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Economic Growth and Carbon Dioxide Emission in Kenya: Evidence from Impulse Response and Granger Causality Approach

Kayitare Aristide[1]
[1](School of Business and Management/ Nanjing University of Information Science and Technology)

Abstract:
***Background**: In the past two decades, the struggle for economic growth in many countries has been a notable aspect and through this struggle, the price to pay has been the environment whereby environmental degradation through air pollution has been increasing from the mid-20th century up to date. Many studies have been carried out to examine the relationship between economic growth and environmental degradation, not forgetting factors that lead to both environmental degradation as well as economic growth. However, there is a lack of extensive research in Kenya. Thus, the present study examines the causal nexus and impulse responses between carbon dioxide emission, gross domestic product per capita, industrialization, and population in Kenya.*
***Materials and Methods**: This study uses Gross Domestic Product per capita, carbon dioxide emission, industrialization and population density data collected from the world bank database. The datasets span from 1965 to 2018. Various econometrics methods and theories were used to examine the relationship between these variables. The econometric methods used include linear regression model for linearity test, unit root test for stationarity, ARDL (auto-regressive distributed lag) for the short and long-run relationship between variables, VECM (vector error correction model) for the causality analysis and finally, the impulse response test to identify the different impulses between variables.*
***Results**: There is a long-run relationship between variables in the study, and there is clear co-integration evidence from the ARDL model and the unit root test. A negative relationship between carbon emission and economic growth was observed, which indicates the relevancy of the environmental Kuznets curve with an inverted U-shaped curve. This can also be seen looking at the impulse response curve where the relationship between carbon emission and economic growth is significant, and also the shape of the curve can be observed. In the short-run analysis of causality, there is uni-directional causality running from population density to economic growth and from industrialization to population density. In the long run a bi-direction causality relationship was identified from industrialisation to economic growth and from economic growth to industrialisation. Finally, the impulse response analysis identified significant responses from population density to economic growth, economic growth to industrialization, and from Industrialisation to carbon emission.*
***Conclusion:** This study identifies the relationship between variables both in the long run and short run and as a result, the environmental Kuznets curve hypothesis was tested positive or valid in the Kenyan economy. There is causality between the variables both in the long run and short run whereby in the long run, the study identified bi-directional causality between the variables running from industrialization to economic growth and from economic growth to industrialization and also from population density to economic growth and in the short run, the uni-directional relationship was identified from population to economic growth and from industrialization to population. The impulse response identified impulse signification from population density to economic growth to industrialization and finally to carbon emission.*
***Key Word**: Economic growth; Carbon dioxide emission; Vector Error Correction Model; impulse response; Kenya.*

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I. Introduction

Global warming has been one of the major problems that many countries have encountered for the past decades, mainly caused by environmental pollution. Different economic activities in these countries have adopted the use of different energy sources, which has led to an increase in air pollution. This has raised the attention of policymakers, investors and planners in different countries to overcome this problem of air pollution. The research highlighted that South Asian countries are so vulnerable to global warming due to their different economic activities, which contribute to carbon dioxide emission, hence global warming. Therefore, t policymakers advise all countries to reduce this emission even if they are not the most carbon dioxide emitters worldwide [1]. Global warming has also been caused by black carbon accumulation in the atmosphere, affecting many parts of the northern hemisphere, leaving a black carbon footprint. Having said that though even if there is a high carbon footprint that affects the environment, it is from only a few developing countries than the whole world [2][3].

This problem has been mostly justified by the increase in industrialization in different countries and a reduction in agriculture practices, and it has led to the increase in population in these economies as well as industrial development, which has resulted in the rise of countries GDP and also converted countries production from traditional to modern production and development.

The relationship between carbon dioxide and economic growth has been highlighted by the environmental Kuznets curve hypothesis (suggested by Simon Kuznets in the years of 1950's and 1960's), which has been tested in different studies and tries to depict this relationship using the different econometrics methods which include the ARDL model, bootstrapped rolling-window granger causality test, multivariate co-integration among others. Most studies gave results of a long-term negative relationship between carbon dioxide and economic growth in the different sample areas [4]–[8]. According to the estimates of the studies, it can be noted that there is a significant relationship between economic growth and carbon emission [8], [9].

Carbon emission globally is mainly from fossil fuels and land-use changes that promote economic modernization. Prior industrial evolution period carbon dioxide emission levels were low until the mid-20th century were in 1950 there was carbon emission of up to 6 billion tons of carbon dioxide, and this kept on rising until the 1990s when the amount of emissions almost quadrupled up to 22 billion tons of carbon dioxide emission. The most dominant emission continents included the united states of America and Europe, where they accounted for more than 90% of the emission, but the letter on, in 1950, these two continents' emissions now accounted for only 85%. The continuous carbon emission has triggered many conferences and meetings like the Paris conference [10] to discuss the policies to overcome or reduce global warming where the use of renewable energy as one of the resolutions to solve the global warming problem has been adopted and shown great results in the long run in some countries [11].

Environmental degradation is one of the common aspects that have been rising over the past few years, mostly in developing and developed economies over the world and this has attracted so much attention to many researchers due to the rapid changes in environmental degradation and in this case, carbon dioxide emission. Kenya being one of the fast-developing countries in the past decade and also one of the potential developing economies in East Africa, made the researcher consider this area of research as a potential area to make research 'us agency for international development USAID 2021'.

Many different studies have attempted to identify the relationship between environmental degradation and economic growth behaviors and different activities that improve the world's life standard, and these activities tend to pollute the environment. A study of projection for the 45 selected countries was conducted and the hardship in stabilizing the climatic purification policies was highlighted due to the increasing pollution in both developed and developing countries [12]. In China, a study that examined the relationship between industrialization economic growth and carbon dioxide emission along with the population and trade openness, the study concluded by identifying the validity of the environmental Kuznets curve (EKC) and found the bi-directional causality relationship from carbon dioxide to industrialization and a unidirectional relationship from population density to trade openness [13]. In Pakistan, a study that examined the relationship between emissions from transportation facilities and carbon dioxide emission was conducted, and the effect of these transport facilities was highlighted; the study highlighted that pollution from the transport facilities had contributed a great deal in the carbon emission in Pakistan the study spanned from 1972 -2017[14].

Carbon dioxide emission worldwide has been increasing over time, and so is the transfer of carbon between regions, either embodied or physical [15]. The emission of greenhouse gasses in the world has been increasing year after year, and this has led to an increase in global warming where the average temperature of the world is raising twice the rate it was almost 50 years ago. Maintaining environmental quality has been a challenge since the early 1970's, and this is mainly because environmental quality has been associated with economic growth [16]. A study in Africa to test the relationship between carbon emission and economic growth took a sample of 43 African countries and tested the validity of the environmental Kuznets curve where the EKC hypothesis was accepted in 21% of the countries and rejected in the 70 % of African countries. Furthermore, the study concluded that the use of renewable energy was recommended by identifying the risk of the increasing emission to many African countries; the study spanned from 1980-2016 [17]. In Senegal, a study to identify contributors of carbon emission that spanned from 1980-2011 identified the contributions of electricity consumption, economic growth, financial development, industrialization and urbanization towards carbon emission [18]. A similar study was carried out in sierra leone to identify the contribution of electricity consumption, economic growth, and industrialization towards carbon dioxide emission [19]. A study of 19 sub-Saharan countries was carried out and it incorporated globalization and energy intensity into carbon dioxide emission, and the U-shaped relationship was found to be valid in some African countries, which was evidence of

EKC validity [20]. In Iran, a study of the causal relationship between carbon emission and economic growth highlighted the unidirectional relationship between carbon dioxide and economic growth in the study spanning 1965 – 2004 [21].

A study based on the EKC hypothesis was carried out in some provinces of china that highlighted the use of solar energy, and also the analysis of the relationship between carbon emission and economic growth reflected an inverted U-shaped curve which is evidence of the EKC hypothesis [22]. A study that tested for the environmental Kuznets curve in Ghana using the bootstrap rolling window granger causality test identified an upward sloping curve which is contrary to the U-shaped EKC hypothesis curve [23]. In turkey, the impact of economic growth on environmental degradation was highlighted, and the EKC hypothesis was not tested positive in the economy of turkey [24]. A study of 21 selected OECD nations was also carried out to examine the relevance of AKC (aviation Kuznets curve), as well as the EKC that study, spanning from 1980-2018, the AKC was proven to exist, but the EKC hypothesis is invalid in the 21 selected OECD countries [25]. In China, with the rapid regional economic growth and energy use being of great concern due to the carbon dioxide emission from energy use, a study highlighted the relationship between economic growth and carbon emission. An inverted U-shaped relationship was identified, which is evidence of the EKC hypothesis [26]. Renewable energy plays an important role in reducing carbon emissions during the economic growth of nations and regions. RKC (renewable Kuznets curve) and EKC were compared in 17 major developing and developed economies; the study identified a long-run relationship between economic growth, RER, and carbon emission [27].

Several different modern econometric techniques have been employed to scientifically prove the causal relationship and effects of environmental pollution in different countries. However, fewer studies have been conducted over Kenya. Therefore, this study examines the causal nexus and impulse responses between carbon dioxide emission, gross domestic product per capita, industrialization, and population in Kenya. Furthermore, the methods employed also throw more light on the estimation of the impulse responses among the different variables of the study. This will help the policymakers in Kenya to continue the analysis of the situation and finally, the study will increase existing literature about the relationship between the variables mentioned above.
The flow of the study consists of a data and methodology 2, results and interpretation in section 3, discussion in section 4, and conclusion in section 5.

II. Material And Methods

This section describes data and methods used to examine the relationship between economic growth, carbon dioxide emission, industrialization and population.

Data description: The present research used carbon dioxide emissions (CO_2) expressed in Kilogram tons (kt), Gross Domestic Product per capita (GDPPC) expressed in (current LCU), Industry (IND) value added (current LCU) and finally population (POP) of Kenya. The vector of industrialization is represented as industry value added (current LCU) because the industry value added represents both private and public industrial contribution towards the GDP in an economy. All data span from 1965 to 2018.

Study Location: Kenya was considered as the case study in this research.

Study Duration: January 1965 to December 2018.

Procedure methodology

First of all, this study uses regression technique to carried out the linearity test of the data, i.e., to find out if the hypothesis estimation is significant or not, and if so, to find out to what extent are the regressors significant toward the dependent variable in this study which will help us identify the level of confidence of the variables in the study.

In addition, the Unit root test was used to test the data stationarity. This help to run the Autoregressive Distributed Lag model (ARDL). To run the ARDL model, the data of both dependent and independent variables are meant to be stationary at the level and 1st difference to prevent spurious regression and give prefect results of the short-run and long-run assumption.

Furthermore, the Granger Causality test was used to identify the direction of causality between variables considered in the study. It is implemented when there is an indication of co-integration between the variables. The study further uses a vector error correction model (VECM) to correct the different errors in the assumption to identify the long-run relationship between variables.

Due to the presence of orthogonal problem that might be associated with the granger causality analysis, which only limits it to the analysis of the causality between variables but fails to bring out the impulse response between the variables, the study employs impulse response test to identify the impulse of the different variables in a 10-period horizon in Kenya.

III. Results

III.1 Descriptive Statistics

The linear regression test was carried out to test for the linearity of the data in other worlds to find out if the hypothesis estimation is significant or not, and if so, to find out to what extent are the regressors significant toward the dependent variable in this study which will help us identify the level of confidence of the variables in the study. Table 1 shows the outcome results of the linear regression analysis, taking carbon dioxide emission in metric tonnes (CO2) as the dependent variable and gross domestic product per-capita (GDPPC), industrialization (IND), and population in a year (POPLN) as independent variables.

Table 1: Summary statistics from the linear regression analysis

variables	coefficient	Std error	prob
GDPPC	-0.036843	0.054996	0.5060
IND	1.13E-08	5.54E-09	0.0475
POPLN	0.000136	3.56E-05	0.0004
ADJUSTED R SQRD	0.967736		
Durbin-Watson stat	0.764882		

Table 1 shows a positive autocorrelation in the data set evidence from the Durbin-Watson stat, which is at 0.764882 less than absolute 2. The probability values (p-value) of the independent variables are significant apart from the GDPPC variable, which is at 0.5060, which is more than 5%, which confirms the null hypothesis of not being linear. In contrast, the other variables are significant with their p-value < 5%. From TABLE 1, the study concludes that the 1% change in carbon dioxide emission (CO2) leads to a -0.036843, 1.13E-08, 0.000136 change in GDPPC, IND, and POPLN, respectively. The r-squared and adjusted r-squared values are also quite high, indicating the percentage at which this model determines the outcomes and also if it is suitable for the data set used.

It is usually important to analyse the state of the data before carrying out some research and analysis of data; this helps determine the right state of data before tackling it. Evidence from Table 2 below population values has a normal skewness, which is normally distributed, which is indicated by a skewness value of 0.368374. It is also mesokurtic according to its value of kurtosis 1.917724, which is less than 3 and this also Implies that it is platykurtic, meaning it has a lot of values below its sample mean. Looking at the rest of the values, that is to say, the GDPPC, CO2, IND have positive skewness evidence from the table below where their values are 1.668307, 1.346962, 1.838046, respectively. Looking at their kurtosis values, they are all greater than 3, meaning that the above-mentioned variables are leptokurtic. Considering the jarque-bera probability value for POPLN, we cannot reject the null hypothesis since it depicts a conclusion that it is a normally distributed curve. It should be noted that the null hypothesis of the jarque-bera test is that the distribution is normal, the rest of the variables are not normally distributed since the probability values are highly significant at a 5% significant level, the values are not normally distributed, which will require the introduce a logarithm transformation LOG variable to stabilize the variables in the further analysis more it will help the study to have a stable variance in the estimation using the econometric analysis it will also reduce the tendency of multi-collinearity. The estimate equation with the logarithm variable is

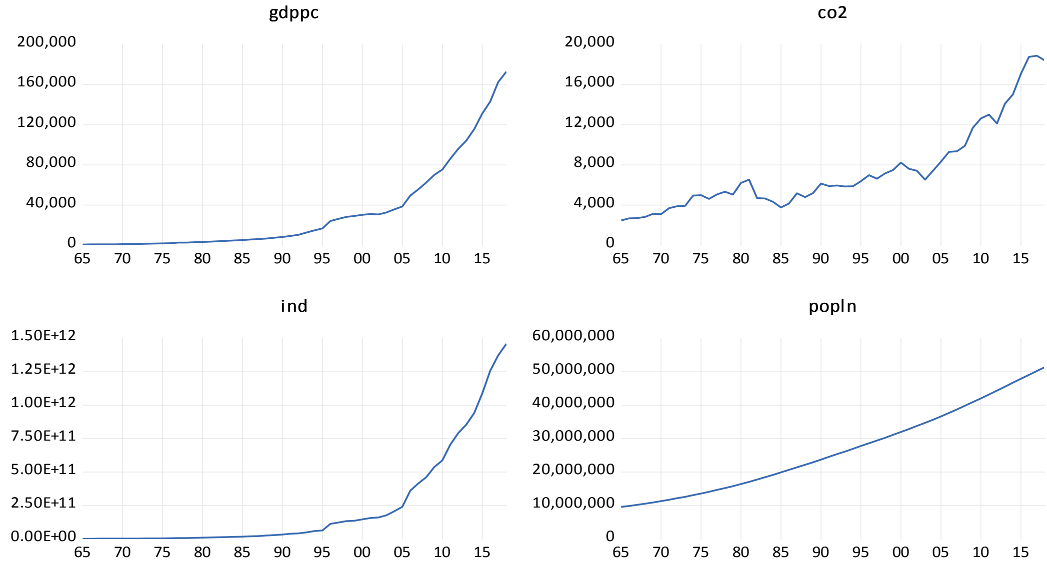
LCO2 = C(1)*LGDPPC + C(2)*LIND + C(3)*LPOPLN + C(4),

where L is a representation of LOG and C is the constant value in the estimation.

Table 2: Descriptive statistics of all variables used in the study

Statistics	GDPPC	CO2	IND	POPLN
Mean	32919.69	7371.663	2.39E+11	26622019
Median	9793.406	6045.000	4.00E+10	24923897
Maximum	173023.3	18890.00	1.46E+12	51392570
Minimum	747.9408	2467.891	1.19E+09	9530163.
Std. Dev.	45003.27	4288.546	3.85E+11	12615725
Skewness	1.668307	1.346962	1.838046	0.368374
Kurtosis	4.848245	3.995701	5.318385	1.917724
Jarque-Bera	32.73524	18.55945	42.49927	3.856770
Probability	0.000000	0.000093	0.000000	0.145383
Sum	1777663.	398069.8	1.29E+13	1.44E+09
Sum Sq. Dev.	1.07E+11	9.75E+08	7.85E+24	8.44E+15
CORRELATION				
GDPPC	1			
CO2	0.978500	1.000000		
IND	0.968962	0.995627	1.000000	
POPLN	0.920540	0.896418	0.857425	1.000000

Figure 1. Time series of GDPPC, CO_2, IND and POP of Kenya from 1965 to 2018



We further used Augmented Dickey Fuller (ADF) to test stationarity of data. The results show that the variables are stationary both at the level and 1st difference, evidence from the P-values with a probability of less than 5%. After getting the results of stationarity, the study carries on ARDL test to estimate the relationship between variables both in the short and long run and the correlation between the variables, and bound test to estimate the long term relationship between variables.

Table 3: ADF test results

Estimated number of lags	**variables**	**P-value at level**	**P-value at 1st difference**
		Intercept	
10	Lgdppc	0.9742	0.0000
10	Lind	0.9106	0.0000
10	Lpopln	0.0271	0.8666
10	Lco2	0.8972	0.0000
		Trend and intercept	
10	Lgdppc	0.0047	0.0002
10	Lind	0.1434	0.0000
10	Lpopln	0.9997	0.0330
10	Lco2	0.5901	0.0000

III.2 Autoregressive Distributed Lag Model

To run the Autoregressive Distributed Lag (ARDL) model, the data of both dependent and independent variables are meant to be stationary at the level and 1st difference to prevent spurious regression and give prefect results of the short-run and long-run assumption.

Table 4 shows results of the ARDL test considering both endogenous and exogenous variables, which signifies co-integration between the variables evidence from the Prob value in TABLE 4 for variables of LCO2, LGDPPC, LIND, LPOPLN. The r-squared value is at 96.8%, which indicates the normality of the representation F-stat is also significant, and the Durbin-Watson stat is 1.997149. LGDPPC is significant at 6th lag, and there is a negative co-efficient relationship with LCO2 in the short run; that is to say, a 1% increase in LCO2 leads to a negative change in the LGDPPC of -0.964927. The probability value of LPOPLN is also significant with the probability at 0.0029, but it has a negative coefficient value for the dependent variable where the 1% increase in LCO2 will lead to a -79.15864change in LPOPLN. Also, a 1% increase in LCO2 will lead to an increase in industrialization by 0.535245 in the short run. The above results can be represented as below, where C (1) is the constant variable in the assumption and C (5) is the error term.

$$LCO2 = C(1)*LCO2(-1) + C(2)*LGDPPC + C(3)*LIND + C(4)*LPOPLN + C(5)$$

Table 4: ARDL Short-run results

Variable	Coefficient	Std.Error	t-statistic	prob
LCO2(-1)	0.667581	0.159111	4.195680	0.0002
LCO2(-2)	0.002682	0.206986	0.012959	0.9897
LCO2(-3)	0.413928	0.200460	2.064891	0.0480
LCO2(-4)	-0.324122	0.204658	-1.583726	0.1241
LCO2(-5)	0.085235	0.211078	0.403805	0.6893
LCO2(-6)	0.573456	0.205061	2.796509	0.0091
LGDPPC	-1.782195	0.779248	-2.287070	0.0297
LGDPPC(-1)	0.210324	0.782175	0.268897	0.7899
LGDPPC(-2)	0.369654	0.841075	0.439501	0.6636
LGDPPC(-3)	-0.595526	0.642833	-0.926409	0.3619
LGDPPC(-4)	0.268487	0.367388	0.730800	0.4708
LGDPPC(-5)	-0.964927	0.326743	-2.953164	0.0062
LIND	1.191331	0.430843	2.765115	0.0098
LIND(-1)	-0.398769	0.454353	-0.877663	0.3873
LIND(-2)	0.179987	0.492152	0.365715	0.7172
LIND(-3)	0.535245	0.390873	1.369359	0.1814
LPOPLN	-79.15864	24.29699	-3.257960	0.0029
LPOPLN(-1)	79.76257	24.90595	3.202551	0.0033
r-squared	0.977626			
Durbin-Watson	1.945539			

Figure 2 shows how the model has been selected while running the ARDL model where the least value was selected (6,5,3,1). These values show at which lag the different variables were most significant. After estimating the ARDL test, the study would like to examine the presence of the long-run relationship between the variables through the Bound test estimation.

Figure 2: Akaike information criteria (AIC) for model selection**.**

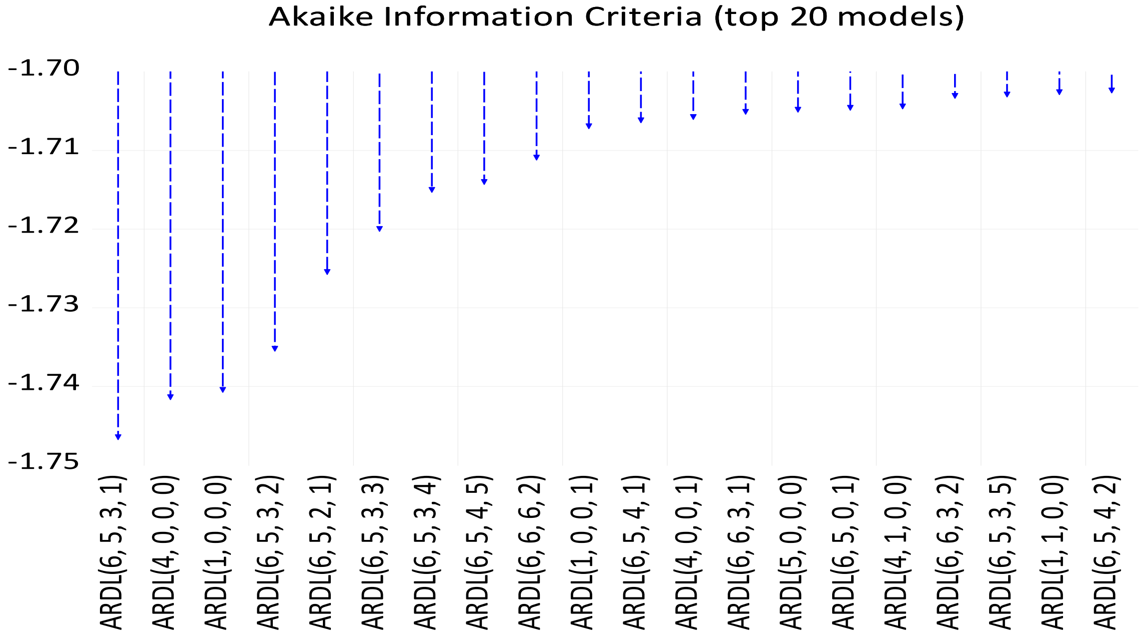


Table 5 depicts that there is a long-run relationship between variables evidence from the F-statistic, which is greater than the value on the upper bound at 5% probability the f-statistics is at 4.585795 while that upper bound is at 3.67 at the probability of 5%. Furthermore, in the long run, we also see that there is a negative relationship between LCO2 and LGDPPC, which depicts the invented U-shaped environmental Kuznets curve EKC nature, which has a shape of this nature, meaning that the EKC in Kenya is relevant both in the short and long-run analysis.

The representation of the long-run analysis can be seen in the following equation.

LCO2 = C(1)*LCO2(-1) + C(2)*LGDPPC + C(3)*LIND + C(4)*LPOPLN + C(5)

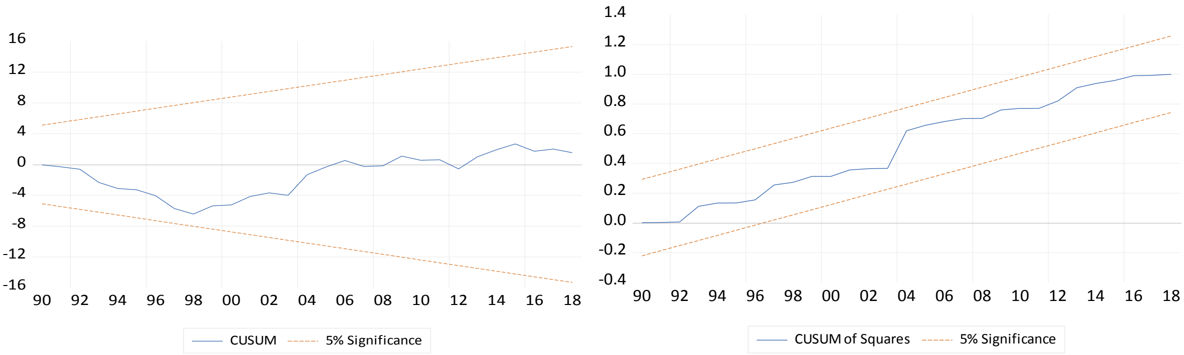
Table 5: ARDL long-run and bound test results

Variables	Co-efficient	t-statistic	Prob	
LCO2(-1)*	0.418760	1.483996	0.1486	
LGDPPC(-1)	-2.494184	-3.339618	0.0023	
LIND(-1)	1.507796	4.138368	0.0003	
LPOPLN(-1)	0.603930	0.765609	0.4501	
Bound test				
Test statistics			**value**	**K***
F-stat			4.585795	3
Critical value bounds				
significance			Lower bound	Upper bound
10%			2.37	3.2
5%			2.79	3.67
2.5%			3.15	4.08
1%			3.65	4.66

Figure 3 represents cusum and cusum of squares test results, the study examines the cointegration validity using these tests, and as evidenced from figure 3, the plots lie within the 5% significance level, which indicates that the parameters of the equation in the ARDL model are stable to make unbiased statistical inferences.

Figure 3: Annual ARDL stability test

(a) Cumulative sum (CUSUM) (b) Cumulative sum of squares (CUSUMS)



Unrestricted co-integration rank test (trace)

The evidence for cointegration can also be seen after running the Johansen cointegration test (trace test method), as the results are seen below. The probability of 0.0000 is less than 5% which means there is a cointegration in the series evidence from table 6.

Table 6: Co-integration test results

Hypothesized No of CE(s)	Eigenvalue	Trace statistic	0.05 critical value	Prob value
B None *	0.652498	89.20180	47.85613	0.0000
At most 1*	0.326735	34.23858	29.79707	0.0144
At most 2	0.152204	13.66656	15.49471	0.0926
At most 3*	0.093082	5.080553	3.841465	0.0242

III.3 Granger Causality Test

The granger causality test helps to identify the direction of causality in the study this is because there is an indication of cointegration between the variables as seen in TABLE 5 and TABLE 6 above. The study uses a vector error correction model to correct the different errors in the assumption to identify the long-run relationship between variables.

Based on the probability value in the above granger causality assumption, it can be noted that there is a causality between our variables running from LPOPLN to LGDPPC and also from LIND to LPOPLN in the short run since the prob value(p-value) is 5% the study rejects the null hypothesis, meaning that the population growth in Kenya granger cause the gross domestic product per capita and also the industrialization granger cause population growth in Kenya. However, the study assumes that there are some errors in this assumption since it is a short-run assumption, so we have to carry out the vector error correction test to identify the direction of causality in the long run. The study would like first to determine the number of lags to be considered for the vector error correction model to be run.

Table 7: Granger Causality test results

Null Hypothesis:	Obs	F-Statistic	Prob.
LGDPPC does not Granger Cause LCO2	52	1.53781	0.2255
LCO2 does not Granger Cause LGDPPC		0.12677	0.8812
LIND does not Granger Cause LCO2	52	1.82025	0.1732
LCO2 does not Granger Cause LIND		0.76189	0.4725
LPOPLN does not Granger Cause LCO2	52	1.72191	0.1898
LCO2 does not Granger Cause LPOPLN		2.92982	0.0632
LIND does not Granger Cause LGDPPC	52	2.77871	0.0723
LGDPPC does not Granger Cause LIND		1.50134	0.2333
LPOPLN does not Granger Cause LGDPPC	52	3.78124	0.0300
LGDPPC does not Granger Cause LPOPLN		2.90313	0.0647
LPOPLN does not Granger Cause LIND	52	2.46996	0.0955
LIND does not Granger Cause LPOPLN		5.57615	0.0067

Table 8: Lag selection criteria

VAR Lag Order Selection Criteria						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	77.89924	NA	6.85e-07	-2.842278	-2.692183	-2.784735
1	479.7136	726.3568	2.47e-13	-17.68129	-16.93082	-17.39358
2	591.7666	185.3183*	6.21e-15*	-1.37564*	-0.02478*	-0.85775*

AIC criteria appear to be the least in the table at a maximum of 2 lags, and the study will use 2 lags in the estimation for endogenous variables since AIC criteria have a less value than other criteria making it more significant and appropriate to be used in the study.

Granger causality test with VECM

Since the series are cointegrated, the study chose to use the VECM (vector error correction model) to estimate Granger causality. In Table 9, the study assumes that the null hypothesis as the independent variables doesn't lead to the dependent variable and conclusions will be made by looking at the probability value of variables in the assumption if the probability value is less than 5%, we shall reject the null hypothesis, and if it is greater than 5%, we shall accept the null hypothesis.

The Chi-sq value also indicated the causality level, which identifies how each variable affects the other in the long run. GDPPC doesn't lead to CO2. We accept the null hypothesis in the assumption, which also confirms the results in Table 7; hence there is no long-run relationship in the long run, which is evident on the EKC (environmental Kuznets curve) hypothesis in Kenya. On the other hand, there is a unidirectional causality relationship between variables from LPOPLN to LGDPPC and from LPOPLN to LIND in the long run, whereby a 1% increase in population will cause 15.74164 and 19.33095 change in GDP growth and industrialization, respectively. After the long-run analysis, the study can conclude that there is a bi-directional causality running from industrialization to population and from population to industrialization and also the unidirectional causality from population to gross domestic product per capita is highlighted again.

Table 9: VECM Granger causality results

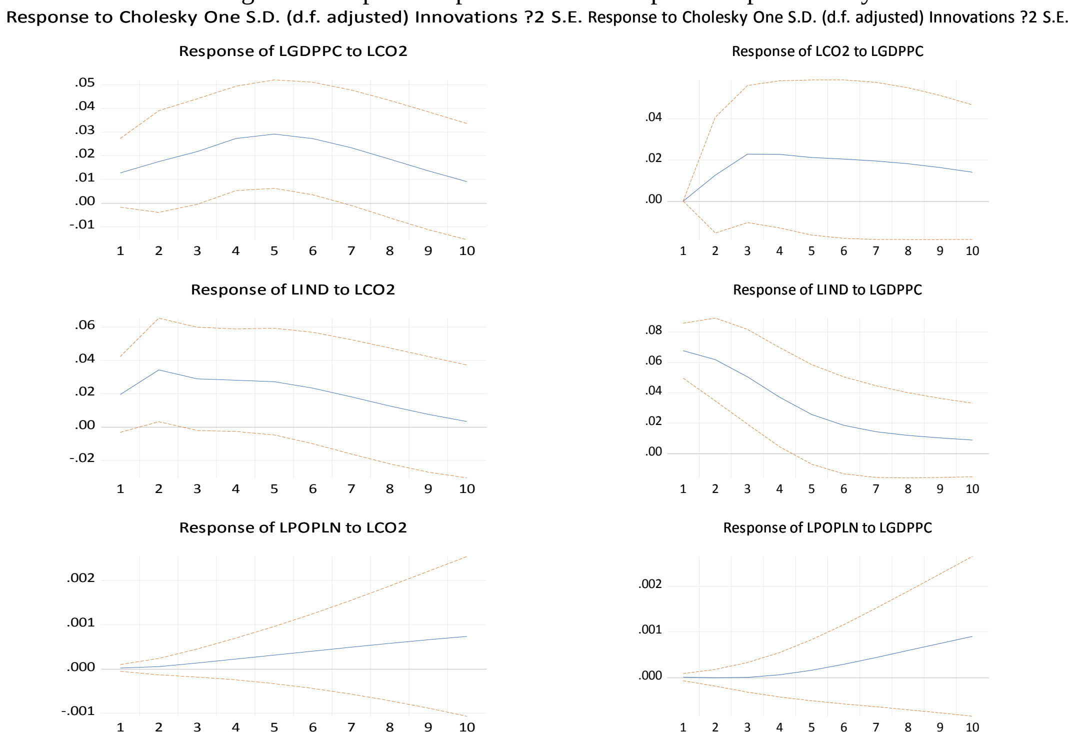
Equation	Excluded	Chi2	df	prob
D(LCO2)	D(LGDPPC)	1.113648	2	0.5730
D(LCO2)	D(LIND)	1.555188	2	0.4595
D(LCO2)	D(LPOPLN)	0.949793	2	0.6219
D(LCO2)	All	2.707019	6	0.8446
D(LGDPPC)	D(LCO2)	1.264590	2	0.5314
D(LGDPPC)	D(LIND)	4.112036	2	0.1280
D(LGDPPC)	D(LPOPLN)	0.425565	2	0.8083
D(LGDPPC)	All	4.911609	6	0.5552
D(LIND)	D(LCO2)	1.808601	2	0.4048
D(LIND)	D(LGDPPC)	2.860606	2	0.2392
D(LIND)	D(LPOPLN)	0.116196	2	0.9436

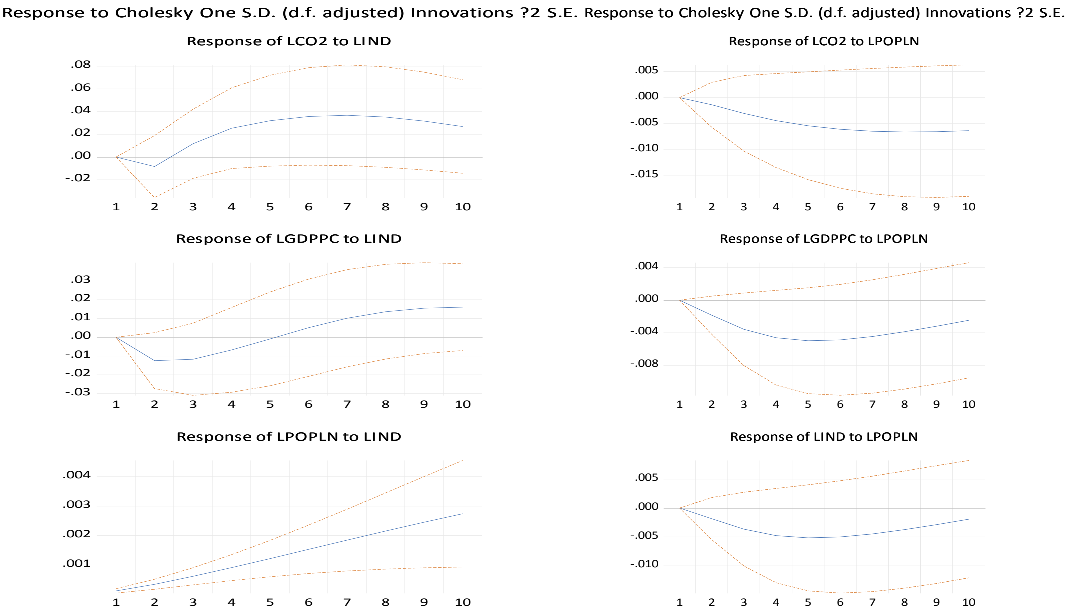
D(LIND)	All	4.548800	6	0.6028
D(LPOPLN)	D(LCO2)	0.790940	2	0.6734
D(LPOPLN)	D(LGDPPC)	15.74164	2	0.0004
D(LPOPLN)	D(LIND)	19.33095	2	0.0001
D(LPOPLN)	All	20.91399	6	0.0019

III.4 Impulse-Response Analysis

Due to the presence of orthogonal problem that might be associated with the granger causality analysis, which only limits it to the analysis of the causality between variables but fails to bring out the impulse response between the variables, the study employs impulse response test to identify the impulse of the different variables in a 10-period horizon in Kenya. Evidence from FIGURE 4 shows that the response from LGDPPC to LPOPLN, LCO2 to LPOPLN, LIND to LPOPLN, LGDPPC to LIND, LCO2 to LIND are insignificant, whereas impulse responses from LPOPLN to LIND to LCO2 to LGDPPC are significant. In other words, the impulse response test helps us identify the impulse in the study. The impulse response runs from population growth to industrialization to carbon emission and finally to gross domestic product per capita in the 10-period horizon in Kenya. Evidence from the impulse responses from LCO2 to LPOPLN, LGDPPC to LPOPLN, LIND to LPOPLN, LCO2 to LIND, LGDPPC to LIND are insignificant, while the responses from LGDPPC to LCO2, LIND to LCO2, LCO2 to LGDPPC, LPOPLN to LGDPPC are significant.

Figure 4: Graphical representation of Impulse-response analysis





IV. Discussion

The aim of the study was attained by running different models, which include the ADF unit root test, ARDL model for short-run analysis, bound test for long run estimation, the granger causality test to find out the causality between factors, and finally, the VECM Granger causality test to see the impulse response of the analysis. The ARDL model was utilized on the variable in the study, and a negative relationship between carbon dioxide and gross domestic product per capita was negative, which indicates an inverted U-shaped curve of the EKC, carbon emission in the first stage of economic growth increases with economic growth up to the breaking point which was later indicted by the impulse response in the third period FIG 4 which examined the impulse responses between variables for the horizon of 10 periods. The causality analysis showed a directional and bidirectional response between the variables running from population density to gross domestic product per capita, from industrialization to population density, and population density to industrialization. This means that the population density leads to the economic growth of Kenya. The industrialization of kenya has led to increased population density in both the long and short run. Population density also influences industrialization in the long run, which is a bidirectional relationship between these two variables. The study identified a bidirectional causality relationship running from industrialization to population density and finally to gross domestic product.

Evidence from the impulse response, the variables exhibited significant and insignificant responses. The responses ranged from population to industrialization to carbon emission and gross domestic product. So it can be seen that the change in population density leads to an increase in industrialization, which increases carbon emission and hence leads to economic growth in the short run; this is seen up to the 3rd period where a breaking point of carbon emission is seen in relation to the economic growth, the fall in carbon dioxide emission might be as a result of using renewable energy and also investing in other economic activities that contribute to fewer carbon emissions like tourism which has contributed up to 60% in the past decade due to the presence of many tourism companies that come up and also tourist sites.

V. Conclusion

Evidence from the ARDL model's short-term and long-term results shows an equilibrium relationship between variables in the estimation. The study observed these relationships mostly the relationship between carbon dioxide emission and GDP per capita, and there seems to be a negative elasticity between these variables both in the short and long run, which implies that looking at the long run results of the bound test, the 1% increase in GDP per capita will lead to a decrease of 2.494184 of carbon dioxide emission. On the other hand, the relationship between carbon dioxide and industrialization seemed to be positive. Therefore, a 1% increase in industrialization in Kenya will increase 1.507796 in the long run. Otherwise increasing economic growth in Kenya will reduce environmental pollution in the long run, which appears to as evidence of the applicability of the environmental Kuznets curve hypothesis in Kenya.

The granger causality and impulse response highlighted the different causality between the variables in the study from industrialization to population density, from population density to industrialization, and from population density to economic growth in the short and long run.

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