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Environmental Damage Theory Applicable to Kenya

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Abstract

Purpose: This study seeks to establish the environmental damage theory applicable to Kenya. The analysis is based on annual data drawn from World Bank on carbon dioxide emissions (CO_2e) and gross domestic product per capita (GDPPC) for Kenya spanning 1963 to 2017. **Research Methodology:** The study adopts explanatory research design and autoregressive distributed lag model for analysis. **Results:** The results revealed a coefficient of -0.017 for GDPPC and 0.004 for GDPPC squared indicating that economic growth has negative effect on CO_2e in the initial stages of growth but positive effect in the high growth regime with the marginal effect being higher in the initial growth regime. The findings suggest a U-shaped relationship consistent with Brundtland Curve Hypothesis (BCH). **Conclusions:** The findings emphasize the need for sustainable development path that enables present generations to meet own needs without compromising the capacity of future generations to meet their own. Sustainable development may include, investment in renewable energies like wind, solar and adoption of energy efficient technologies in production and manufacturing. The study concludes that BCH is applicable to Kenya and that developing affordable and effective mechanisms to boost sustainable development implementation is necessary to decrease the anthropogenic impact in the environment without any attendant reduction in the economic growth.

Keywords : Carbon dioxide emission; Economic growth; Gross Domestic Product per capita; Autoregressive distributed lag model; Brundtland curve hypothesis

JEL Classification Code: P28, Q5, O1, P3

1. Introduction

Since the times of agrarian and industrial revolutions, nations of the world are racing to achieve higher and higher economic growth at the expenses of utilizing the existing, particularly, non-renewable natural resources. This race of nations has resulted to an increase in Greenhouse Gases (GHG) emissions, particularly carbon dioxide emissions (CO_2e), which majorly contributes to the global warming and ozone depletion through absorption of infrared radiation and retention of heat in the atmosphere, thus responsible for the greenhouse effect and overall cause a negative impact on the environment (Tiwari, 2011). Further, many scientists also contend that the increased accumulation in the CO_2e in the atmosphere precipitates into global warming, which is more accurately called global climate change. A basic warming effect will produce complex effects on climate patterns with warming in some areas, cooling in others, and increased climatic variability and extreme weather events. Many countries are already experiencing some of the disruptive consequences of climate change (Harris and Roach, 2017; Kaygusuz, 2009; Intergovernmental Panel on Climate Change (IPCC), 1996).

According to the United States Environmental Protection Agency (USEPA), CO_2 enters the atmosphere through burning of fossil fuels (coal, natural gas, and oil), solid

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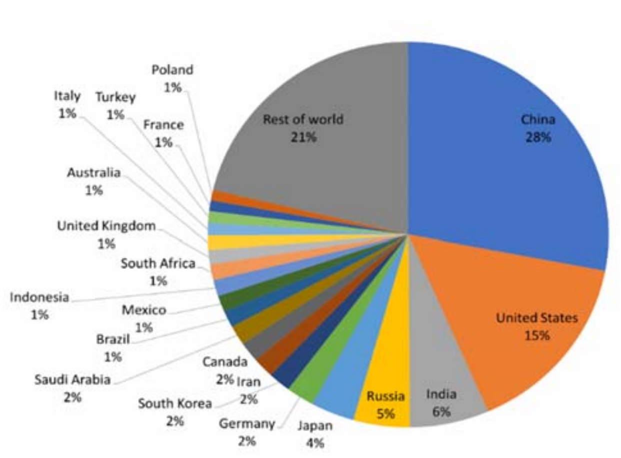
waste, trees and other biological materials, and certain chemical reactions and human activities like manufacturing of cement, energy consumption agricultural activities and industrial activities, among others. (Tiwari, 2011). Mohajan (2015) and Stern (2007) state that the concentrations of GHG in the space has been on the increase since 1750 (industrial revolution) due to human activities from a CO_2 equivalent of 280 parts per million to 450 parts per million against the proposed boundary of 350 parts per million, leading to a higher concentration of CO_2 in the atmosphere. The abundance of GHG in the atmosphere can be measured in kilotons (kt), metric tonnes (mt), parts per million, parts per billion, and even parts per trillion. One part per million is equivalent to one drop of water diluted into about 13 gallons of liquid (United States Environmental Protection Agency, 2017; Tiwari, 2011).

In the year 2015, two thirds of the world emissions were caused by 10 countries alone and, among these countries, the share of global emissions by China and United States of America (USA) was above those of all other countries. These two countries alone emitted 43% of the total global CO_2e (International Energy Agency (IEA), 2016). Figure 1. presents a summary global share of CO_2e in 2015.



Source: International Energy Agency (IEA) Data, 2018

Figure 1: Share of global carbon dioxide emissions from fuel combustion (2015)

The image that materializes from figure 1 is one where developed countries and major emerging economies are typically leading in total CO_2e, while some developing countries lead in the growth rate of CO_2e. Obviously, these uneven contributions to the climate problem are central to the challenges the world community faces in finding effective and equitable solutions. Further, Cetintas and Sarikaya (2015) also contend that, despite the fact that most anthropogenic GHGs have been emitted by the industrialized countries, the share of the developing countries' increased rapidly and is expected to increase into the future as well.

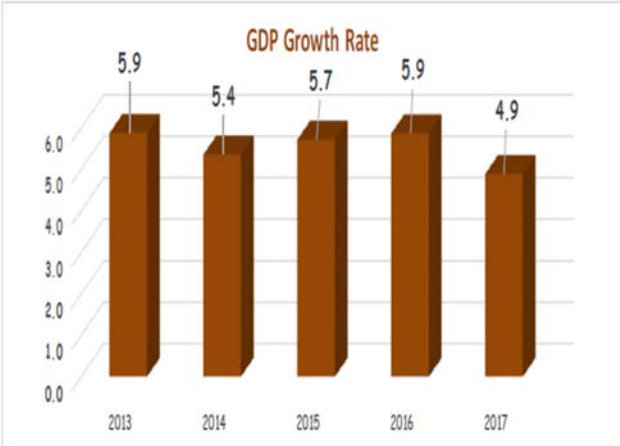


Figure 2: Kenya's Economic performance
Source: KNBS, 2018

According to Kenya National Bureau Statistics (2018), CO_2e of Kenya increased from 6,884.6 kt in 1997 to 16,334.9 kt in 2016, growing at an average annual rate of 4.91 %, and the Kenyan economy slowed down in 2017 from 5.9% growth in 2016 to 4.9%. Key sectors of the economy, such as Agriculture and Manufacturing, recorded significant deceleration in 2017. The slowed growth was attributed to uncertainty associated with electioneering period, adverse weather conditions that affected production of key crops, rearing of animals and generation of electricity, and slowed uptake of credit by private sector due to interest rate capping policy. The Kenyan economic performance and Carbon dioxide emissions trend are summarized in figures 2 and 3 respectively.

Source: World Bank data atlas

Figure 3: Carbon dioxide emissions trend

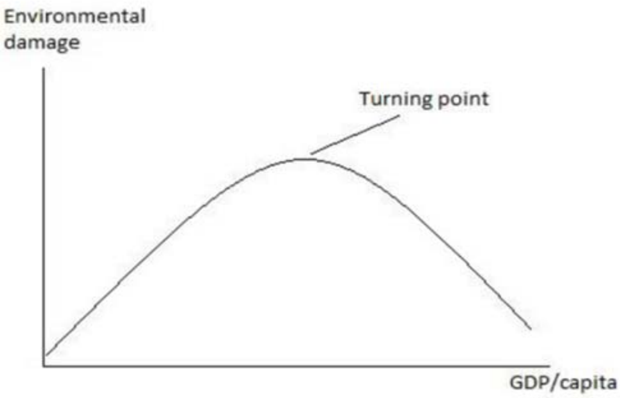
2. Theoretical framework

The established theories used to describe the relationship between environmental damage and economic activities that the study reviewed included; the Environmental Kuznets Curve (EKC), Brundtland Curve Hypothesis (BCH), and Environmental Daly Curve (EDC). These theories suggest existence of co-integration between carbon dioxide emissions (CO_2e) and the identified macroeconomic variables (Cederborg & Snobohm, 2016).

2.1. Environmental Kuznets Curve

The Environmental Kuznets Curve (EKC) reveals how a technically specified measurement of environmental quality like carbon dioxide (CO_2) changes as the fortunes of a country summed up as Gross Domestic Product change. This aspect of the theory makes it very relevant to this study in that it was possible to model the relationship between the environmental quality measured by the amount of carbon dioxide (CO_2) present in the atmosphere and the Gross Domestic Product.

The theory postulates an inverted U-shaped relationship between different pollutants and per capita income, that is, environmental pressure increases up to a certain level as income goes up after which it decreases (Dinda, 2004). Although Stern (2004) affirms that the empirical support for this generalization is scarce and has been criticized by many, the hypothesis of an inverted U-shaped relationship between per capita income and environmental issues still has a sizeable literature, which has grown over the recent period (Dinda, 2004; Cedrborge and Snobohm, 2016). The common point of all the literature is the assertion that the environmental quality deteriorates at the early stages of economic development/growth but subsequently improves at the later stages. The EKC hypothesis is presented in figure 4.

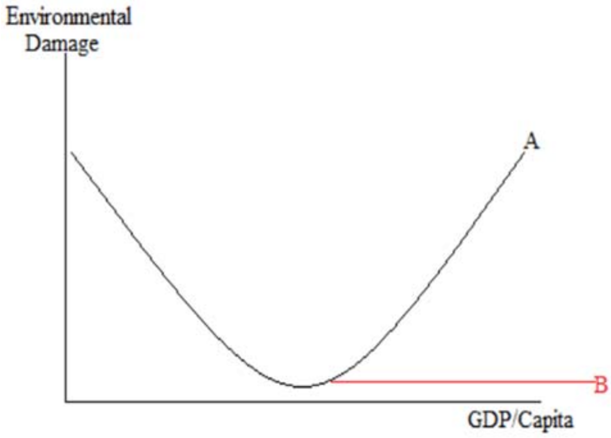


Source: Kuznets (1955)

Figure 4: Environmental Kuznets Curve

2.2. Brundtland Curve Hypothesis

The Brundtland Curve Hypothesis (BCH) argues that poor countries cause high levels of environmental degradation initially, followed by a decrease in environmental degradation when the economies grow until a turning point is reached, after which environmental degradation increases. The BCH therefore assumes a U-shape as presented in figure 5.



Source: World Commission on Environment and Development (WCED) (1987)

Figure 5: Brundtland Curve Hypothesis

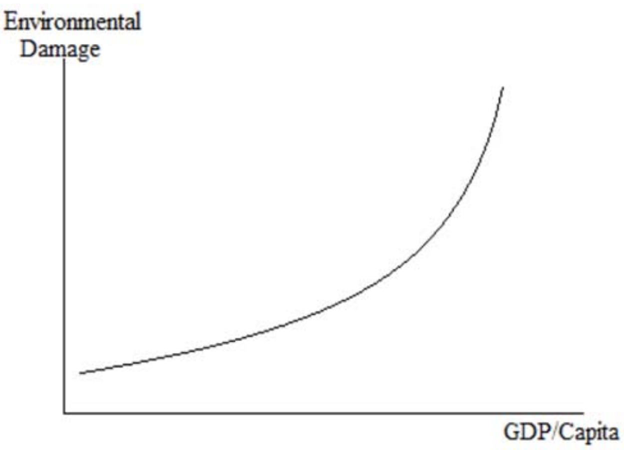
According to the BCH, countries in poverty cause high damage to the environment due to the lack of ability to prioritize environmental wellbeing. High levels of deforestation and over exploitation of sensitive land are necessary for citizens living in high poverty to make a living (Larsson et al., 2011). As the economy grows, environmental damage decreases mainly due to the fact that mechanisms holding the level of environmental damage high is alleviated, that is, poverty decreases. When the turning point is reached, the pollution is thought to increase with economic growth and eventually get as high as it were initially. The positive trend in environmental degradation is caused by increased consumption, which leads to increased production. The environmental damage caused by increased production is as damaging to the environment as the problems initially caused by poverty, according to the BCH theory (Field and Field, 2013).

The BCH might project the future to appear very bleak and unpromising. However, the curve includes an alternative prediction. The path marked (B), in figure 2.2, suggests a possibility for an immobility of the level of environmental degradation at the turning point. This path of very low levels of environmental damage is only possible when green technology in development is of high priority. Developed countries can invest in green, innovative production in order to counteract the increasing pollution levels. This means, depending on how ingenious high-income countries are willing to get in the framework, environmental friendly technology could have a positive effect on the environment (Bratt, 2012). One of the mechanisms allowing for green development is increased willingness to pay for a clean environment. (Field & Field, 2013).

2. 3. Environmental Daly Curve

Environmental Daly Curve indicates that; today's economy driven by increased production resulting from human creativity and innovation is doomed and the incentives for green technology is not enough to lower pollutions or countervail the usage of scarce natural resources and the overall environmental damage. Furthermore, the incentives for a better, high quality environment might occur when a country reaches a particular point of wealth, but the damage will already be too severe to reverse. Therefore environmental damage will increase as the economic status grows in a country, no matter the willingness of the citizens and policymakers (Daly and Farley, 2004).

The Environmental Daly Curve (EDC) suggests that an increase in per capita GDP will lead to higher environmental damage due to increased production. This aspect of the theory makes it very relevant to this study, in that, it is possible to model the relationship between the environmental quality measured by the amount of carbon dioxide present in the atmosphere and the economic growth measured by gross domestic product. Evidently, the EDC does not exhibit a turning point at any level of wealth. The environmental damage worsens with economic growth. The Environmental Daly Curve is presented in figure 2.3.



Source: Daly (1973)

Figure 6: Environmental Daly Curve

3. Empirical literature review

3.1. Carbon dioxide emissions

Scientists dealing with climate change have observed that concentrations of carbon dioxide (CO_2) in the atmosphere have increased considerably over the last century, as compared to the rather stable level of the pre-industrial era (Bello et al., 2018). In recent decades, global economic growth has caused various side effects, including climate change due to global warming. A basic warming effect will produce complex effects on climate patterns, with warming in some areas, cooling in others, and increased climatic variability and extreme weather events. Accordingly, international interest in CO_2 has been on the increases since the late 1970s with a number of scientific publications concerning controlling of CO_2e in the atmosphere (Harris & Roach, 2017; Ntanos et al., 2015). Sarkodie and Owusu (2016) and Zerbo (2015) supports this claim by positing that a lot of studies have examined the causal effect of CO_2e in different scope of studies using the recent econometric methods on time series in a multidimensional framework. For example, Soytas and Sari (2009), in their study, examined challenges faced by an EU candidate member on energy consumption, economic growth, and CO_2e. Their results established that CO_2e Granger cause energy consumption. Zhang and Cheng (2009), in their study of energy consumption, CO_2e, and economic growth in China, have also found no evidence of causality from CO_2e or energy consumption to economic growth. Further, Gul et al. (2015), in their study of causal nexus between energy consumption and CO_2e for Malaysia using maximum entropy bootstrap approach, have found evidence of a unidirectional causality running from energy consumption to CO_2e. The majority of the studies shows evidence of a long-run and short-run equilibrium relationship and a causal effect between environmental pollution and macroeconomic variables (Asumadu & Owusu 2016a; 2016b; 2016c; 2016d).

3.2. Gross domestic product

Based on the notion that increased production equals increased pollution, economic growth is often pointed out to be the cause of environmental issues. However, some hypothesize that the relationship between economic growth and environmental degradation is more complex than that. Some even argue that economic growth could improve the environment (Cederborg and Snobohm, 2016; Dinda, 2004).

The environmental consequences of economic growth have been studied many times before with varying results. For instance, Hatzigeorgiou et al. (2011) have examined the relationship between GDP per capita, energy intensity, and carbon dioxide emissions (CO_2e) in Greece for the period 1977 – 2007, and the results have indicated that GDP per capita and energy intensity had a positive causal relationship with CO_2e. In particular; the results have indicated that there is a unidirectional causality between energy intensity, GDP, and CO_2 running from GDP to energy intensity and from GDP to CO_2e, as well as a bi-directional relationship between CO_2e and energy intensity. Thus, it can be understood that the possibility of separating CO_2e and economic growth in Greek economy seems to be extremely questionable. The bi-directional causal relationship between CO_2e and energy intensity, signifies an obvious connection, meaning, that a more efficient energy system structure will result to reduced emissions. Usama (2014) has also examined the impact of nuclear energy consumption on GDP growth and CO_2e in thirty (30) developed and developing countries for the time period of 1990-2010, and the results have demonstrated that that fossil fuel energy production is more significant in increasing GDP growth than nuclear energy production. In addition, GDP growth and fossil fuel energy consumption are mentioned as major sources of CO_2e while nuclear energy consumption and urbanization are not. Moreover and most importantly, findings have been that a) there is a bidirectional negative short run causal relationship between fossil fuel and nuclear energy consumption and b) nuclear energy consumption has a negative short run causal relationship with CO_2e, while fossil fuel energy consumption has a positive short run causal relationship with CO_2e.

Further, Ntanos et al. (2015), by using data covering one hundred forty (140) countries for the year 2012, investigated the relationship among GDP, energy consumption, and CO_2e. Using one-way analysis of variance (abbreviated one-way ANOVA), their findings indicated that there was a connection between GDP, per capita, and energy consumption. The study furthermore established that GDP per capita had a positive causal relationship to CO_2e. In particular, they investigated the correlation between energy sectors, CO_2e, and GDP per capita. The findings indicated that there is correlation between GDP and CO_2e from electricity generation and transport but there was no correlation between GDP and CO_2e from industry and residence. These results were compatible with results from various reviewed studies concerning the causal relationship between energy consumption and economic growth. Furthermore, Bello et al. (2018) examined the relationship among GDP, electricity energy consumption, and CO_2e by using data from 22 Organisation of Economic Cooperation and Development (OECD) countries. Three clusters were formed, showing different patterns. For countries belonging to the first cluster, it was found that increase in the per capita income over the point of around 20,000 USD (in2000 prices) led to gradual reduction of per capita Co_2e and per capita electricity consumption (Austria, Belgium, Denmark, Finland, Greece, Italy, Japan, Norway, Sweden and Turkey). For countries belonging to the second cluster, it was found that growing GDP led to an increase in per capital electricity consumption with a parallel decrease in per capita CO_2e. It was not surprising to find heavy nuclear energy countries in this group, where it appears reasonable to expect that an increasing-in-GDP energy consumption goes along with decreasing patterns of per capita CO_2e (France, Portugal, Spain, and Switzerland). For countries belonging to the third cluster, it was noted that with growing GDP there is a decrease in per capital electricity consumption with a parallel increase in per capita CO_2e (Bello et al., 2018). There could be several reasons why electricity consumption does not cause CO2e in the long-run in this group of countries. As confirmed by the international statistics, CO_2e are largely misaligned from electrical consumption, because of the heavy role of other emitting sectors, among which transportation is the leading source (Australia, Canada, Ireland, the Netherlands, New Zealand, UK, and USA). Bello et al. (2018) further established that there was evidence of feedback hypothesis between real GDP to all environmental degradation indices. Again for Tunisia, Fodha et al. (2010) provided support for a long-run relationship between the per capita emissions of two pollutants and per capita GDP, indicating that there is a monotonically increasing linear relationship between per capita CO_2e and per capita GDP, while the relationship between the other environmental indicator, that is; CO_2 and per capita GDP, follows an N-shape, representing the EKC hypothesis.

Bratt (2012) has examined the three different theories explaining the relationship between environmental degradation and GDP. The theories argued are the Environmental Kuznets curve (EKC), the Brundtland curve and the Daly curve. All three hypotheses appreciate that the level of GDP affect the environmental degradation, but in dissimilar ways. The EKC hypothesis argues that an increasing level of GDP would initially increase pollution until a certain level of GDP, at which the level of pollution starts to decrease. The relationship between environmental degradation and economic growth is in the case of the EKC graphically shown as an inverted U-shape. The Brundtland curve theory provides another perspective, where the graphical form is U-shaped, which implies the poorest and wealthiest countries to have the highest levels of pollution. The Daly curve theory suggests increasing levels of pollution with an increasing GDP that keeps on going up without any turning point. Bratt points out that the three different environmental/GDP curves deals with different aspects of environmental degradation. The EKC hypothesis can be used when measuring emissions or concentration. The Brundtland curve can be used when measuring production and the Daly curve when measuring consumption. Bratt's final conclusion is that even though either curve could be true, the most possible scenario seems to be a positive, monotonic relationship between environmental degradation and GDP.

4. Methodology

4.1. Data

Time series data for the study variables spanning from 1963 to 2017 was extracted from the World Development Indicators (WDI) in the official website of the World Bank (WB) in excel format and consolidated homogeneously as per the variables for the period under review. Deliberate and conscious effort was made to ensure high level of credibility, trustworthiness, and consistency of the data collected. The major advantages of analysis of secondary data were the cost effectiveness and convenience it provides. Deliberate and conscious effort was made to ensure that a high level of credibility, trustworthiness, truth, value, applicability, consistency, and conformability was achieved.

4.2. Measurement of variables

4.2.1. Carbon dioxide

The dependent variable in this study was carbon dioxide emissions (CO_2e). CO_2e was described as carbon dioxide (CO_2) equivalent greenhouse gas (GHG) emissions from the various economic activities in the country. These included agriculture, forestry, industry, power, transport, buildings, and associated businesses. CO_2e was measured in kilotons (kt), consistent with how Sarkodie and Owusu (2016a; 2016b) measured CO_2e in their studies. According to the official website of World Bank (WB), CO_2e is the GHG emissions stemming from the burning of fossil fuels and the manufacturing of cement. They include CO_2 produced during consumption of solid, liquid, and gas fuels and gas flaring.

4.2.2. Gross domestic product (GDP) per capita

GDP per capita is measured in terms of GDP per capita purchasing power parity (PPP) based on current international United States dollar (USD). The official websites of the World Bank GDP per capita in current USD is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data is in current U.S. dollars.

4.3. Data analysis and presentation techniques

Data on the study variables was analysed using statistical software E-views 9. The recorded values for the variables were reviewed for completeness. Descriptive statistics and correlation matrix were run to provide a general view on the distribution, trends, and/or changes on data sets over time for the period of analysis. This entailed showing trends of the variables in the form of graphs. Inferential statistics were also applied to make inferences about regression parameters.

To achieve the study's main objective of establishing the relationship between the carbon dioxide emissions (CO_2e) and GDP per capita and, thus, isolating the environmental damage theory existing for Kenya, the study estimated the autoregressive distributed lag (ARDL) bounds testing model for short run and long run co-integration following the methodology proposed by Pesaran (1998) and Pesaran et al. (2001).

4.4. Model specification

Guided by the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) equation as set out in Halicioglu (2009) and Kohler (2013), the functional representation was formulated asfollows:

$$CO_{2t} = f(GDPPC_t GDPPC_t^2) \ldots\ldots\ldots\ldots\ldots..(1)$$

The empirical specification for the environmental damage and growth nexus model is quantified as:

$$LnCO_{2t} = \alpha_0 + \beta_1 LnGDPPC_t + \beta_2 GDPPC_t^2 + \mu_t \ldots\ldots\ldots \quad (2)$$

Where:

$LnCO_{2t} -$ is the natural log of carbon dioxide emission in year t

$LnGDPPC_t -$ is the natural log of GDP per capita inyear t

$LnGDPPC_t{}^2 -$ is the natural log of GDP per capita squared in year t

$\alpha_0 -$ is the intercept of the regression line

$\beta_1, \beta_2 -$ are the regression coefficients to be estimated

μ_t – is the stochastic error term

The subscript *t* refers to year t

The study employs the ARDL model to test for the environmental damage theory applicable to Kenya and cointegration among the variables, with a subsequent estimation of the short-run and long-run equilibrium relationships. Following the works of Bannerjee etal. (1993) and Pesaran (1998), the ARDL co-integrating equation is expressed as follows:

Where the parameter α_0 is the drift component (intercept), μ_t is the white noise error component (error term), β_1, β_2 *and* β_3 explain the long run coefficients, β_4, β_5 *and* β_6 explain the short run coefficients of the equation, and D is the first difference operator. The adoption of ARDL co-integration among variables makes it possible for estimation at either I(0) or I(1) without pre-specification of variables, which are either I(0) or I(1). Further, unlike Johansen's method of co-integration approach, which employs a set of co-integration equations to analyse the long-run equilibrium relationship between variables, the ARDL method of co-integration by Pesaran (1998) adopts only one equation. Moreover, ARDL has desirable small sample properties and provide unbiased long-run estimation, even when some endogenous variables behave as regressors.

$$D(LnCO_2)_t = \alpha_0 + \beta_1(LnCO_2)_{t-i} + \beta_2 LnGDPPC_{t-1} + \beta_3 LnGDPPC_{t-1}{}^2 + \sum_{i=1}^{n} \beta_4 . D(LnCO_2)_{t-i} + \sum_{i=1}^{n} \beta_5 . D(LnGDPPC)_{t-i} + \sum_{i=1}^{n} \beta_6 . D(LnGDPPC)_{t-i}{}^2 + \mu_t \dots \dots \dots (3)$$

The primary step of ARDL co-integration is the bounds testing procedure, which is based on the F-test. The null hypothesis of no significant co-integration among the variables is expressed as H_0: $\beta_0 = \beta_1 = 0$ against the alternative hypothesis H_1: $\beta_0 \neq \beta_1 \neq 0$. Thedecision criteria is as follows: if the calculated F statistics is more than the upper critical bound, there is a co-integration relationship among the variables (Pesaran et al., 2001). If the F statistics is lower than the lower critical bound, then the null hypothesis that there is no co-integration is accepted. The decision regarding co-integration would be inconclusive when the F statistic lies within the upper and lower critical bounds, in which case either the estimation of Johansen's test of co-integration or through testing the constancy of the co-integration space using CUSUM and CUSUM of squares of residuals would be undertaken.

To evaluate the goodness of fit of the model, the model stability test Ramsey regression equation specification error test (RESET) technique was employed. The RESET for omitted variables was used to test for the stability of the model. The Akaike Information Criterion were used to fix the optimum lag for each variable at lag 2. To establish the environmental damage theory applicable to Kenya,

The Environmental Kuznets Hypothesis for CO_2e in Kenya would be accepted, if the coefficient of GDPPC, (β_2) is positive and the coefficient of $GDPPC_t{}^2$, β_3 is negative.

The Brundtland Curve Hypothesis for CO_2e in Kenya would be accepted, if the coefficient of GDPPC, (β_2) is negative and the coefficient of $GDPPC_t{}^2$, $\beta_3$is positive.

The Environmental Daly's Curve Hypothesis for CO_2e in Kenya would be accepted, if both coefficients of GDPPC, (β_2) and $GDPPC_t{}^2$, β_3 are negative.

Granger causality test was conducted to determine the direction of causality between growth and carbon dioxide emissions in Kenya. As such, a stationary variable y_t is said to Granger cause another stationary variable x_t if the past of y_t improves the one period ahead prediction of x_t (Granger, 1969). The granger causality between two variables, say y_t and x_t, involves estimating the variance autoregressive (VAR) models

Binh (2013) cites four different possible outcomes. First, lags of Δx_t are statistically different from zero but those of Δy_t are not, in which case Δx_t Granger causes Δy_t. Second, lags of Δy_t are statistically different from zero, but those of Δx_t are not, in which case, Δy_t Granger causes Δx_t. Third, both sets of lags of Δx_t and Δy_t are statistically different from zero in both equations, in which case, we have a bi-directional causality between Δx_t and Δy_t. Fourth, both sets of lags of Δx_t and Δy_t are not statistically different from zero in both equations, in which case, the two variables are independent of one another. The criteria for hypothesis testing is that if the p-value exceeds 0.05, then null hypothesis stated as no Granger causality cannot be rejected. This would imply non-existence of causality (Harjito and McGowan, 2007)

4.5. Diagnostic tests for time series properties

To enhance the flow of the study, Table 1. provides an overview of the test processes undertaken.

Table 1: Time series diagnostic tests performed

Diagnostic test	Test statistic
A. Normality	A. Jarque-Bera
B. Serial correlation	B. Breusch- Godfrey

C. Heteroscedasticity	C. Breusch-Pagan-Godfrey

Source: Research data (2020)

5. Results

This section presents the empirical findings of the study and their interpretation. A descriptive statistical analysis of the variables is briefly examined, and diagnostic test results and ARDL estimation results analysis are presented.

5.1. Descriptive statistics

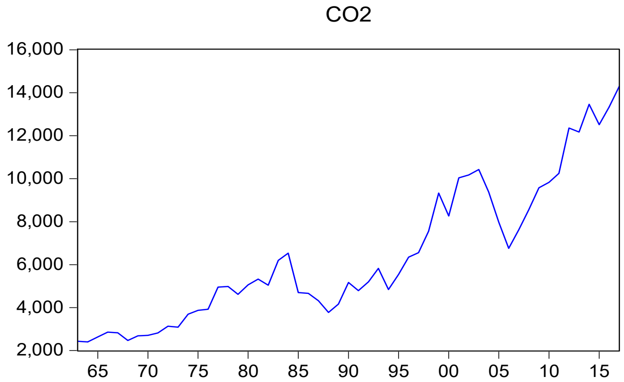
The study presents the descriptive statistical analysis of the time series variables from 54 observations, as shown in Table 2. Information from Table 2. shows none of the variables mirror normal skewness in their raw forms with values not equal to zero (0), suggesting non-normal distribution around their respective means. Specifically, GDPPC has positive skewness indicating a long right tail, suggesting higher values than respective means. The data was, therefore, normalized by taking natural logs of the variables to provide a more stable data variance for the subsequent analysis.

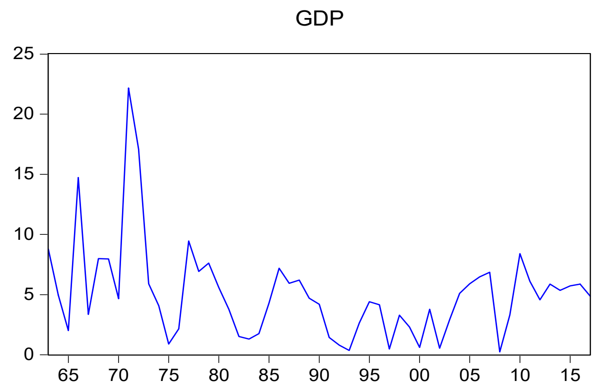
Table 2: Descriptive statistics

	CO_2e	GDPPC
Mean	6434.118	5.081212
Median	5192.472	4.655447
Maximum	14286.63	22.17389
Minimum	2401.885	0.232283
Std. Dev.	3304.047	3.999829
Skewness	0.744694	2.021788
Kurtosis	2.508046	8.815231
Jarque-Bera	5.638177	114.9670
Probability	0.059660	0.000000
Sum	353876.5	279.4667
Sum Sq.Dev.	5.90E+08	863.9260
Observations	55	55

Source: Research data (2020)

Figure 7. shows the trend of the study variables. CO_2e and GDPPC increase and decrease periodically, which suggests the existent of a strong relationship amongst them. CO_2e presents a sustained increasing trend for the period under investigation. This provides the statistical evidence necessary to qualify the decision by the Kenya government to sign up as a party to the Kyoto protocol on climate change in the year 2005. The Kyoto protocol requires member states to commit to reduce greenhouse gasses emissions based on the scientific consensus that global warming is occurring and it is extremely likely that human made CO_2 have majorly to blame.





Source: Research data (2020)

Figure 7: Trend of variables

5.2. Stationarity test

Data analysis commences with testing for the stationarity properties of the variables. This is necessary to know the order of integration presented by the variables to prevent spurious regression results. Following the process discussed by Asteriou and Hall (2015), the study adopted Augmented Dickey Fuller (ADF) unit root test technique. The ADF unit root test was conducted at level and first difference using intercept, trend and intercept and without trend and intercept (none). The null hypothesis stated as, presence of a unit root, was rejected at all significance levels since the p-value was 0 at first difference for each of the series under consideration. It was therefore concluded that there were no unit roots in first differences, and so each of the series must be either I(0) or I(1). Thus, the null hypothesis of no stationarity was rejected. The result is summarized in the appendix section table 3.

Table 3: Augmented Dickey Fuller (ADF) unit root test

Variable	Level (5%)					
	None		Intercept		Trend and intercept	
	t-statistics	ρ - value	t-statistics	ρ - value	t-statistics	ρ - value
CO_2e	2.019439	0.9888	-0.66972	0.8454	-2.704529	0.2391
GDPPC	-2.727739	0.0073	-4.880640	0.0002	-4.922392	0.0010
	1st Difference (5%)					
	None		Intercept		With trend and intercept	
	t-statistics	ρ - value	t-statistics	ρ - value	t-statistics	ρ - value
CO_2e	-7.118441	0.0000	-7.653376	0.0000	-7.578959	0.0000
GDPPC	-9.973783	0.0000	-9.877343	0.0000	-9.787142	0.0000

Source: Research data (2020)

5.4. ARDL bounds test

Having performed the stationarity test and determined that the variables are integrated of I(0) and I(1), the study deployed ARDL bounds test to determine the presence of cointegration. Table 4. shows that the F – statistics is lower than the I(1) value, therefore the null hypothesis of no cointegration cannot be rejected. Thus the study proceeds to estimate the short-run model which is the autoregressive lag (ARDL) model.

Table 4: ARDL bounds test

Test Statistic	Value	k
F-statistic	0.303757	2
Critical Value Bounds		
Significance	I0 Bound	I1Bound
10%	3.17	4.14
5%	3.79	4.85
2.5%	4.41	5.52
1%	5.15	6.36

Source: Research data (2020)

5.5 ARDL Estimation results

Having performed the stationarity test and determined that the variables are integrated at I(1), the absence of cointegration hence no long-run relationship was also established through ARDL bounds test results. The study then selected an optimal model using the Akaike information criteria for the ARDL model to diagnose the environmental damage theory existing for Kenya. This was done using the quadratic check by estimating the coefficients of GDP per capita and GDP per capita squared. The results revealed that the coefficient of GDP per capita was negative (-0.017) and that GDP per capita squared coefficient was positive (0.004) consistent with the Brudntland Curve Hypothesis (BCH). The BCH postulates a U-shaped relationship between different pollutants and GDP per capita income. According to BCH, increasing economic growth initially leads to a decline in CO_2e levels, reaches a threshold, beyond which increasing levels of GDP increases CO_2e (Aslanidis & Iranzo, 2009; Ahmed et al., 2017). As the economy grows, environmental damage decreases mainly due to the fact that mechanisms holding the level of environmental damage high such as poverty is alleviated. When the turning point is reached, the pollution is thought to increase with economic growth and eventually get as high as it were initially. The positive trend in environmental degradation is caused by increased consumption, which leads to increased production. Further, lower GDP rates imply lower income; hence, individuals are subsisting and focusing on basic needs. This is likely to affect energy intensive sectors consequently supressing energy demand of CO_2e. The observed increase in CO_2e as the economy grows is as a result of growth in industrial and manufacturing sector. This signifies a period of boom coupled with swelling population; therefore, individuals as well as firms have improved per capita income. This may lead to increased demand and consumption of energy from electric devices and or appliances and transportation, among others, that contribute to high pollution. The population growth could contribute to CO_2e through its effect on deforestation. The destruction of the forests, changes in land use, and combustion of fuel wood could significantly contribute to greenhouse gas emissions. This implies that beyond a certain level of GDP, a desired further rise of GDP can be achieved but at a cost to the environment (Everett et al., 2010). This is intuitive because higher income levels will lead to pursuit of more manufacturing economy. If there are no complementary policies that constrain the industries to limit their level of pollution by adopting environmentally friendly production techniques and processes, the presence of these industries will ultimately result in high environmental degradation. The effect of GDP growth on CO_2e is negative, albeit not significant. A summary of the ARDL results is presented in the appendix section table 5.

Table 5: ARDL results

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
$CO_2e(-1)$	0.976535	0.033982	28.73692	0.0000
GDP	-0.017083	0.026014	-0.656695	0.5144
GDP2	0.003876	0.013295	0.291528	0.7719
C	0.246861	0.300512	0.821467	0.4153
R-squared	0.948043	Mean dependent var		8.656346
Adjusted R-squared	0.944925	S.D. dependent var		0.507460
Prob(F-statistic)	0.000000			
*Note: p-values and any subsequent tests do not account for model selection.				

Source: Research data (2020)

The time series diagnostic tests were also conducted to ensure the robustness of the results. The results of the diagnostic tests are as summarized in table 6.

Table 6: The results of time series diagnostic tests

Diagnostic test	Prob. (F-statistic)
A. Normality	$\rho = 0.27 > 0.05$
B. Serial correlation	$\rho = 0.58 > 0.05$
C. Heteroscedasticity	$\rho = 0.35 > 0.05$
A. Jarque-Bera	
B. Breusch-Godfrey	
C. Breusch-Pagan-Godfrey	

Source: Research data (2020)

The null hypothesis is that the residuals are not normally distributed. The F-statistic p-value of 0.27 indicates that the study fails to reject the null hypothesis and thus concludes that the residuals are normally distributed. Further, since the null hypothesis means that the residuals are serially uncorrelated, the F-statistic p-value of 0.58 indicates that the study fails to reject the null hypothesis and therefore, conclude that the residuals are serially uncorrelated. Finally, since the null hypothesis indicates that the residuals are homoscedastic, the F-statistic p-value of 0.35 indicates that the study fails to reject the null hypothesis and therefore, conclude that the residuals are homoscedastic.

6. Discussion

This study confirms the validity of a U-shaped Brundtland curve hypothesis in Kenya. It suggests that as with economic growth, environmental pollution tends to initially decline for some period; however, as income level reaches a turning point, environmental pollution begins to increase as income level increases. The findings have important practical policy implications. For instance, in the energy sector, there is need to support and promote investment in production of clean and renewable energy from solar power, wind power, natural gas, and hydroelectric power. Reliance on non-renewable energy source such as coal, petroleum, and their derivatives, which are harmful to the environment, must be discouraged. Further, investment in research and development on low carbon technologies aimed at reducing emissions for sustainable economic growth can be actively pursued. This would include, among others, policy interventions and practices that promote energy efficiency where less energy is used to provide the same level of energy, such as eco-friendly buildings, cars, aeroplanes and electric appliances. This is necessary to increase energy security. It is noteworthy that reducing pressure on energy demand remarkably lead to a significant cut in CO_2e without adversely affecting economic growth. Through civic education, the government can seek to create environmental awareness and support to the population so that citizens are encouraged to adopt and embrace environmentally healthy lifestyles such as solar powered household items, liquefied petroleum gas for cooking, and power saving bulbs, amongst others. Where such items are costly, the government can intervene with subsidies.

Measures to promote reforestation and afforestation should also be adopted as trees act as carbon extractors from the atmosphere. In the manufacturing and industrial sector, emission levels can be effectively controlled and managed through permit prices and tax with elaborate monitoring strategies to ensure compliance.

Lastly, international cooperation and treaties are vital to curbing emissions rates. The treaties and cooperation's should recognize the importance of taking corrective measures to condense global warming and its impact on the world's ecosystem. One such unified environmental vehicle is the Kyoto protocol, which apart from being complementary to the individual country's national policies and measures to reduce climate change, is also among the most comprehensive multinational efforts both in political and geographical sense. Kenya, which became a party to the protocol in the year 2005, can be an active participant of the protocol which extends the 1992 United Nations Framework Convention on Climate Change (UNFCCC) that commits the member states to reduce GHG as part of her global responsibility.

7. Conclusion

The findings emphasize the need for sustainable development that ensures meeting the needs of the present generations without compromising the ability of future generations to meet their own, through keeping the economy green and preserving the environment for future generations. The ARDL model estimation confirmed a U-shaped curve validating the Brundtland curve hypothesis in Kenya. Meaning, as economy grows, the mechanisms holding environmental damage high such as poverty, is alleviated causing environmental damage to decreases. When the turning point is reached, pollution then increases with economic growth and eventually get as high as it were initially. The positive trend in environmental degradation is caused by increased consumption, which leads to increased production. The increased production is just as damaging to the environment as the problems initially caused by poverty (Field and Field, 2013).

The study concludes that the BCH is applicable to Kenya and that developing affordable and effective mechanisms to boost sustainable development implementation is necessary to decrease the anthropogenic impact on the environment without any attendant reduction in the economic growth.

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