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Macroeconomic Determinants Of Carbon Emissions In Kenya: An Ardl Approach

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ABSTRACT

Environmentally sustainable economic growth portends numerous benefits to developing economies. However, development of energy sources whereas maintaining environmental quality presents diverse challenges. Nevertheless, stakeholders concur on the decisiveness and urgency on adoption of renewable resources and environmentally affable powering of the economy. The primary objective of this study was to examine the macroeconomic determinants of CO2 emissions in Kenya. Specific objectives included determining the effect of economic indicators such as; gross domestic product, population growth and trade openness on carbon emissions in Kenya. The study also analysed the effect of energy mix such as; Energy generated from renewable sources, fossil fuel sources, Alternative and Nuclear Energy sources and Imported Energy on carbon emissions in Kenya. The study spanned from 1970 to 2015, relying on data from Energy Information Administration database and World Bank's World Development Indicators database. The study utilized the Autoregressive Distributed Lag (ARDL) model to analyse the dynamic interactions and to estimate the long-run and short-run relationships amongst the variables under study from the ECM. The Augmented Dickey Fuller and Philip Perron determined that gross domestic product was stationary at level with the rest of the variables stationary at first difference. The models did not exhibit multicollinearity and normality assumptions which were tested by VIF test and Lomnicki-Jarque-Bera test for normality respectively. The results established that in the long run, changes in population growth (p – value $0.001 < 0.05$), gross domestic product (p – value $0.031 < 0.05$) and trade openness (p – value $0.001 < 0.05$) have significant effect on CO2 emissions. Further, results indicated that except renewable energy (p – value $0.326 > 0.05$), fossil fuel (p – value $0.001 < 0.05$), alternative and nuclear energy (p – value $0.042 < 0.05$), imported energy (p – value $0.012 < 0.05$) have significant effect on CO2 emissions in Kenya. In the short run carbon IV oxide, fossil fuels, imported energy, alternative and nuclear energy had coefficients of 0.3600, 0.9907, 0.6753, and 0.0899 all significant at 5% level of significance respectively. Gross domestic product, population growth and trade openness had coefficients of 0.034934, 12.8319 and -0.5133 significant at 5% level of significance. Except for trade openness with a negative coefficient all other variables had positive coefficient hence contribute to increase in carbon emissions. The adjustment coefficients were -0.62482 and -0.40046 significant at 5% level of significance indicating presence of short run adjustments and a long run equilibrium. The study proposes adoption of trade policies restricting high carbon emitting products and more tax incentives to products with less carbon emissions. Adoption of energy sources with low carbon IV emissions such as solar and wind will reduce the use of fossil fuels consequently reducing carbon emissions.

Key Words: Kenya; ARDL; Trade Policy; Energy Sources; CO2 Emissions

1. BACKGROUND INFORMATION

Economic expansion and development is a crucial objective for most developing countries to be fully industrialized but at the same time, economic expansion usually causes environmental degradation. Therefore, execution of suitable policies vis-à-vis termination of environmental degradation without harming economic development in the country portents crucial challenge for policy makers. Kenya posted a striking performance in economic growth after independence in 1963. The GDP growth was 8.8 percent in 1963 with an average of 7.11 percent over the period 1963 to 1970. The high growth compared favourably with the now newly industrialised countries in Asia. The high growth resulted from focus on improving small scale agriculture, increased domestic demand, and expansion of market in East Africa (M'Amanja & Morrissey, 2005). The average growths in the next two decades declined significantly with growth rates of 4 percent and 2 percent for the 1990/80 and 2000/90 periods. The decline emanated from strong external macroeconomic shocks and application of imprudent macroeconomic policies that set a stage for declining economic growth. The past decade had average GDP growth of 4.6 percent (Meier, 2010). Kenya recorded low GDP growth rates compared to other East African countries. Kenya's neighbours Tanzania recorded 7.2 percent while Uganda had 6.5 percent and 7.5 percent for Rwanda compared to 4.7 percent for Kenya for the year 2013 (KNBS, 2014)

The increase in economic growth demands significant energy levels to sustain development. Increase in gross domestic product demands increased energy supply to meet the rapid demand especially in the major areas that are sustaining economic growth such as infrastructure development, agricultural machinery and industrial developments. The World Bank estimates that energy production grew by over 25 percent for the period 1980 to 2010.

In Kenya, production of energy from primary sources, natural gas, oil fuels, and combustible renewable and crucial electricity increased continuously from the year 1980 to the year 2010. This is in line with the increase in total population of the country that is estimated to have increased from 16,267,906 in 1980 people to 44,353,691 people in the year 2012 (KNBS 2013). Energy imports as a percentage of net energy use decreased continuously from 21.57 percent in 1970 to 19.70 percent in 2012. The decrease in energy imports owes to increased investment to the energy sector in Kenya increasing the ability of the country's energy supply.

Carbon (IV) oxide has two main primary sources. The first one is ignition of fossil fuels, like crude oil, natural gas and coal. The second one is from manufacturing activities that emit CO_2 resulting from chemical reactions. In all these instances, CO_2 emissions – energy use nexus is primarily chemical and physical. But the correlation varies in regard to the combustion types, production means and energy creation and efficacy. The levels of CO_2 discharge have shot to high of 12, 427 kWh by the year 2010 from 6,124 kWh in 1980. Despite a decline from the year 1980 to 1985, the sharp increase was experienced. The increase in emissions of CO_2 is attributed to increase in population and increased economic activity. The rise of CO_2 is almost consistent with the rise of energy production and consumption indicating a correlation in levels of CO_2 and the demand –supply side.

The growing emissions are resulting to global warming that will significantly affect the environment. The adverse effects of environmental pollution increase the cost on achievement of development and alleviation of poverty. Increase in diseases, reduced agricultural production, poverty, flooding, drought and increased insecurity due to fighting for scarce resources is an additional burden to African countries (Shahbaz, Solarin, & Ozturk, 2016).

In trying to address the challenges of global climate change, world's climate change experts and policy makers met in November, 2016 in Marakesh, Morocco, to try to set the world on track to reducing greenhouse gas emissions that cause climate change. The same experts as earlier stated also met in 2015 in Paris and reached a welcome agreement that seeks to limit the rise in global temperature above pre-industrial levels by two degrees Celsius. However, the emissions of greenhouse gases are not falling yet the effects of climate change are worsening.

1.1 STATEMENT OF THE PROBLEM

The effects of environmental pollution are adverse ranging from drought, flooding, increased insecurity resulting from scarcity of resources such as water and food. Sustainable economic development is key in ensuring the benefits accruing from modernization of agriculture, increase in the production and use of energy do not negatively influence the environment. Increase in the manufacturing sectors through setting up of factories both by the local and multinational companies promotes growth in job opportunities, economy and increase local production. The CO_2 emissions in Kenya have been rising over the years. The increase may be attributed to the increased electricity supply accelerated growth of up to 9.7 percent in 2015.

The energy mix in Kenya has diversified over the years from relying on hydroelectric power, to the development of geothermal which currently contributes to large amount of power to the grid. There is a shift from use of solid fuel at homesteads to adoption of gases and electric sources which has significantly influenced CO_2 emissions. The energy mix is poised for more changes with inclusion of wind and solar as significant contributors to the grid. The recent discoveries of oil in Kenya are poised to shift the energy mix hence an understanding of the correct energy mix even in extracting and processing this valuable product is crucial for reducing carbon (IV) oxide emissions. The study was anchored on the need to reduce the environmental effects of economic growth and other factors.

2. EMPIRICAL LITERATURE REVIEW

Behnaz, Saboori and Sulaiman (2013) probed the cointegration and causal relationship between economic growth, CO_2 emissions and energy consumption in five ASEAN nations for the period 1971-2009, they established inverse relationships between economic growth and CO2 emission. Shahbaz, *et al.,* (2015) used the Pedroni cointegration test and Johansen cointegration test to analyze the relationship between economic growth, energy intensity and CO_2 emissions in 12 African nations for the period, 1980–2012. Mistri and von Hauff (2015) assert that there is exceptionally extreme tradeoff between economic growth and environmental sustainability in a more quickly developing nation like India.

Farhani and Ozturk (2015) inspected the causal association amid CO_2 emissions, real GDP, energy utilization, financial development, trade openness, and urbanization in Tunisia over the time of 1971–2012. Li *et al.,* (2016) also applying a panel of 28 provinces of China from 1996 to 2012 to scrutinize the impact of economic growth, energy usage, openness of trade, and urbanization on the CO_2, waste water, and waste solid emissions by approximating a dynamic panel model with the system Generalized Method of Moments (GMM) estimator and an ARDL model with alternative panel estimators, respectively.

Paramati *et al.,* (2016) empirically examined the dynamic relationships among tourism, economic growth, and CO_2 emissions and compared the effects of tourism on economic growth and CO_2 emissions between developed and developing economies. Heidari *et al.,* (2015) explored the relationship between economic growth, CO_2 releases, and energy utilization in five Association of South East Asian Nations (ASEAN) countries (Indonesia, Malaysia, Philippines, Singapore, and Thailand) by applying the Panel Smooth Transition Regression (PSTR) technique as a new econometric technique. Bento and Moutinho (2016) applied the ARDL bounds testing tactic to cointegration to scrutinize the dynamic causative association amid CO_2 releases per capita, real GDP per capita, per capita non-renewable electricity generation and per-capita renewable electricity generation, and international trade in Italy case from 1960 to 2011.

Jebli *et al.,* (2016) analyzed the causal connections among per capita CO_2 emissions, GDP, renewable and non-renewable energy utilization, and international trade for a panel group of 25 OECD states over the period 1980–2010. Bastola and Sapkota (2015) inspected the causal relationship among energy consumption, pollution discharge, and economic growth for Nepal utilizing time series econometric technique. Al-Mulali *et al.,* (2015) investigated the impact of economic growth, renewable energy utilization and financial development (FD) on CO_2 discharge in Latin America and Caribbean nations by applying a panel data analysis on CO_2 model in the timeline 1980–2010. Further, in examining the occasions that brought about the environmental debasement in the MENA states, Al-Mulali and Ozturk (2015) made use of a Panel model that represented the environmental degradation using ecological footprint as a better indicator. Brahmasrene and Lee (2016) investigated the impact of growth and environment in Southeast Asia, Shahbaz *et al.*, (2015) investigated the relationship between coal consumption, industrial production, and CO_2 emissions in China and India for the period, 1971 –2011.

3. MATERIALS AND METHODS

The equations that relate CO_2 emissions to different factors are outlined in equation 3.1 and 3.2 in tandem with the objectives of the study.This study adopted the Al-Mulali *et al.*, (2016) model and makes suitable modification to capture the particular features of Kenya. The general relationship between the variables was specified as follows:

$$\mathrm{co_2} = \mathrm{f(ie, fo, re, ane)} \ldots\ldots\ldots 3.1$$

$$\mathrm{co_2} = \mathrm{f(gdp, trd, ppl)} \ldots\ldots\ldots 3.2$$

The relevant specific long-run equations in this study can be expressed as:

$$\mathrm{lnco_{2t}} = \mathrm{a_0} + \mathrm{a_1} \ln \mathrm{ie_t} + \mathrm{a_2} \ln fo_\mathrm{t} + \mathrm{a_3} \ln re_\mathrm{t} + \mathrm{a_4} \ln ane_\mathrm{t} + \varepsilon_1 \ldots\ldots\ldots 3.3$$

$$\mathrm{lnco_{2t}} = \mathrm{b_0} + \mathrm{b_1} \ln \mathrm{gdp_t} + \mathrm{b_2} \ln \mathrm{trd_t} + \mathrm{b_3} \ln \mathrm{ppl_t} + \varepsilon_1 \ldots\ldots\ldots 3.4$$

Longrun equations 3.3 and 3.4 were estimated to examine the effect of imported energy, renewable energy sources, fosil fuel, alternative and nuclear energy use, economic growth, trade openess and population growth on carbon emissions. It was essential to transform the data to remove the non-normality in subsequent analysis. Natural logs transformation were used because they are monotonic transforms and always reduce the values of the coeficient. Log linear specifications also provides appropriate and more efficient results compared to simple linear functional form of a model (Hamilton, 1994).

4. RESULTS AND DISCUSSION

4.1 UNIT ROOT TEST

Unit root tests showed that variables were not stationary in their levels. The first difference of the variables have a mean reverting characteristic as they are visually mean reverting. These characteristics of these variables are confirmed by the stationarity tests done by Dickey Fuller and Phillips Perron in the next section.

The determination of the stationarity of the variables in Cointegration analysis provides insight in determination of integration characteristics of variables. It is important to determine the stationarity since it informs the choice of model to determine the relationship of the variables. If all variables are integrated of order one, the Johansen and Juselius (1990) method of Cointegration is employed. However, if the variables have different levels of stationary both I (1) and I (0) then a dynamic model of analysis such as ARDL model is employed in

Cointegration analysis (Nkoro & Uko, 2016). If the stationarity of the variables is not determined there is a likelihood of using an inappropriate model in determination of the short run and long run relationships of the variables.

Table 4.1: Unit Root Test at Level and First Difference

	Level					Differenced				
Variable	ADF	Prob	PP	Prob	Remarks	ADF	Prob	PP	Prob	Remarks
LGDP	-5.211	0.000	-6.946	0.000	No Unit root	-9.903	0.000	-5.207	0.00	No Unit root
LCO2	-2.599	0.2805	-1.235	0.6584	Unit root	-6.945	0.000	-6.946	0.00	No Unit root
LPPL	1.530	0.9976	1.345	0.9968	Unit root	-7.661	0.000	-7.625	0.00	No Unit root
LANE	-1.940	0.3134	-2.059	0.2612	Unit root	-7.076	0.000	-7.137	0.00	No Unit root
LIE	-2.127	0.2339	-2.133	0.2316	Unit root	-6.350	0.000	-6.348	0.00	No Unit root
LRE	-1.273	0.6412	-1.300	0.6290	Unit root	-6.205	0.000	-6.148	0.00	No Unit root
LFO	-1.357	0.2598	-1.178	0.6831	Unit root	-6.807	0.000	-6.978	0.00	No Unit root

Source: Data Analysis Results (2017)

The critical values for Augmented Dickey Fuller (ADF) are -3.621. -2.947 and -2.607 for 1%, 5% and 10% respectively for difference data. The critical values for Phillip Perron (PP) are -3.614, -2.944 and -2.606 for 1%, 5% and 10% respectively for difference data. Gross domestic product is stationary at level since its calculated value of -5.211 is greater than the critical value. All other variables are stationary at first difference as their coefficients are less than the critical values in ADF and Phillip Perron tests.

4.2 LAG LENGTH DETERMINATION MODEL I

The determination of the lag length used in Cointegration analysis allows adequate number of lags to be employed to avoid overestimation in model analysis. The determination is crucial since it shows the length of time for an effect to have impact on a variable. The Schwarz Information Criterion selects the most parsimonious models with the fewest coefficients whereas AIC selects the most lavish models (Lutkepohl, 2005). The ARDL model estimation employs the variables in their level form. The estimation of the model should be estimated using AIC and SBIC model of lag determination to evaluate and determine the model with the least standard errors and a high R^2.

Table 4.2: Lag Determination

Sample: 1974-2015				Number of observations = 42				
Lag	LL	LR	Df	P	FPE	AIC	HQIC	SBIC
0	162.629	3.80E-10			-7.5061	-7.43032	-7.300	-7.5061
1	310.364	295.47	25	0	1.1e-12*	-13.3507	-12.896*	-12.1095*
2	327.616	34.503	25	0.098	1.70E-12	-12.9817	-12.1476	-10.7062
3	364.12	73.008	25	0	1.10E-12	-13.595*	-12.3163	-10.2197
4	388.472	48.705*	25	0.003	1.50E-12	-13.4987	-11.9064	-9.1545
Endogenous: lco2 lfo lie lre lane Source: Data Analysis Results (2017)								

4.3 COINTEGRATION ANALYSIS

Cointegration test examines how time series, which though may be individually non-stationary and drift extensively away from equilibrium can be paired such that the workings of equilibrium forces will ensure they do not drift too far apart. Cointegration mimics the existence long run relationship in time series that converges over time. The determination of cointegration follows the determination of the lag length and cointegrating rank of the models in study. Determination of Cointegration is crucial in model specification to avoid misspecification which can result to biased coefficients. The variables under study are integrated of order one and at level. This implies that a model of analysis dynamic is required to test for the long run and short run relationships.

4.4 ARDL MODEL I

The ARDL models of cointegration allows for analysis for variables integrated at level and at order one. The error correction model estimates the short run and long run coefficients using lags determined by the ARDL model specification (Pesaran , Shin, & Smith , 2001)**.** The ARDL analysis is determined using the best model of analysis under STATA to ensure all the effects of the variables are captured without underestimating the lag. The model also ensures that the model with the least standard errors is estimated.

Table 4.3: ARDL analysis

Sample: 1974 – 2015
Number of observations = 42
R-squared = 0.966932
Adj R-squared = 0.956265

	Coef	Std. Err	T	P>t	[95% Conf interval]	
lco2						
L1.	0.601025*	0.135104	4.45	0.000	0.325478	0.876572
L2.	-0.00064	0.139774	0.00	0.996	-0.28571	0.284433
L3.	0.35917*	0.140394	2.56	0.016	0.072835	0.645505
L4.	-0.36001*	0.109895	-3.28	0.003	-0.58415	-0.13588
Lfo	0.990749*	0.259026	3.82	0.001	0.462463	1.519036
Lie	0. 0064461	0. 2240602	0.03	0.977	-0.45053	0.463420
L1.	0.906566*	0.313024	2.9	0.007	0.26815	1.544982
L2.	-0.67537*	0.254636	-2.65	0.012	-1.19471	-0.15604
Lre	0.692851	0.694582	1	0.326	-0.72376	2.10946
Lane	0.089938*	0.042416	2.12	0.042	0.00343	0.176445
Cons	-3.10759	3.505893	-0.89	0.382	-10.2579	4.042725

*Legend: * indicates the coefficient is statistically significant at 5%*

Source: Data Analysis Results (2017)

From the results we have a high R and adjusted R^2 of 96.69 and 95.63 percent affirming the model's significance in explaining the changes in levels of carbon (IV) oxide. We deduce that the first, third and fourth lags of carbon (IV) oxide are significant with probability of 0.000, 0.016 and 0.003 respectively at 5% level of significance indicative of the effect of previous CO_2 levels in influencing present levels of CO_2. The effect of fossil fuel on the levels of CO_2 is also significant given that the $0.001<0.05$. The coefficient of fossil fuels affirms the direct contribution of these fuels in increasing the levels of carbon (IV) oxide. Imported energy has first and second lag significant with probability of 0.007 and 0.012 respectively implying that changes in imported energy significantly affects levels of CO_2. Alternative and nuclear energy sources has a coefficient of 0.0899 with (p – value 0.042 < 0.05), indicating that alternative and nuclear sources of energy significantly contribute to changes in CO_2 levels. The analysis gives the long run effects of the model.

4.5 ESTIMATION OF THE ECM MODEL I

The ECM model is estimated using the optimal lags selected after analysis of the ARDL model. The model generates the error correction which is also the adjustment term, the long run coefficients and the short run coefficients. The optimal lags selected for this model are [4 0 2 0 0] for [lco2 lfo lie lre lane]. The selected lags take into consideration the least standard errors and optimal lag selection for determination of long run equilibrium. The estimated error correction model results are presented in table 5.

Table 4.4: Error Correction Model I

Sample: 1974 – 2015
Number of obs = 42
R-squared = 0.686495
Adj R-squared = 0.585365

	D.lco2	Coef.	Std. Err	T	P>t	[95% Conf	Interval]
Ecm t		-0.40046*	0.078584	-5.1	0.000	-0.56073	-0.24018
LR	Lfo						
	L1.	2.474048*	0.416218	5.94	0.000	1.625165	3.322931
	Lie						
	L1.	0.593417	0.760758	0.78	0.441	-0.95816	2.144992
	Lre						
	L1.	1.730152	1.726927	1	0.324	-1.79194	5.252244
	Lane						
	L1.	0.224588*	0.099086	2.27	0.031	0.0225	0.426676
SR	lco2						
	LD.	0.001482	0.114731	0.01	0.99	-0.23251	0.235478
	L2D.	0.000844	0.112686	0.01	0.994	-0.22898	0.230669
	L3D.	0.360013*	0.109895	3.28	0.003	0.13588	0.584147
	Lfo						
	D1.	0.990749*	0.259026	3.82	0.001	0.462463	1.519036
	Lie						
	D1.	0.006444	0.224061	0.03	0.977	-0.45053	0.463419
	LD.	0.675373*	0.254636	2.65	0.012	0.156039	1.194706
	Lre						
	D1.	0.692851	0.694582	1	0.326	-0.72376	2.10946
	Lane						
	D1.	0.089938*	0.042416	2.12	0.042	0.00343	0.176445
	cons	-3.10759	3.505893	-0.89	0.382	-10.2579	4.042725

*Legend: * indicates the coefficient is statistically significant at 5%*

Source: Data Analysis Results (2017)

The R has a value of 68.6 and R squared has a value of 58.5 which are reliably high to ascertain the creditability of the coefficients. An excessively high value of R is indicative of a problem of multicollinearity (Gujarati, 2004). The adjustment in the equilibrium is negative and significant (p – value 0.000 < 0.05), indicating a convergence. The existence of the adjustment of -0.40046 is evidence of short run adjustments and a long run equilibrium in the model. The adjustment variable is significant with P value of 0.00 < 0.05.

In the long run, fossil fuel changes and changes in alternative and nuclear energy significantly influence level of carbon (IV) oxide. Fossil fuel directly influences changes to CO_2 by 2.474048 in the long run. This implies that a unit change in fossil fuel increases the levels of carbon (IV) oxide emissions by 247.4048%. The coefficient of first lag of alternative and nuclear energy is significant at 5% level of significance with a probability of 0.031 < 0.05 level of significance. This implies that a unit change in the first lag of alternative and nuclear energy causes 22.45% increase in CO_2 emissions.

The results above further provides the short run analysis. The short run results establishes significant effect of first difference of fossil fuel, first lagged difference of imported energy and first difference of alternative and nuclear energy. The significance of these variables is confirmed with P values of 0.001, 0.012 and 0.042 respectively which are less than 0.05 significance level. Alternative and nuclear energy sources have a coefficient of 0.089938 implying that a unit change in this variables increases the CO_2 emissions by 8.9938%. Also, a unit change in use of fossil fuels results to change of CO_2 emissions by 99.0749%. Imported energy has a coefficient of 0.675373 significant at 5% implying a unit change in imported energy increases CO_2 emission levels by 67.5373%. The adjustment value is significant hence we reject the null hypothesis of absence of short run adjustments and long run equilibrium. We also reject the null hypothesis that fossil energy, imported energy and alternative and nuclear energy do not influence the levels of carbon emission.

4.6 BOUNDS TEST MODEL I

The bounds test is important in confirming the presence of a long run equilibrium in the variables under study. Variables that exhibit a long run relationship are cointegrated and can be analyzed to determine the nature of cointegration i.e. convergent or divergent relationship.

Table 4.5: Bounds Test Model I

H0: no levels relationship F = 5.422 t = -5.096								
Critical value 0.1			0.05		0.025		0.01	
k_4	[I_0] L_1 2.45	[I_1] L_1 3.52	[I_0] L_05 2.86	[I_1] L_05 4.01	[I_0] L_025 3.25	[I_1] L_025 4.49	[I_0] L_01 3.74	[I_1] L_01 5.06
accept if F < critical value for I(0) regressors reject if F > critical value for I(1) regressors								
Critical value 0.1			0.05		0.025		0.01	
k_4	[I_0] L_1 -2.57	[I_1] L_1 -3.66	[I_0] L_05 -2.86	[I_1] L_05 -3.99	[I_0] L_025 -3.13	[I_1] L_025 -4.26	[I_0] L_01 -3.43	[I_1] L_01 -4.6
accept if t > critical value for I(0) regressors reject if t < critical value for I(1) regressors k: # of non-deterministic regressors in long-run relationship								

Source: Data Analysis Results (2017)

The null hypothesis for the bounds test is accepted if the F statistic is greater than the upper bound critical value implying that the underlying variables are cointegrated. If the F-statistic is below the lower bound critical value, then the H_0 cannot be rejected implying that there is no cointegration among the variables (Nkoro & Uko, 2016). The bounds test in the above table confirms existence of a long run relationship since the F statistic of 5.422 is greater than the upper bounds at 10%, 5%, 2.5% and 1% significance levels which is 3.52, 4.01, 4.49 and 5.06 respectively. Therefore, we reject the null hypothesis that there is no level relationship among the underlying variables.

4.7 DIAGNOSTIC TESTS MODEL I

The presence of multicollinearity confirms the presence of perfect linear relationships among the explanatory variables. This implies that either of the explanatory variables can be written as a linear combination of another (Gujarati, 2004). The presence of multicollinearity makes precise estimation difficult. Also, the confidence intervals tend to be much wider, leading to the acceptance of the null hypothesis. Testing multicollinearity employs the variance inflation factor (VIF). A model is considered to exhibit multicollinearity if the variance inflation factor is greater than ten. 1/VIF delimits the tolerance levels which determine the degree of collinearity of variables. A tolerance level of less than 1 is paralleled to a VIF of 10. This infers that it may be a linear combination of other variables.

Table 4.6: Test for Multicollinearity

Variable	VIF	1/VIF
L.lco2	5.16	0.193764
Lane	4	0.250064
Lie	3.38	0.29618
Lfo	3.26	0.307121
Lre	2.1	0.476732
Mean VIF	3.58	

Source: Data Analysis Results (2017)

All the variables have a tolerance above 1 signifying none is a linear combination of another. The mean VIF is 3.58 well within the accepted levels i.e. lower than 20, values exceeding 20 are indicative of a problem of multicollinearity (Greene, 2017).

Autocorrelation refers to the correlation between members of a series of observations ordered in time. The estimates from analysis exhibiting autocorrelation may be linearly unbiased but are inefficient. Thus, it is crucial to establish that there is no autocorrelation in determining the regression estimates.

Table 4.7: Breusch-Godfrey LM Test for Autocorrelation

LAGS(p)	χ^2	DF	Prob $> \chi^2$
1	0.681	1	0.4091

Source: Data Analysis Results (2017)

The Breusch-Godfrey LM test for autocorrelation confirms the null hypothesis of no serial autocorrelation. The probability is greater than 0.05 significance level prompting acceptance of the null hypothesis. This establishment of no serial correlation affirms the statistical independence of the variables regressed.

The presence of heteroscedasticity may result in overestimation of the coefficients if the model of analysis is not used. Heteroscedasticity may rise from presence of outliers in the data or presence of skewness in one of the variables.

Table 4.8: LM test for autoregressive conditional heteroscedasticity (ARCH)

LAGS(p)	χ^2	DF	Prob $> \chi^2$
1	0.119	1	0.7304

H0: No ARCH effects vs. H1: ARCH (p) disturbance

Source: Data Analysis Results (2017)

The probability exceeds the set level of significance of 0.05. The test for heteroscedasticity accepts the null hypothesis that the errors are not autoregressive conditional heteroskedastic. This affirms that the disturbances appearing in the population regression have constant variances. The estimates from the model are reliable and usable in making conclusions and recommendations.

Table 4.9 Jarque-Bera Test

Equation	χ^2	DF	Prob $> \chi^2$
lco2	0.262	2	0.87725
Lfo	1.266	2	0.53103
Lie	4.497	2	0.10558
Lre	436.217	2	0.000*
Lane	40.808	2	0.000*
ALL	483.049	10	0.000*

*Legend: * indicates the coefficient is statistically significant at 5%*

Source: Author's Data Analysis Results, 2017

The test for normality indicate that the model has normal distributions given that the probability is less the 0.05 significance level. Alternative energy and renewable energy have normal distribution. The distribution of fossil fuels and imported energy do not have normal distribution.

4.8 TESTS FOR MODEL I STABILITY

The Cusum tests were estimated to test for the structural stability of the model. The cusum test is based on a plot of the sum of the recursive residuals. If this sum goes outside a critical bound, it implies that there was a structural break at the point at which the sum began its movement toward the bound. The cusum-of-squares test plots the cumulative sum of squared recursive residuals, expressed as a fraction of these squared residuals summed over all observations. The cusum and cusum squared test result are given in figure 4.1 and figure 4.2.

It is deduced that the model is stable given that the stability line lies between the set limits. Hence both the cusum and the cusum squared test confirm the structural stability of the model.

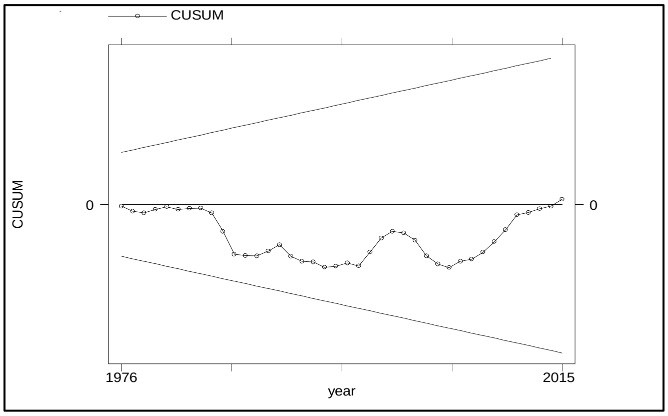

Figure 4.1: Cusum Test

Source: Author's Data Analysis Results, 2017

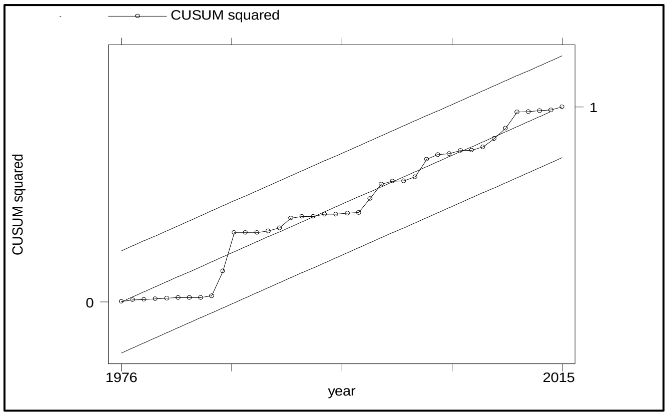

Figure 4.2: Cusum Squared Test

Source: Data Analysis Results (2017)

The cusum test requires that the line of fit lies within the confidence interval (Lutkepohl 2005). The cusum and cusum squared indicate that the model is stable. The line of fit in both test lies with the confidence interval which is indicative of the stability of the model.

4.9 DETERMINATION OF LAG LENGTH MODEL II

The lag length enables determination of time lapse in which the dependent variable is affected by changes in the model variables. The effects of the independent variables on the endogenous variables may not necessary exhibit an instantaneous effect but instead comprise of both instantaneous and lagged effect spread over a period of time. This determination provides background to establishment of the rank of Cointegration of the model.

Table 4.10: Determination of Lag Length Model II

Sample: 1974 - 2015 Number of obs = 42

Lag	LL	LR	DF	P	FPE	AIC	HQIC	SBIC
0	26.6014				4.00E-06	-1.07626	-1.0156	-0.91077
1	180.466	307.73	16	0	5.70E-09	-7.64125	-7.33795*	-6.8379*
2	190.248	19.564	16	0.241	7.80E-09	-7.34514	-6.79921	-5.85571
3	213.262	46.028	16	0	5.90E-09	-7.67914	-6.89056	-5.52774
4	234.119	41.714*	16	0	5.2e-09*	-7.91042*	-6.8792	-5.09705

Source: Data Analysis Results (2017)

Table above shows the lag as established by FPE, AIC, HQIC and SBIC. AIC determines that there are four lags while HQBIC and BIC defines it to be one lag. The model with the smallest lag length between AIC and SBIC is selected to provide the lag length. This informed the selection of one lag length in determining the cointegrating rank.

4.9.1 ARDL MODEL II

The ARDL analysis done with the variables at their level establishes the presence of long run relationship. The analysis on STATA selects the best model with the least standard errors and a high R^2.

Table 4.11: ARDL Analysis of Long Run Relationship

Sample: 1974 - 2015
Number of obs = 42
R-squared = .97986153
Adj R-squared = .96410098

	Coef.	Std. Err.	T	P>t	[95% Conf. Interval]	
lco2						
L1.	0.58342*	0.133863	4.36	0.000	0.306504	0.860336
L2.	-0.10816	0.160695	-0.67	0.508	-0.44058	0.224267
L3.	0.131753	0.159074	0.83	0.416	-0.19732	0.460822
L4.	-0.23184	0.125776	-1.84	0.078	-0.49203	0.028348
Lgdp	0.034934*	0.015161	2.3	0.031	0.003572	0.066297
L1.	0.029387	0.016275	1.81	0.084	-0.00428	0.063054
L2.	0.015578	0.017204	0.91	0.375	-0.02001	0.051168
L3.	0.021207	0.014894	1.42	0.168	-0.0096	0.052018
L4.	0.028273	0.013847	2.04	0.053	-0.00037	0.056919
Lppl	-1.17751	2.578595	-0.46	0.652	-6.51174	4.156723
L1.	1.830199	3.18515	0.57	0.571	-4.75879	8.419184
L2.	13.92078*	3.678876	3.78	0.001	6.310448	21.53112
L3.	-6.21885	3.461254	-1.8	0.086	-13.379	0.941305
L4.	-6.61314*	3.032269	-2.18	0.04	-12.8859	-0.34041
Ltrd	0.019172	0.14617	0.13	0.897	-0.2832	0.321547
L1.	0.226206	0.185393	1.22	0.235	-0.15731	0.609721
L2.	-0.32724	0.176413	-1.85	0.076	-0.69218	0.037696
L3.	0.513302*	0.140753	3.65	0.001	0.222132	0.804472
Cons	-0.24233	0.880183	-0.28	0.786	-2.06312	1.578471

*Legend: * indicates the coefficient is statistically significant at 5%*

Source: Data Analysis Results (2017)

The above results have R-squared of 97 percent indicative of the models relevance in explaining changes in levels of CO_2. The first lag of CO_2 is significant p –value 0.000 < 0.05 with coefficient of 0.58342 implying a unit change of t-1 increases the current levels of CO_2 emissions by 58.342%. We have a gross domestic product coefficient of 0.034 with a probability of 0.031 < 0.05.The positive coefficient indicates the direct relationship in influencing CO_2 levels in the long run. The third lag of trade is significant with a probability of 0.001and a coefficient of 0.5913 implying that it directly influences levels of CO_2. The second and fourth lag of population growth with p -values 0.001 and 0.04 which are less than 0.05 are significant implying that the second lag of population change has a positive influence towards CO_2 emissions by 13.92078 units while the fourth lag of population change has a negative influence towards CO_2 emissions by -6.61314 units. This coefficients are significant at 5% level of significance (p – values 0.001& 0.04 < 0.05).

4.9.2 ERROR CORRECTION MODEL II AND TEST OF HYPOTHESES

The error correction model estimates both the long run and the short run coefficients. The determination of the ECM is dependent on the optimal lags identified from the ARDL model. The optimal lags are identified as [4 4 4 3] for the variables [lco2 lgdp lppl ltrd] following the order of presentation. Using the optimal lags identified from the model the estimated ECM model is presented in table 4.13.

Table 4.12: ECM for Model II

Sample: 1974 -2015
Number of obs = 42
R-squared = 0.809076
Adj R-squared = 0.659658

	D.lco2	Coef.	Std. Err.	T	P>t	[95% Conf. Interval]	
Ecmt		-0.62482*	0.111574	-5.6	0.000	-0.85563	-0.39401
LR	lgdp						
	L1.	0.207065*	0.081443	2.54	0.018	0.038588	0.375542
	lppl						
	L1.	2.787178*	0.19684	14.16	0.000	2.379983	3.194373
	Ltrd						
	L1.	0.690498*	0.286683	2.41	0.024	0.09745	1.283546
SR	lco2						
	LD.	0.208242	0.143803	1.45	0.161	-0.08924	0.505721
	L2D.	0.100086	0.131495	0.76	0.454	-0.17193	0.372104
	L3D.	0.231839	0.125776	1.84	0.078	-0.02835	0.492027
	lgdp						
	D1.	0.034934*	0.015161	2.3	0.031	0.003572	0.066297
	LD.	-0.06506*	0.028894	-2.25	0.034	-0.12483	-0.00528
	L2D.	-0.04948*	0.020354	-2.43	0.023	-0.09158	-0.00738
	lppl						
	D1.	-1.17751	2.578595	-0.+46	0.652	-6.51174	4.156723
	LD.	-1.0888	2.864429	-0.38	0.707	-7.01432	4.836726
	L2D.	12.8319*	2.779453	4.62	0.000	7.08225	18.58172
	Ltrd						
	D1.	0.019172	0.14617	0.13	0.897	-0.2832	0.321547
	LD.	-0.18606	0.15537	-1.2	0.243	-0.50747	0.135347
	L2D.	-0.5133*	0.140753	-3.65	0.001	-0.80447	-0.22213
	Cons	-0.24233	0.880183	-0.28	0.786	-2.06312	1.578471

*Legend: * indicates the coefficient is statistically significant at 5%*

Source: Data Analysis Results (2017)

The estimated model has a high R value of 80 and R squared is 65 indicating that the coefficients are reliable. We have ECMt as the adjustment or the error correction term. The coefficient of the error correction term is negative -0.62482 and significant at P value 0.0 < 0.05. With the negative sign, it implies a long run convergence (adjustment). The existence of the error correction term is evidence of a long equilibrium.

Therefore, this is a signal for the tendency in the model for carbon dioxide emissions per capita to go back to its long-run equilibrium path whenever it shifts away. More precisely, close to 62% of the disequilibrium between actual rate of carbon dioxide emissions per capita at previous year and the long-run rate of carbon dioxide emissions per capita would adjust back in the current year.

In the long run, gross domestic product, population changes and changes in trade significantly influence level of carbon (IV) oxide. Population growth directly influences changes to CO_2 by 2.787 in the long run. This implies that a unit change in population growth increases the levels of carbon (IV) oxide by 278.7 percent. The coefficient of population growth is significant at 5% level of significance with a probability of 0.000 < 0.05 level of significance. Trade affects changes in CO_2 by 0.69 in the long run. The coefficient of trade openness is significant with a probability of 0.024 < 0.05 level of significance. The coefficient of gross domestic product is statistically significant with probability 0.018 < 0.05 level of significance in the long run and has a positive direct influence at changes in CO_2 emissions by 0.2071 units. This implies that a unit change in the first lag of GDP increases the current level of CO_2 emissions by 20.71%.

The short run analysis under the ECM present similar results as the ARDL analysis. In the short run past levels of carbon IV oxide is not significant in influencing current levels. The coefficients of carbon IV oxide are insignificant in the short run. Changes in the first difference of gross domestic product affects carbon (IV) oxide by 0.034. The coefficient is significant as the probability of 0.031 is less than the threshold of 0.05 level of significance. However the the first and second lagged difference of GDP have a negative impact to CO_2 emissions with coefficients -0.06506 and -0.04948 with p – values 0.034 and 0.023 both significant at 5% level of significance. The second lagged difference of population growth significantly influences changes in the level of CO_2 at the level of 12.8319 units. This implies that population growth changes affect carbon (IV) oxide emission over a period of two years. The second lagged difference of trade openness is significant with a coefficient of -0.5133 implying that in the short run trade openness does result to lower carbon emissions.

The results are significant, consequently we rejected the null hypothesis of absence of long run equilibrium and short run adjustment in the estimated variables. Also, the null hypothesis that population growth, gross domestic product and trade openness don not influence changes in carbon emissions is rejected.

4.9.3 BOUNDS TEST

Table 4.13: Bound Test II

H0: No levels relationship F = 12.676 t = -5.60								
Critical Values 0.1			0.05		0.025		0.01	
	[I_0]	[I_1]	[I_0]	[I_1]	[I_0]	[I_1]	[I_0]	[I_1]
	L_1	L_1	L_05	L_05	L_025	L_025	L_01	L_01
k_3	2.72	3.77	3.23	4.35	3.69	4.89	4.29	5.61
accept if F < critical value for I(0) regressors reject if F > critical value for I(1) regressors								
Critical Values 0.1			0.05		0.025		0.01	
	[I_0]	[I_1]	[I_0]	[I_1]	[I_0]	[I_1]	[I_0]	[I_1]
	L_1	L_1	L_05	L_05	L_025	L_025	L_01	L_01
k_3	-2.57	-3.46	-2.86	-3.78	-3.13	-4.05	-3.43	-4.37
accept if t > critical value for I(0) regressors reject if t < critical value for I(1) regressors k: # of non-deterministic regressors in long-run relationship								

Critical values from Pesaran/Shin/Smith (2001)

Source: Data Analysis Results (2017)

The F statistic from the bounds is 12.676 and the upper bounds at 10%, 5%, 2.5% and 1% significance levels is 3.77, 4.35, 4.89 and 5.61 respectively. Since the F statistic is higher than the higher bounds in all significance levels, we reject the null hypothesis that there is no level relationship among the underlying variables. The existence of a level relationship among variables evidences a long run equilibrium among the variables analyzed (Enders, 2015).

4.9.4 DIAGNOSTIC TEST MODEL II

Autocorrelation refers to the correlation between members of a series of observations ordered in time. The estimates from analysis exhibiting autocorrelation may be linearly unbiased but are inefficient. Thus, it is crucial to establish that there is no autocorrelation in determining the regression estimates.

Table 4.14: Breusch-Godfrey LM Test for Autocorrelation

lags(p)	χ^2	DF	Prob $> \chi^2$
1	0.271	1	0.6028

H0: No Serial Correlation

Source: Data Analysis Results (2017)

The Breusch-Godfrey test for autocorrelation has the probability of 0.6028 which is greater than 0.05 which prompts acceptance of the null hypothesis that there is no serial correlation among the variables.

Table 4.15: LM Test for Autoregressive Conditional Heteroskedasticity (ARCH)

lags(p)	χ^2	DF	Prob $> \chi^2$
1	1.078	1	0.2992

H0: No ARCH effects vs. H1: ARCH (p) disturbance

Source: Data Analysis Results (2017)

The test for heteroskedasticity accepts the null hypothesis that the errors are not autoregressive conditional heteroskedastic since the probability of 0.2992 is more than the 0.05 level of significance. Hence we accept the null hypothesis. This affirms that the disturbances appearing in the population regression have constant variances. The estimates from the model are reliable and usable in making conclusion and recommendation.

Table 4.16: VIF test for Multicollinearity

Variable	VIF	1/VIF
L1.lco2	8.08	0.123686
Lppl	7.95	0.125805
Ltrd	1.2	0.831778
Lgdp	1.1	0.905583
Mean VIF	4.59	

Source: Data Analysis Results (2017)

The variance inflator function mean is less than twenty pointing to the lack of multicollinearity in the model. The 1/VIF for all the variable are less than 1 implying that no variable is a linear semblance of the other (Greene, 2017). Values in excess of 20 are suggested as indicative of a problem of multicollinearity (Belsley, Kuh, & Welch, 1980).

Table 4.17 Jarque-Bera Test

Equation	χ^2	DF	Prob > χ^2
lco2	0.597	2	0.74196
Lgdp	27.045	2	0.000*
Ltrd	0.147	2	0.9293
Lppl	0.293	2	0.86387
ALL	28.081	8	0.00046*

*Legend: * indicates the coefficient is statistically significant at 5% level of significance*

Source: Author's Data Analysis Results, 2017

The normality test indicate that gross domestic product has a normal distribution. Carbon IV oxide, trade and population separately does not have normal distributions. The model has a normal distribution. The null hypothesis is significant at 5% level of significance.

4.9.5 TEST FOR MODEL II STABILITY

The Cusum tests were estimated to test for the structural stability of the model. The cusum test is based on a plot of the sum of the recursive residuals. If this sum goes outside a critical bound, it implies that there was a structural break at the point at which the sum began its movement toward the bound. The cusum-of-squares test plots the cumulative sum of squared recursive residuals, expressed as a fraction of these squared residuals summed over all observations. The cusum tests were estimated to test for the structural stability of the model. The cusum and cusum squared test result are given in figure 4.3 and figure 4.4. It is deduced that the model is stable given that the stability line lies between the set limits. Hence both the cusum and the cusum squared test confirm the structural stability of the model.

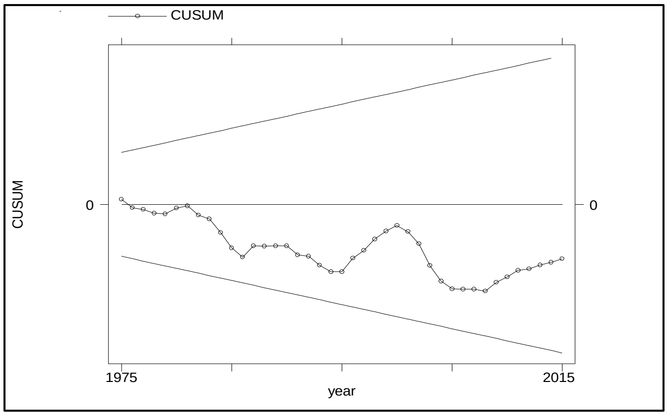

Figure 4.3: Cusum Test

Source: Author's Data Analysis Results, 2017

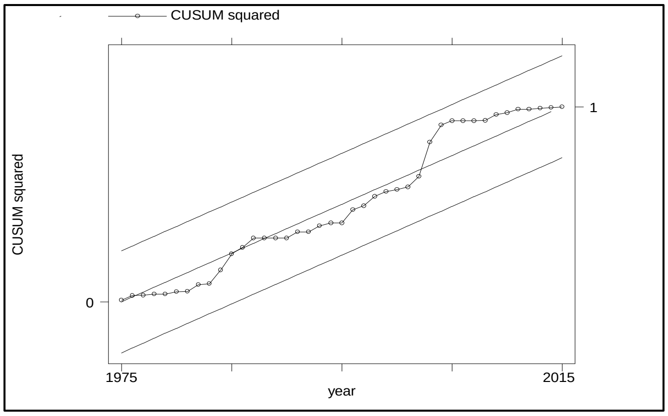

Figure 4.4: Cusum Squared Test

Source: Data Analysis Results (2017)

4.10 ANALYSIS OF THE HYPOTHESES

The first hypothesis stated that energy mix has no significant effect on the emissions of CO_2 in Kenya. The results indicated that except renewable energy (p – value 0.326 > 0.05), fossil fuel, alternative and nuclear energy, imported energy have significant effect on CO_2 emissions in Kenya (p – value 0.001 < 0.05), (p – value 0.042 < 0.05), (p – value 0.007&0.012 < 0.05) respectively. The results therefore concluded that energy mix has a significant effect on carbon IV emissions in Kenya. Therefore the hypothesis was rejected.

The second hypothesis stated that economic indicators have no significant effect on CO_2 emissions in Kenya. The results indicated that change in population growth impacted CO_2 emission (p – value 0.001 < 0.05), economic growth has significant effect on carbon (IV) oxide emissions (p – value 0.031 < 0.05). Further, the result indicated that trade openness has a significant effect on carbon (IV) oxide emissions (p – value 0.001 <

0.05). The results therefore indicated that the economic indicators used for analysis in this study affected carbon IV oxide emissions significantly. Hence, the hypothesis was rejected.

The last hypothesis stated that a long-run equilibrium relationship between energy mix, economic indicators and CO_2 emissions in Kenya does not exist. The bounds test confirmed the presence of a long run equilibrium in the analyzed variables in both models of analysis. In model I ($F = 5.422 > 3.52$, 4.01, 4.49 and 5.06) at 10%, 5%, 2.5% and 1% significance levels respectively and ($t = -5.096 < -3.66$, -3.99, -4.26 and -4.6) at 10%, 5%, 2.5% and 1% significance levels respectively. In model II ($F=12.676 > 3.77$, 4.35, 4.89 and 5.61) at 10%, 5%, 2.5% and 1% significance levels respectively and ($t = -5.60 < -3.46$, -3.78, -4.05 and -4.37) at 10%, 5%, 2.5% and 1% significance levels respectively. The results of the bounds test therefore confirms existence of a long run relationship. This was also confirmed by the coefficient of the error correction term which was negative -0.62482 and significant at P value $0.0 < 0.05$. The negative sign implied a long run convergence (adjustment). Hence the hypothesis was rejected.

5. CONCLUSION

The study established that gross domestic product had a positive effect on CO_2 levels both in the short and long run. Population growth had a positive effect on changes on carbon IV oxide both in the short run and log run. These effects were significant pointing to the adverse effect of increase in population that increases demand for more energy. Trade openness has a significant positive effect on carbon IV oxide both in the short run and in the long run. It was also determined that fossil energy sources and alternative and nuclear energy had a positive effect on the levels of carbon IV oxide. The findings are similar to findings by Al-Mulali, Solarin, & Ozturk, 2015; Shahbaz, Solarin, & Ozturk, 2016 who determined that fossil fuels and trade openness positively influenced increases in levels in cabon emissions in Kenya.

The alternative and nuclear energy sources are deemed to increase carbon IV oxide as nuclear energy is yet to be developed which has a reducing effect on carbon IV oxide levels. Imported energy has a significant short term effect with an insignificant effect in the long term. The effect of renewable energy in the short and long term was not significant. The lack of significance eliminates these variables from policy analysis related to their effect.

The estimated results are in line with other studies such as Lacheheb, Rahim, and Sirag (2015), Jalil and Mahmud (2009), Saboori *et al.,* (2012) the results therefore contradicts with other results such as Al-Mulali *et al.,* (2016) and (Shahbaz, Solarin, & Ozturk, 2016). The bounds test for both models confirmed presence of long run equilibrium between the variables. The F statistics for the bounds test were higher than the upper bounds thus confirming the existence of long run equilibrium. This was further confirmed by the coefficient of the error correction term which was negative implying a long run equilibrium.

6. RECOMMENDATIONS

The outcomes of this study provide insights to improving on reduction of carbon emissions. The use of fossil fuels is significant both short and long run demanding for applicable policies that points towards the use of clean energies such as wind, solar energy and geothermal power to reduce CO_2 emissions and reduce environmental degradation that results from solid and liquid fuel consumption. In line with the focus on using less fossil fuels, the government can reduce the use of this fuels through increased financing and development of other sources of fuels with less emissions. The increase in population growth is significantly contributing to increase in carbon emissions owing to increased demand of energy. The increase in use of fossil fuels over the years in Kenya accompanied by increased motorization have combined to result in high carbon emissions. This calls for increased use of fuels generating less carbon through investments which will provide these to many people significantly reducing carbon emissions. The study also determined that trade openness resulted to increases in carbon emissions. The government should therefore review trade policies that curtail high carbon emissions. The introduction of incentives to promote importation of products and manufacturing materials that reduce carbon emissions should be put forward. These incentives may also include tax incentives to products with low carbon emissions such as solar energy products. This incentive will accelerate intake of these products in place of high carbon emission products thus reducing levels of carbon emissions in the long run with no damage to the Kenyan economy. Further, the government can explore measures that encourage service intensive rather than resource intensive activities in the economy.

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