0.104]	0.2994E-7
lnEC	0.0054286	0.35152 [0.727]	0.015443
lnPop	-0.1725E-6	-1.4851 [0.146]	0.1162E-6
C	0.0809	2.7084 [0.144]	0.679E-8
Diagnostic test statistic			
Serial correlation	1.0925 [0.296]		
Functional Form	1.7014 [0.192]		
Normality	2.3193 [0.314]		
Heteroskedasticity	1.3090 [0.253]		
F(1,41)	1.2873 [0.263]		
F (1,36)	0.93850 [0.339]		

Where ** is significant at the 1% level
Only Y was significant at the 1% level. So if GDP increases by 1% CO2 also increase by 2.9%

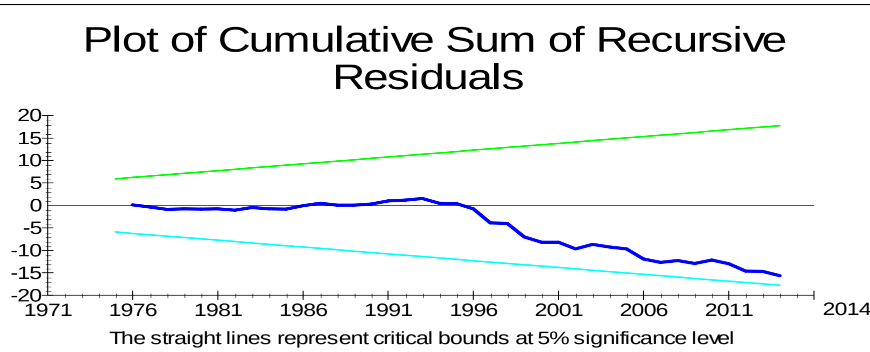
Figure 4:
Long-run EKC relationship



According to (Behnaz Saboori 2012), following the findings of Kremers et al (1992) that the significant lagged error correction term (ECTt – 1) is a more efficient way of establishing cointegration, it can be concluded that there exists a strong cointegration relationship among variables in the model because the coefficient of ECTt – 1 is statistically significant at 1% significance level and has the correct sign. The ECTt – 1 indicates any deviation from the long-run equilibrium between variables is corrected about 70% for each period and that it takes about 2.7 periods to return to the long-run equilibrium level.

To check the stability of the coefficients, CUSUM and CUSUMSQ were employed.

Figure 5:



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The statistics are plotted within two straight lines bounded by the 5% significance level. If any point lies beyond the 5% level, the null hypothesis of stable parameters is rejected. The plots of both statistics are well within the critical bounds, implying that all coefficients in the error-correction model are stable.

Table 10:
The results of error correction/ short-run for the selected ARDL model
ARDL (1,0,0,0,0,0) selected based on SBC

Regressors	**Coefficient**	**T- Ratio [p-value]**	**Standard Error**
ΔlnY	0.8091E-3	2.7199 [0.010] **	0.2975E-3
Δ(lnY)²	-0.7380E-8	-0.51754 [0.608]	0.1426E-7
ΔlnIT	0.3522E-7	1.6351 [0.111]	0.2154E-7
ΔlnEC	0.0038305	0.35352 [0.726]	0.010835
ΔlnPop	-0.1217E-6	-1.5026 [0.141]	0.8101E-7
ΔC	0.26288	2.9457 [0.005]	0.12492
ECTt-1	-0.70562	-5.3543 [0.000] **	0.13179
Diagnostic test statistic			
R-squared	.4561		
F (5,37)	6.2060 [0.000]		
DW- statistic	1.7467		

ECTt-1 = 2.6288lnE – 0.8091E-3*lnY – 0.7380E-8*(lnY)² + 0.3522E-7*lnIT + 0.0038305*lnEC – 0.1217E-6*lnPop
Where ** is significant at the 1% level
A 1% increase in Y will lead to a 2.7% increase in CO2 emissions

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Table 11:
Granger causality result

	Short-run Granger causality F-statistics [Prob]						Long run Granger Causality
	$\Delta\ln E$	ΔlnY	Δ(lnY)²	ΔlnIT	ΔlnEC	ΔlnPop	ECTt-1 (t-stats)
$\Delta\ln E$	-	2.71481 [0.1073]	1.05322 [0.3109]	0.00738 [0.9320]	0.03586 [0.8508]	0.50186 [0.4828]	-0.00345 [-0.03293]
ΔlnY	3.77214 [0.0592]	-	0.57055 [0.4545]	0.32209 [0.5735]	0.06708 [0.7970]	0.11481 [0.7365]	-0.0971 [-2.4485]
Δ(lnY)²	0.00253 [0.9602]	0.14075 [0.7095]	-	8.00532 [0.0073]	0.22240 [0.6398]	57.9871 [3.E-09]	-1111443. [-0.11770]
ΔlnIT	16.3899 [0.0002]	2.69432 [0.1085]	1.50612 [0.2269]	-	0.18368 [0.6705]	0.01069 [0.9182]	-0.0517 [-0.75081]
ΔlnEC	4.42078 [0.0418]	0.48047 [0.4922]	0.76822 [0.3860]	9.96240 [0.0030]	-	38.5969 [2.E-07]	-0.0064 [-0.6061]
ΔlnPop	6.68091 [0.0135]	6.07860 [0.0181]	2.04379 [0.1606]	1.46590 [0.2331]	0.00036 [0.9850]	-	-0.00078 [-1.9199]

The long-run cointegrating relationship between CO2 emissions per capita and real GDP per capita implies the existence of a causal relationship between the variables. To identify whether the relationship appears to be either uni, bi, or no-directional. More testing was carried out, using the VECM Granger causality test. The t-statistics of ECTs in Table 11 provide the existence of a uni-directional long-run causality from economic growth to carbon emissions, but there is no short-run causal relationship between CO2 emissions (E), lnY, ln(Y)², lnIT, lnEC, lnPop.

CONCLUSION

In line with the empirical literature, our research and results have shown similar outcomes to those of Saboori et al. (2012). An inverted-U shape relationship between CO2 emissions and income was expected based on the EKC hypothesis, although, we failed to find an association between the short and long-run per time series analysis. Therefore, our results fail to support the EKC hypothesis for Malaysia. However, regardless of our findings, it is important to note this result doesn't provide enough information about the reasons behind the observed inverted-U relationship between environmental degradation (CO2 emissions) and income. Several factors, such as changes in energy composition, level of international trade, and population density affects the environment, output, introduction of cleaner production technology, environmental policies and environmental awareness, play a significant role in making the decoupling between economic growth and environmental degradation (Panayotou, 1997).

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Data and Sources:

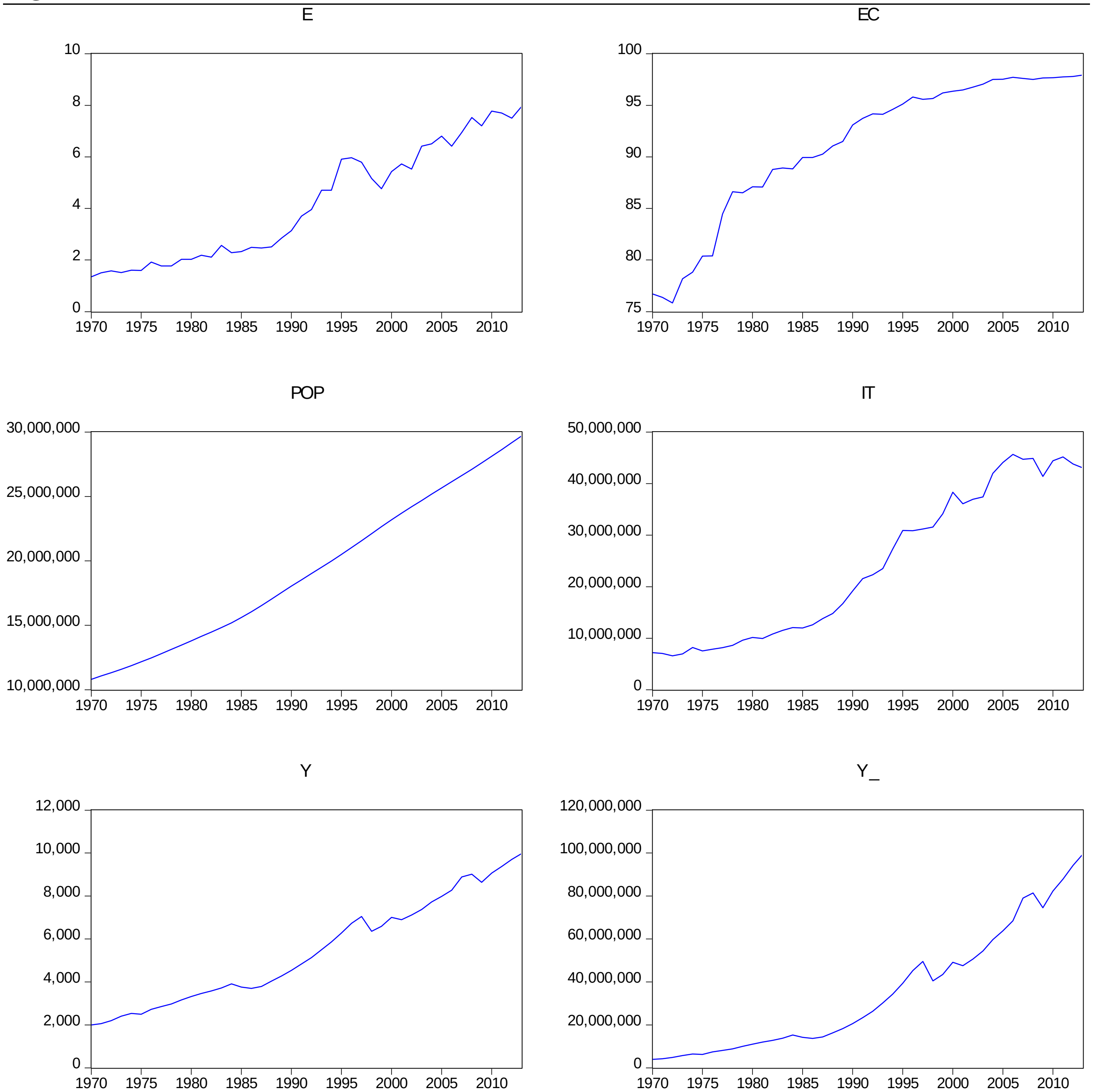
Table 12:

Variable	**Description:**	**Source**
E	CO2 emissions per capita (metric tons) https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?cid=GPD_27&end=2014&locations=MY&start=1970&view=chart	1 or 3
Y & Y^2	Per Capita Real GDP (2010 constant USD) https://data.worldbank.org/indicator/NY.GDP.PCAP.KD?locations=MY	3
IT	International Trade	3
EC	Energy Consumption	3
Pop	Total Population	3

Table 13:
Data Sources:

1	Energy Information Administration (EIA) https://www.eia.gov/
2	World Development Indicator (WDI) https://data.worldbank.org/data-catalog/world-development-indicators
3	World Bank Data Base (WB) https://data.worldbank.org

Figure 6:



Where Y_ is Y² in the study:

References

Behnaz Saboori, and Saidatulkmal Mohd. "Economic Growth and CO2 Emissions in Malaysia: A Cointegration Analysis of the Environmental Kuznets Curve." (Elsevier) 2012.

Behnaz, Saboori and Jamalludin Sulaiman. "Environmental degradation, economic growth, and energy consumption: Evidence of the environmental Kuznets curve in Malaysia." *Energy Policy*, 2013 Vol.60, issue C, 892 - 905.

Ibrahim Dogan, Nadide Sevil Tuluce, and Aydan Dogan. "Dynamics of Health Expenditure in OECD Countries: Panel ARDL Approach." *Theoretical Economics Letter*, 2014: 649 - 655.

Leitao, Muhammad Shahbaz, and Nuno Carlos. "Economic growth, energy consumption, financial development, international trade, and CO2 emission in Indonesia." *Renewable and Sustainable Energy Review*, 2013 Vol. 25: PP 109 - 121.

Manel Ben Ayache, Mounir Barhoumi, Mohamed Amine Hammas. "Causal Linkage between economic Growth, Financial Development, Trade Openness, and CO2 Emission in European Countries." *American Journal of Environmental Engineering*, 2016; 6(4): 110 - 122.

Mohamed El Hedi Arouri, Adel Ben Youssef, Hatem M'henni, and Christophe Rault. "Energy Consumption, Economic Growth, and CO2 Emissions in the Middle East and North African Countries." *Discussion Paper No. 6412*, 2012.

Obeng, Paul Owusu Takyi, and Camara Kwesi. "Determinants of Financial Development in Ghana." *International Journal of Development and Sustainability*, 2013: pp. 2324 - 2336.

Olawale, Lawal Ganiyu Omoinyi and Aweda Nurudeen. "An Application of ARDL Bounds Testing Procedure to the Estimation of Level Relationship between Exchange rate, crude oil and the inflation rate in Nigeria." (International Journal of Statistics and Application) 2015, 5(2): 81 - 90.

Shin, M. Hashem Pesaran, and Yongcheol. "An Autoregressive Distributed Lag Modelling Approach to Cointegration Analysis." 1997.

Zaghdoud, Mouez Fodha, and Oussama. "Economic growth and pollutant emission in Tunisia: An empirical analysis of the environmental Kuznets curve." *Energy Policy*, 2010, Vol. 38, issue 2, 1150 - 1156.