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Article

The Kenya Case of Multivariate Causality of Carbon Dioxide Emissions

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Abstract

In this study, an attempt was made to investigate the Kenya case of multivariate causality of carbon dioxide emissions by employing a time series data spanning from 1961-2011 using the ARDL method of cointegration analysis. The long-run elasticities show that, a 1% increase in financial development increases carbon dioxide emissions by 0.28%, a 1% increase in GDP per capita increases carbon dioxide emissions by 1.32% and a 1% increase in urbanization decreases carbon dioxide emissions by 1.14%. There was a unidirectional causality running from financial development, food production index, GDP per capita, industrialization and urbanization to carbon dioxide emissions. The innovation accounting shows that 20% of future shocks in carbon dioxide emissions are due to fluctuations in financial development, 9% of future shocks in financial development are due to fluctuations urbanization and 22% of future shocks in food production index are due to fluctuations in carbon dioxide emissions.

Keywords: Granger-causality; carbon dioxide emissions; ARDL; Kenya; variance decomposition; climate change

JEL Classification: Q53; O44; Q10; Q54

1. INTRODUCTION

Climate change has taken the centre stage in the developmental agenda in developed and developing countries [1]. Global effort has been made through the establishment of the sustainable development goals to promote renewable and clean energy technologies, sustainable agriculture and food security, and mitigate climate change and its impact. There is a close relationship between carbon dioxide emissions, industrialization, urbanization, financial development, economic growth and human well-being [2,3,4,5]. This is because industrialization, urbanization, financial development, economic growth and carbon dioxide emissions have significant bearing on human development indicators such as incomes, wage employment, skill formation, improved livelihoods (air quality, clean environment, nutrition and health care), gender parity, and entrepreneurship. Significantly, industrial and technological advancement have played a role in food production, processing, storage, nutrition, food security and agricultural tools and techniques [6,7].

The human development index measures the geometric mean of life expectancy, educational attainment and standard of living which are critical for climate change mitigation vulnerability index [6]. The 2015 version of the human development report by the United Nations Development Programme indicates that Kenya has a low human development index of 0.548/1 ranking below Zambia (0.586/1) but higher than the other East African countries such as; Burundi (0.4/1), Djibouti (0.47/1), Eritrea (0.391/1), Ethiopia (0.442/1), Madagascar (0.51/1), Malawi (0.445/1), Mozambique (0.416/1), Rwanda (0.483/1), South Sudan (0.467/1), Tanzania (0.521/1), Uganda (0.483/1) and Zimbabwe (0.506/1). The report further indicates that Kenya has a gross national income (GNI) per capita of US$ 2,761.6, 48.2% of the population are in multidimensional poverty, 0.3 tonnes of carbon dioxide emission per capita and a population of 45.5 million [8].

As a result of the high levels of multidimensional poverty, the Government of Kenya is working closely to improving the welfare of Kenyans through industrialization. There has been significant improvement in Kenya's industry policies since mid-1980s leading to its vast contribution to the country's GDP, source of employment opportunities and increasing the industrial output through manufacturing activities [6]. Notwithstanding, there are challenges associated with industrialization such as; rapid urbanization and poor environmental and health quality as a result of industrial carbon dioxide emissions [9].

According to UNDP [8], changes in climatic patters as a result of global carbon dioxide emissions are now creating harmful impacts on the Kenyan environment, society and economy. As a result of uncertainties about weather patterns, economic sectors like tourism and agriculture are accruing a significant economic loss. According to IMF [10], "Kenya remains vulnerable to financial shocks that could have a significant adverse impact on the economy". It is projected that Kenya will require about US$ 1-2 billion yearly by 2030 to address the current and future climate change effects [11].

Against the backdrop, it is worthwhile to examine the multivariate causality of carbon dioxide emissions in Kenya using a time series data spanning from 1961-2011. To the best of our knowledge, the scope of the study is the first time in Kenya which will contribute to existing literature from the Kenya case and further increase the global debate on climate change from the Kenya perspective. Since carbon dioxide emissions, energy consumption/production and GDP have been proven to be collinear in many studies from different countries [12,13]. The current study eliminates energy consumption/production and rather examines the equilibrium relationship between carbon dioxide emissions, food production index, financial development, economic growth, industrialization and urbanization using the ARDL method of cointegration analysis. The study further estimates the Granger-causality and the variance decomposition based on VAR.

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The remainder of the study consist of "*Literature review*", "*Methodology*", "*Results and Discussion*" and "*Conclusion and Policy recommendations*".

2. LITERATURE REVIEW

Within the last decades, the relationship between environmental pollution, energy consumption and macroeconomic variables (financial development and economic growth) have received considerable attention in scientific literature.

The first set of studies including Cerdeira Bento and Moutinho [14], SekerErtugrul and Cetin [15], Apergis and Ozturk [16], Baek [17], NarayanSaboori and Soleymani [18], Acaravci and Ozturk [19], OsabuohienEfobi and Gitau [20], Tutulmaz [21], TiwariShahbaz and Adnan Hye [22], Ben AbdallahBelloumi and De Wolf [23], ShahbazLean and Shabbir [24], Balaguer and Cantavella [25], Babu and Datta [26], Asici and Acar [27], Ben JebliBen Youssef and Ozturk [28], BilgiliKocak and Bulut [29], Al-MulaliSolarin and Ozturk [30], Fujii and Managi [31], KangZhao and Yang [32], Asumadu-Sarkodie and Owusu [33], Hao and Liu [34], Javid and Sharif [35], OzturkAl-Mulali and Saboori [36], Narayan and Narayan [37], among others have investigated the validity of the Environmental Kuznets Curve hypothesis which suggests that environmental degradation/pollution decreases overtime as a country's GDP per capita increases. Cerdeira Bento and Moutinho [14], SekerErtugrul and Cetin [15], Apergis and Ozturk [16], ShahbazLean and Shabbir [24], Charfeddine and Khediri [38], Balaguer and Cantavella [25], Al-MulaliSolarin and Ozturk [30], BilgiliKocak and Bulut [29], Hao and Liu [34], Javid and Sharif [35] and among others support the validity of the Environmental Kuznets Curve hypothesis while Al-TorkistaniSalisu and Maimany [39], LiuYan and Zhou [40], among others reject the validity of the Environmental Kuznets Curve hypothesis.

The second set of studies including Acaravci and Ozturk [19],Ohler and Fetters [41],Azhar KhanZahir KhanZaman et al. [42],CaraianiLungu and Dascălu [43],Fuinhas and Marques [44],

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Apergis and Ozturk [16],Chang [45],ChenKuo and Chen [46], Azhar KhanZahir KhanZaman et al. [42],Ozturk and Acaravci [47],Sadorsky [48], Asumadu-Sarkodie and Owusu [49], Pao and Tsai [50], HatzigeorgiouPolatidis and Haralambopoulos [51], Asumadu-Sarkodie and Owusu [52], Soytas and Sari [53], HuangHwang and Yang [54], Lozano and Gutiérrez [55], GulZouHassan et al. [56], Jammazi and Aloui [57], QureshiRasli and Zaman [58], Asumadu-Sarkodie and Owusu [59], MohiuddinAsumadu-Sarkodie and Obaidullah [60], examines the relationship between environmental pollution, energy consumption and economic growth. HuangHwang and Yang [54] found no relationship between energy consumption and GDP. Soytas and Sari [53] found that carbon dioxide emissions Granger cause energy consumption while Zhang and Cheng [61] found no evidence of causality from carbon dioxide emissions or energy consumption to economic growth. GulZouHassan et al. [56] found evidence of a unidirectional causality running from energy-consumption to carbon dioxide emissions. Jammazi and Aloui [57] found a bidirectional causality between energy consumption and economic growth, and a unidirectional causality between energy consumption and carbon dioxide emissions.

Finally, the third set of studies; Al-MulaliSolarin and Ozturk [30], SekerErtugrul and Cetin [15], Javid and Sharif [35],ShahbazJamBibi et al. [62], KangZhao and Yang [32], OzturkAl-Mulali and Saboori [36], Asumadu-Sarkodie and Owusu [63, 64, 65, 66], Saidi and Hammami [67], AhmedShahbaz and Kyophilavong [68], Asumadu-Sarkodie and Owusu [63] include other macroeconomic variables such as industrialization, urbanization, financial development, trade openness, etc. to the already existing variables in literature such as; carbon dioxide emissions, population, energy consumption and economic growth. A 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 [52,63,64,65,66].

Almost a majority of literature in the scope of the study are investigated in European countries [19,41,42,43,44], Asian countries [16,45,46,69] and the Middle East countries [42,47,48] with a handful of literature in Africa [7,12,13,20,30,70].

Nevertheless, the scope of the study is sporadic and limited in Kenya. To the best of our knowledge, only Al-MulaliSolarin and Ozturk [30] have examined the validity of the Environmental Kuznets Curve hypothesis in Kenya with a time series data spanning from 1980-2012 using the ARDL method of cointegration analysis. Their study does not support the validity of the EKC in Kenya. Unlike their study, the current study examines the relationship between carbon dioxide emissions, food production index, GDP per capita, financial development, industrialization and urbanization. In addition, the direction of causality and innovation accounting using Cholesky's technique is employed in the Kenya case which were absent in previous study [30]. The study contributes to existing literature by expanding the period of the time series data from 1961-2011 compared to previous 1980-2012, in order to provide formidable statistical evidence. Moreover, the study increases the global debate on climate change and its impact from the Kenya context and serve as a policy document for future national planning and strategies on climate change mitigation.

3. METHODOLOGY

3.1 Data

The study investigates the Kenya case of multivariate causality of carbon dioxide emissions by employing a time series data from the World Bank [71] at a period spanning from 1961-2011 using the ARDL method of cointegration analysis. Six study variables are used in the study which include: CO_2 - Carbon dioxide emissions (kt), GDPPC – Gross Domestic Product per capita (current LCU), IND-Industry, value added (current LCU), FPI-Food production index (2004-2006 = 100), FD-Money and quasi money (M2) (current LCU), URB-Urban population.

The World Bank [71] defines Money and quasi money as "the sum of currency outside banks, demand deposits other than those of the central government, and the time, savings, and foreign currency deposits of resident sectors other than the central government", it is therefore used as a proxy for financial development (FD). Moreover, the World Bank [71] defines Industry value added as "the value added to mining, manufacturing, construction, electricity, water and gas", it is therefore used as a proxy for industrialization (INV) [71].

3.2 Descriptive Analysis

The study presents the descriptive statistical analysis of the time series variables from 51 observations as showed in Table 1. Information from Table 1 shows that all the variables exhibit a long-right-tail (positive skewness) with INV having the higher skewness. While FD, GDPPC, and INV exhibit leptokurtic distribution, CO_2, FPI and URB exhibit a platkurtic distribution.

The correlation analysis shows that all the independent variables have a positive monotonic relationship with CO_2. Jarque-Bera test statistic suggests that FD, GDPPC and INV are not normally distributed based on 5% significance level. Therefore, a logarithmic transformation is applied to the variables in order to provide a more stable data variance for the subsequent analysis. At this juncture, let LCO_2, LFD, LFPI, LGDPPC, LINV and LURB represent the logarithmic transformation of CO_2, FD, FPI, GDPPC, INV and URB.

Figure 1 shows the trend of the study variables. Figure 1 shows that carbon dioxide emissions, financial development, food production index, GDP per capita, industrialization, and urbanization increase periodically which suggest the existent of a strong relationship among them. However, the trend of carbon dioxide emissions decreased over the period 2000-2003 due to a decline of oil imports as a result of Kenya's energy efficiency and conservation policy [2].

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Table 1. Descriptive Statistical Analysis

Statistic	**CO_2**	**FD**	**FPI**	**GDPPC**	**INV**	**URB**
Mean	6110.784	2.16E+11	59.12549	17282.69	1.01E+11	3917490
Median	5170	3.57E+10	57	5760	1.90E+10	3300000
Maximum	13600	1.52E+12	124	90000	7.04E+11	9930000
Minimum	2400	2.22E+08	23.9	677	9.25E+08	633000
Std. Dev.	2920.942	3.49E+11	28.45324	22788.33	1.68E+11	2705770
Skewness	0.7509	2.0892	0.6805	1.6062	2.1058	0.6118
Kurtosis	2.6607	6.9793	2.5152	4.7652	6.6566	2.2499
Jarque-Bera	5.0370	70.7493	4.4355	28.5499	66.1043	4.3771
Probability	0.0806	0.0000	0.1089	0.0000	0.0000	0.1121
Correlation						
CO_2	1					
FD	0.8670	1				
FPI	0.9018	0.8870	1			
GDPPC	0.9096	0.9889	0.9288	1		
INV	0.8531	0.9947	0.8818	0.9857	1	
URB	0.9311	0.8914	0.9896	0.9377	0.8788	1

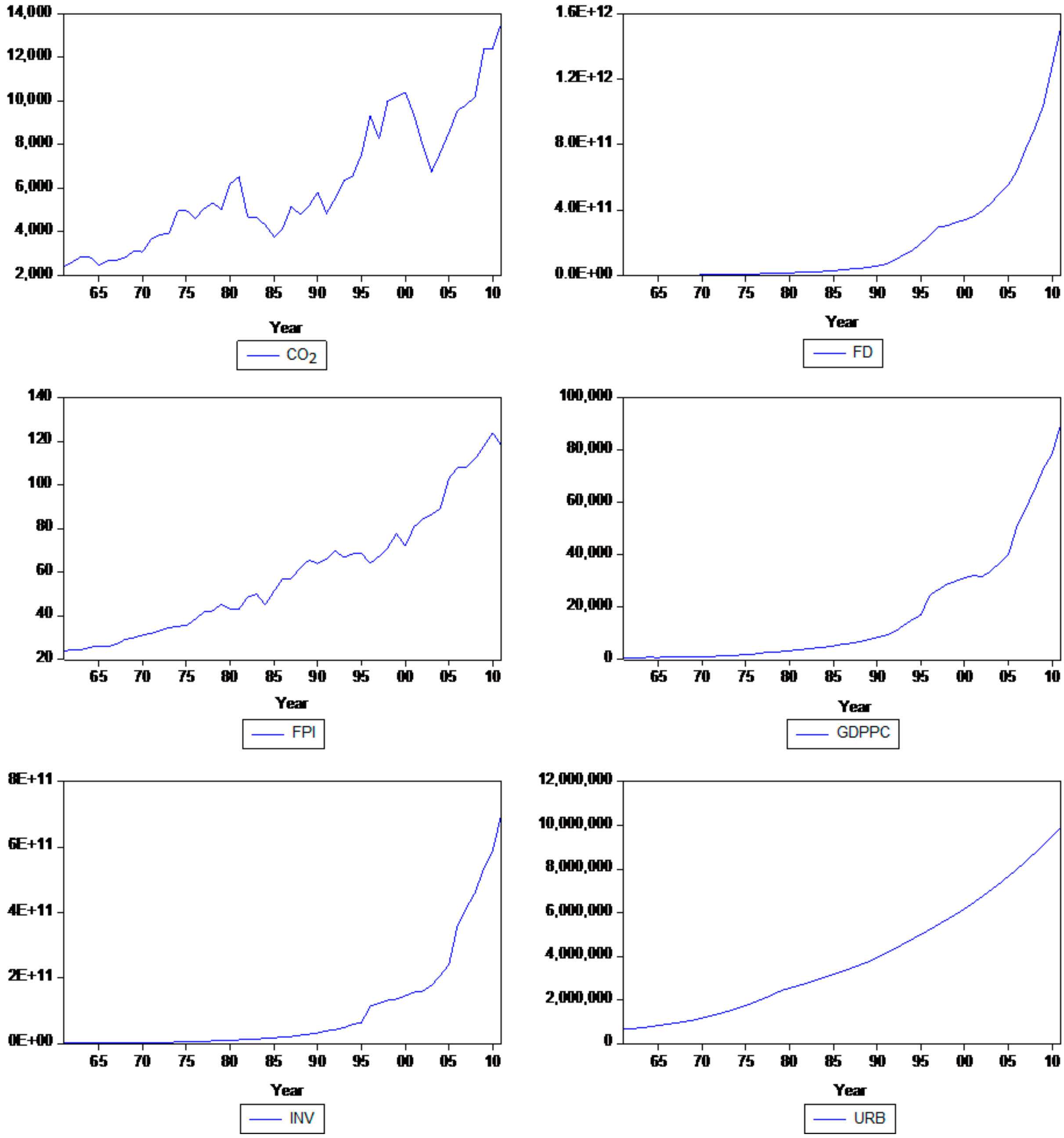

Figure 1. Trend of Variables

3.3 Stationarity Test

The empirical analysis begins with testing for the stationarity properties of the variables. The study employs the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) and Vogelsang's breakpoint tests in order to have a robust result. KPSS test results in Table 2 shows some different specifications, however the null hypothesis of stationarity is rejected at level in all the variables but cannot be rejected at first difference based on 5% significance level. Since KPSS fails to

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test the stationarity in the presence of structural breaks, the study estimates the order of integration with Vogelsang's breakpoint unit root test by considering the presence of innovational outliers. Information from Table 2 shows that, the null hypothesis of non-stationarity cannot be rejected at level, but rejected at first difference based on 5% significance level. Meaning that KPSS and Vogelsang's breakpoint tests suggest that the variables are integrated of I(1).

Table 2. Kwiatkowski-Phillips-Schmidt-Shin and Breakpoint Tests

Test	**LCO_2**		**LFD**		**LFPI**		**LGDPPC**		**LINV**		**LURB**	
KPSS Level	Test Stats	Prob	Test Stats	Prob	Test Stats	Prob	Test Stats	Prob	Test Stats	Prob	Test Stats	Prob
Intercept	0.8913	0.4630*	0.9525	0.4630*	0.9484	0.4630*	0.9524	0.4630*	0.9561	0.4630*	0.9456	0.4630*
Trend and Intercept	0.0591	0.1460	0.1508	0.1460*	0.0747	0.1460	0.1116	0.1460	0.0983	0.1460	0.2331	0.1460*
KPSS 1st Diff												
Intercept	0.0512	0.4630	0.2410	0.4630	0.0278	0.4630	0.1925	0.4630	0.1887	0.4630	0.3470	0.4630
Trend and Intercept	0.0492	0.1460	0.0880	0.1460	0.0277	0.1460	0.0785	0.1460	0.0569	0.1460	0.0945	0.1460
Break test Level												
Intercept	-2.2343	0.9580	-2.2840	0.9493	-1.5761	> 0.99	-0.2615	> 0.99	0.0807	> 0.99	-2.9021	0.7379
Trend and Intercept	-4.7817	0.0622	-3.1726	0.9312	-4.5622	0.1126	-3.0540	0.6751	-3.6665	0.3183	-2.9604	0.9228
Break test 1st Diff												
Intercept	-7.7485	< 0.01*	-6.8732	< 0.01*	-8.4967	< 0.01*	-6.7204	< 0.01*	-7.5567	< 0.01*	-7.9637	< 0.01*
Trend and Intercept	-7.6755	< 0.01*	-6.9269	< 0.01*	-8.3607	< 0.01*	-7.6873	< 0.01*	-9.3659	< 0.01*	-7.9070	< 0.01*

*rejection of the null hypothesis at 5% significance level

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3.4 Model Estimation

The relationship between carbon dioxide emissions, food production index, financial development, GDP per capita, industrialization and urbanization in Kenya is expressed as a linear function showed in equation (1):

$$LCO2_t = f(LFD_t, LFPI_t, LGDPPC_t, LINV_t, LURB_t) \quad (1).$$

The empirical specifications for the selected ARDL (1, 1, 1, 1, 0, 2) model is quantified as:

$$LCO_{2_t} = \beta_1 LCO_{2_{t-1}} + \beta_2 LFD_t + \beta_3 LFD_{t-1} + \beta_4 LFPI_t + \beta_5 LFPI_{t-1} + \beta_6 LGDPPC_t + \beta_7 LGDPPC_{t-1} + \beta_8 LINV_t + \beta_9 LURB_t + \beta_{10} LURB_{t-1} + \beta_{11} LURB_{t-2} + \beta_{12} \quad (2),$$

where LCO_{2_t} is the dependent variable while LFD_t, $LFPI_t$, $LGDPPC_t$, $LINV_t$ and $LURB_t$ are the explanatory variables in year t, $t-1$ and $t-2$ represents lag 1 and 2 and β's are the elasticities to be estimated. The substituted coefficients from the estimated equation are; $\beta_1 = 0.63\ (0.00)$, $\beta_2 = -0.04\ (0.25)$, $\beta_3 = 0.15\ (0.00)$, $\beta_4 = -0.20\ (0.36)$, $\beta_5 = 0.63\ (0.00)$, $\beta_6 = 1.05\ (0.00)$, $\beta_7 = -0.56\ (0.00)$, $\beta_8 = -0.34\ (0.03)$, $\beta_9 = -5.70\ (0.02)$, $\beta_{10} = 13.89\ (0.00)$, $\beta_{11} = -8.61\ (0.00)$ and $\beta_{12} = 8.82\ (0.00)$. The estimated coefficients are all significant at 5% level with the exception of LFD_t and $LFPI_t$.

The study employs the ARDL method of cointegration to estimate the long-run and short-run equilibrium relationship between LCO_2, LFD, LFPI, LGDPPC, LINV and LURB. Following the work of Asumadu-Sarkodie and Owusu [7],Asumadu-Sarkodie and Owusu [12] and Al-MulaliSolarin and Ozturk [30], the ARDL co-integrating equation is expressed as:

$$\Delta LCO_{2_t} = \alpha_0 + \delta_1 LCO2_{t-1} + \delta_2 LFD_{t-1} + \delta_3 LFPI_{t-1} + \delta_4 LGDPPC_{t-1} + \delta_5 LINV_{t-1} + \delta_6 LURB_{t-1} + \sum_{i=1}^{k} \beta_1 \Delta LCO_{2_{t-i}} + \sum_{i=0}^{k} \beta_2 \Delta LFD_{t-i} + \sum_{i=0}^{k} \beta_3 \Delta LFPI_{t-i} + \sum_{i=0}^{k} \beta_4 \Delta LGDPPC_{t-i} + \sum_{i=0}^{k} \beta_5 \Delta LINV_{t-i} + \sum_{i=0}^{k} \beta_6 \Delta LURB_{t-i} + \varepsilon_t \quad (3),$$

where α is the intercept, k is the lag order, ε_t is the error term and Δ is the first difference operator. The application of ARDL cointegration among variables can be estimated at either I(0) or I(1) without pre-specification of variables which are either I(0) or I(1). Moreover, ARDL has desirable small sample properties and provide unbiased long-run estimation, even when some endogenous variables behave as regressors. The initial step of ARDL cointegration is the bounds testing procedure which is based on the F-test. The Null hypothesis of no cointegration between LCO_2, LFD, LFPI, LGDPPC, LINV and LURB is $H_0: \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$ Against the Alternative hypothesis $H_1: \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq \delta_6 \neq 0$. According to PesaranShin and Smith [72], the calculated F-statistic is compared with the critical values of the lower and upper bounds respectively. If the calculated F-statistic goes above the upper bound, the null hypothesis of no cointegration between is rejected. However, if the F-statistic is smaller than the critical value of the lower bound, the null hypothesis of no cointegration cannot be rejected. In addition, if the F-statistic lies between the critical values of the lower and the upper bounds, the null hypothesis of no cointegration become inconclusive, which requires either the estimation of Johansen's test of cointegration [73] or through testing the constancy of the cointegration space using CUSUM and CUSUM of squares of residuals [74].

Unlike Johannsen's method of cointegration approach which employs a set of cointegration equations to analyse the long-run equilibrium relationship between variables, the ARDL method of cointegration by PesaranShin and Smith [72] adopts only one equation as expressed in equation (4):

$$Cointeq = LCO_2 - (0.2799 * LFD + 1.1445 * LFPI + 1.3193 * LGDPPC - 0.9094 * LINV - 1.1365 * LURB + 23.8058) \quad (4)$$

The joint short-run effect is estimated using the Wald test of linear restrictions to the coefficients of LFD, LFPI, LGDPPC, LINV and LURB in equation (2). From equation (2), we derive that $\beta_2 = \beta_3 = 0$, $\beta_4 = \beta_5 = 0$, $\beta_6 = \beta_7 = 0$, $\beta_8 = 0$ and $\beta_9 = \beta_{10} = \beta_{11} = 0$.

4. RESULTS AND DISCUSSION

This section presents the results and a discussion of the empirical analysis.

4.1 ARDL Co-integration

Having determined the integration of variables at I(1), the study selects an optimal model using the Schwarz Criteria. As stated in equation (2), the selected model using the Schwarz Criteria is ARDL (1, 1, 1, 1, 0, 2) as shown in Figure 2. Using the optimal model, the ARDL bounds testing is estimated as showed in Table 3. Table 3 shows that the F-statistic lies above the critical values of the upper bound at 10, 5 and 2.5% significance level, therefore the null hypothesis of no long-run relationship is rejected at 5% significance level. Table 3 further presents the error correction, long-run elasticities and short-run equilibrium relationship. Table 3 shows that the speed of adjustment [ECT (-1) = -0.37] is negative and significant at 5% level, meaning that a long-run equilibrium relationship exist running from LFD, LFPI, LGDPPC, LINV and LURB to LCO_2. The joint test of linear restrictions of the coefficient in the short-run estimates shows that LFD, LFPI, LGDPPC, LINV and LURB affect LCO_2 in a short-run.

The evidence from the long-run elasticities in Table 3 has policy implications for Kenya. Table 3 shows that, a 1% increase in LFD increases LCO_2 by 0.28%, a 1% increase in LGDPPC increases LCO_2 by 1.32% and a 1% increase in LURB decreases LCO_2 by 1.14%.

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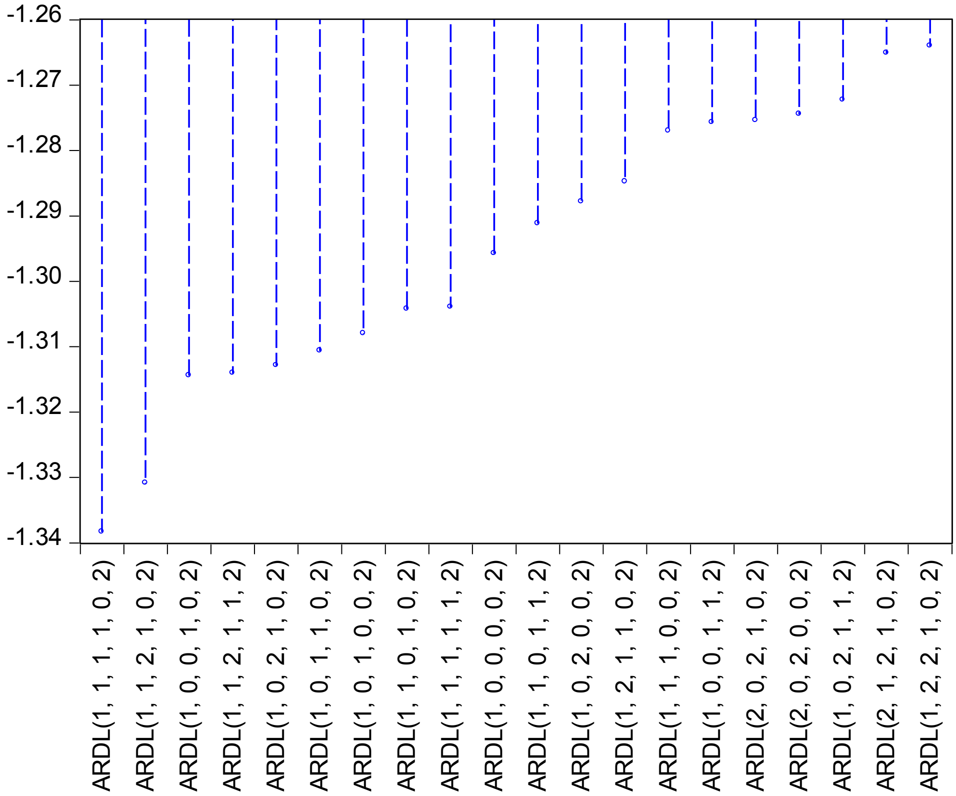

Figure 2. Schwarz Criteria for Model Selection

Table 3. ARDL Bounds Test, Error Correction, Long-Run and Short-Run Relationship

		5. Bounds Test		
Test Statistic		Value		k
F-statistic		3.77		5
		Critical Value Bounds		
Significance		I0 Bound		I1 Bound
10%		2.08		3.00
5%		2.39		3.38
2.50%		2.7		3.73
1%		3.06		4.15
Variable	Coefficient	Std. Error	t-Statistic	Prob.
ECT (-1)	-0.3685	0.0621	-5.9321	0.0000
		Long-Run Coefficients		
LFD	0.2799	0.1238	2.2605	0.0298
LFPI	1.1445	0.8359	1.3692	0.1792
LGDPPC	1.3193	0.5841	2.2586	0.0299
LINV	-0.9094	0.5802	-1.5674	0.1255
LURB	-1.1365	0.5072	-2.2408	0.0311
C	23.8058	10.2562	2.3211	0.0259
		Short-Run Estimates		

	Test Statistic	Value	df	Prob.
LFD	F-statistic	23.8124	(2, 37)	0.0000
LFDI	F-statistic	6.6181	(2, 37)	0.0035
LGDPPC	F-statistic	7.9245	(2, 37)	0.0014
LINV	F-statistic	5.0021	(1, 37)	0.0314
LURB	F-statistic	196.8092	(3, 37)	0.0000

5.1 Granger-Causality

Due to the inability of the ARDL model to estimate the direction of causality, the study employs the Granger-causality based on VAR to examine the direction of causality among the variables. Table 4 shows that the null hypothesis that LFD does not Granger Cause LCO_2, LFPI does not Granger Cause LCO_2, LGDPPC does not Granger Cause LCO_2, LINV does not Granger Cause LCO_2, LURB does not Granger Cause LCO_2, LFPI does not Granger Cause LGDPPC, LINV does not Granger Cause LGDPPC and LURB does not Granger Cause LGDPPC is rejected at 5% significance level. In other words, a unidirectional causality exists running from LFD → LCO_2, LFPI → LCO_2, LGDPPC → LCO_2, LINV → LCO_2, LURB → LCO_2, LFPI → LGDPPC, LINV → LGDPPC and LURB → LGDPPC.

Table 4. Granger-Causality Test

Null Hypothesis:	Obs	F-Statistic	Prob.
LFD does not Granger Cause LCO_2	49	4.0666	0.0240*
LCO_2 does not Granger Cause LFD		0.6512	0.5264
LFPI does not Granger Cause LCO_2	49	6.3708	0.0037*
LCO_2 does not Granger Cause LFPI		0.4272	0.6550
LGDPPC does not Granger Cause LCO_2	49	3.2004	0.0504*
LCO_2 does not Granger Cause LGDPPC		0.0393	0.9615
LINV does not Granger Cause LCO_2	49	3.2650	0.0476*
LCO_2 does not Granger Cause LINV		0.8357	0.4403
LURB does not Granger Cause LCO2	49	7.1208	0.0021*
LCO_2 does not Granger Cause LURB		0.1288	0.8795
LFPI does not Granger Cause LFD	49	2.3579	0.1065
LFD does not Granger Cause LFPI		1.6267	0.2082
LGDPPC does not Granger Cause LFD	49	1.7796	0.1806

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LFD does not Granger Cause LGDPPC		1.9466	0.1549
LINV does not Granger Cause LFD	49	2.8386	0.0693
LFD does not Granger Cause LINV		1.5907	0.2153
LURB does not Granger Cause LFD	49	2.2687	0.1154
LFD does not Granger Cause LURB		1.5732	0.2188
LGDPPC does not Granger Cause LFPI	49	1.0746	0.3502
LFPI does not Granger Cause LGDPPC		4.1597	0.0221*
LINV does not Granger Cause LFPI	49	2.1020	0.1343
LFPI does not Granger Cause LINV		2.7031	0.0781
LURB does not Granger Cause LFPI	49	2.1663	0.1267
LFPI does not Granger Cause LURB		1.0893	0.3454
LINV does not Granger Cause LGDPPC	49	3.5537	0.0371*
LGDPPC does not Granger Cause LINV		0.9156	0.4078
LURB does not Granger Cause LGDPPC	49	3.8929	0.0278*
LGDPPC does not Granger Cause LURB		0.7085	0.4979
LURB does not Granger Cause LINV	49	2.2773	0.1145
LINV does not Granger Cause LURB		1.2396	0.2994

*Rejection of the null hypothesis at 5% significance level

5.2 Innovation Accounting

The ARDL method is able to examine the long-run and short-run equilibrium relationship while the Granger-causality test examines the direction of causality. Nevertheless, the impulse-response function that traces the effect of a shock from one endogenous variable on the other variables is uncertain in both ARDL and Granger-causality. Against the backdrop, the study employs the innovation accounting based on Cholesky's technique in order to analyze the variance decomposition of each random innovation affecting the variables in the VAR.

Table 5 shows that 20% of future shocks in LCO_2 are due to fluctuations in LFD, 12% of future shocks in LCO_2 are due to fluctuations in LURB, 12% of future shocks in LCO_2 are due to fluctuations in LGDPPC, 12% of future shocks in LCO_2 are due to fluctuations in LFPI and 10% of future shocks in LCO_2 are due to fluctuations in LINV.

Table 5 shows that 9% of future shocks in LFD are due to fluctuations in LURB, 7% of future shocks in LFD are due to fluctuations in LFPI, 5% of future shocks in LFD are due to fluctuations in LCO_2, 4% of future shocks in LFD are due to fluctuations in LINV and 3% of future shocks in LFD are due to fluctuations in LGDPPC.

Table 5 shows that 22% of future shocks in LFPI are due to fluctuations in LCO_2, 17% of future shocks in LFPI are due to fluctuations in LINV, 4% of future shocks in LFPI are due to fluctuations in LFD, 3% of future shocks in LFPI are due to fluctuations in LGDPPC and 3% of future shocks in LFPI are due to fluctuations in LURB.

Moreover, evidence from Table 5 shows that 16% of future shocks in LGDPPC are due to fluctuations in LFD, 15% of future shocks in LGDPPC are due to fluctuations in LFPI, 6% of future shocks in LGDPPC are due to fluctuations in LCO_2, 6% of future shocks in LGDPPC are due to fluctuations in LURB and 3% of future shocks in LGDPPC are due to fluctuations in LINV.

Table 5 shows that 43% of future shocks in LINV are due to fluctuations in LGDPPC, 22% of future shocks in LINV are due to fluctuations in LFPI, 13% of future shocks in LINV are due to fluctuations in LFD, 8% of future shocks in LINV are due to fluctuations in LCO_2, and 7% of future shocks in LINV are due to fluctuations in LURB.

Table 5 shows that 22% of future shocks in LURB are due to fluctuations in LFPI, 17% of future shocks in LURB are due to fluctuations in LFD, 11% of future shocks in LURB are due to fluctuations in LCO_2, 4% of future shocks in LURB are due to fluctuations in LINV and 3% of future shocks in LURB are due to fluctuations in LGDPPC.

Table 5. Innovation Accounting based on Cholesky's technique

Cholesky Ordering: LCO2 LFD LFPI LGDPPC LINV LURB							
Variance Decomposition of LCO2:							
Period	S.E.	LCO_2	LFD	LFPI	LGDPPC	LINV	LURB
1	0.0993	100	0	0	0	0	0
2	0.1269	79.7608	1.4338	6.4066	1.7759	6.9513	3.6717
3	0.1418	66.0882	4.6148	5.8308	7.2927	7.1410	9.0324
4	0.1539	56.2366	9.1601	5.1358	11.5908	6.1644	11.7123

5	0.1648	49.0876	13.8754	5.5366	12.6515	6.3847	12.4643
6	0.1751	43.5824	17.2190	7.1549	12.3862	7.0601	12.5974
7	0.1844	39.7180	18.9764	8.7894	12.0108	7.8950	12.6103
8	0.1923	37.2444	19.7227	9.9723	11.8212	8.7004	12.5389
9	0.1986	35.7097	19.9575	10.8655	11.7997	9.2882	12.3795
10	0.2035	34.7564	19.9377	11.6039	11.9070	9.6165	12.1785

Variance Decomposition of LFD:

Period	S.E.	LCO_2	LFD	LFPI	LGDPPC	LINV	LURB
1	0.2169	2.8661	97.1339	0	0	0	0
2	0.2858	1.7426	93.8924	0.0073	0.2592	3.1604	0.9382
3	0.3219	1.9174	90.2623	0.1890	0.3001	5.1323	2.1988
4	0.3433	2.4485	87.1642	1.2769	0.3184	5.1899	3.6021
5	0.3584	3.1038	83.9272	2.5853	0.4743	4.8416	5.0677
6	0.3700	3.7001	80.8845	3.5903	0.9000	4.5503	6.3748
7	0.3794	4.1253	78.2185	4.4068	1.5225	4.3289	7.3980
8	0.3877	4.4091	75.8622	5.2001	2.1989	4.1536	8.1761
9	0.3954	4.6258	73.6977	6.0043	2.8580	4.0195	8.7948
10	0.4028	4.8282	71.6546	6.7935	3.4754	3.9358	9.3125

Variance Decomposition of LFPI:

Period	S.E.	LCO_2	LFD	LFPI	LGDPPC	LINV	LURB
1	0.0504	12.7232	1.9408	85.3360	0	0	0
2	0.0603	15.1654	4.6623	73.9175	0.3397	5.2729	0.6423
3	0.0679	17.9235	5.4093	61.9620	1.4613	12.0699	1.1739
4	0.0727	19.2927	5.1299	56.3978	1.8458	15.9650	1.3689
5	0.0757	20.2140	4.7770	54.2947	1.9300	17.2673	1.5171
6	0.0779	20.9908	4.5240	53.2360	2.0288	17.4938	1.7267
7	0.0794	21.6207	4.3488	52.4400	2.2243	17.3821	1.9841
8	0.0806	22.0382	4.2256	51.8394	2.4881	17.1571	2.2515
9	0.0815	22.2623	4.1403	51.4051	2.7766	16.8918	2.5239
10	0.0824	22.3507	4.0859	51.0547	3.0742	16.6195	2.8150

Variance Decomposition of LGDPPC:

Period	S.E.	LCO_2	LFD	LFPI	LGDPPC	LINV	LURB
1	0.0614	14.1719	16.2512	0.3096	69.2673	0	0
2	0.0896	10.6471	18.3542	1.2900	66.1941	2.9986	0.5161
3	0.1107	7.3407	18.7102	3.0310	65.0289	4.6290	1.2602
4	0.1263	5.6365	18.6419	4.4928	64.9566	4.3493	1.9229
5	0.1386	4.7605	18.4578	6.2295	64.3740	3.6768	2.5013
6	0.1492	4.3729	18.1698	8.2555	62.9244	3.1998	3.0777
7	0.1589	4.3595	17.7693	10.2890	60.8863	3.0058	3.6901
8	0.1680	4.6333	17.3037	12.1199	58.5865	3.0361	4.3205
9	0.1767	5.0890	16.8265	13.7103	56.2473	3.1907	4.9362
10	0.1849	5.6324	16.3685	15.0879	54.0083	3.3837	5.5191

Variance Decomposition of LINV:

Period	S.E.	LCO_2	LFD	LFPI	LGDPPC	LINV	LURB
1	0.0889	4.6359	3.2100	0.9000	62.9882	28.2659	0
2	0.1164	4.7104	8.5930	5.0555	60.3068	20.8084	0.5258

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3	0.1394	3.3592	12.2569	11.4412	56.0837	14.8820	1.9770
4	0.1596	3.5428	13.7250	14.0148	53.4961	11.7461	3.4752
5	0.1769	4.2468	14.2054	15.4809	51.4310	10.1394	4.4964
6	0.1920	4.9494	14.2873	17.0316	49.3355	9.2131	5.1831
7	0.2054	5.6325	14.1178	18.5772	47.3487	8.5825	5.7414
8	0.2175	6.3104	13.8105	19.8489	45.6411	8.1363	6.2529
9	0.2285	6.9516	13.4677	20.8348	44.2035	7.8166	6.7257
10	0.2386	7.5271	13.1450	21.6358	42.9573	7.5738	7.1609
Variance Decomposition of LURB:							
Period	S.E.	LCO_2	LFD	LFPI	LGDPPC	LINV	LURB
1	0.0056	12.2377	3.7533	7.6849	1.0828	3.7750	71.4663
2	0.0112	11.9661	5.8353	10.5835	1.4188	3.2566	66.9397
3	0.0171	11.0554	8.2430	13.0398	1.6510	2.0954	63.9154
4	0.0231	10.3657	10.5453	15.2238	1.8386	1.1804	60.8462
5	0.0292	10.0080	12.5437	16.9903	1.9962	0.8452	57.6165
6	0.0355	9.9363	14.1670	18.3636	2.1341	1.0483	54.3507
7	0.0419	10.0698	15.4169	19.4379	2.2641	1.5911	51.2202
8	0.0483	10.3359	16.3324	20.3032	2.4012	2.2760	48.3514
9	0.0545	10.6780	16.9686	21.0229	2.5592	2.9683	45.8030
10	0.0604	11.0541	17.3836	21.6392	2.7474	3.5964	43.5793

4.4 Diagnostic and Stability Checks

Diagnostic and stability checks were performed to examine the independence of the residuals. The Jarque-Bera test in Figure 3 shows that the null hypothesis of normal distribution in the residuals cannot be rejected at 5% significance level. Table 6 shows the diagnostic tests of the ARDL model. The Breusch-Godfrey Serial Correlation Lagrange-multiplier test shows that, the null hypothesis of no serial correlation at lag order h cannot be rejected at 5% significance level. The Breusch-Pagan-Godfrey heteroskedasticity test shows that, the null hypothesis of constant variance cannot be rejected at 5% significance level. The Ramsey RESET test shows that, the null hypothesis of no omitted variables in the model cannot be rejected at 5% significance level.

Table 6. ARDL Diagnostic Test

	Value	df	Prob.
Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	0.6832	(2,35)	0.5116
Heteroskedasticity Test: Breusch-Pagan-Godfrey:			
F-statistic	0.4900	(11,37)	0.8974
Ramsey RESET Test:			
F-statistic	0.0070	(1, 36)	0.9337

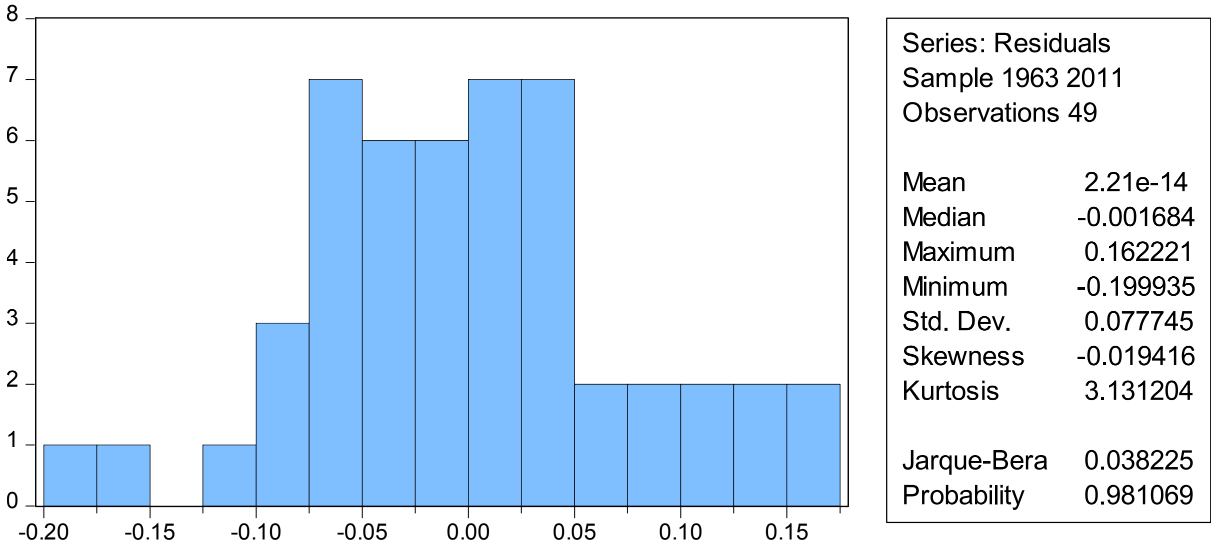

Figure 3. Jarque-Bera Test of Residuals

Figure 4 shows the CUSUM of Squares and CUSUM tests for checking the constancy of the cointegration space in the residuals of the ARDL model. Figure 4 shows that the CUSUM of Squares and CUSUM plots lie within the 5% significance level. The diagnostic and stability checks shows that the residuals in the ARDL model are independent and have stable parameters to make unbiased statistical inferences.

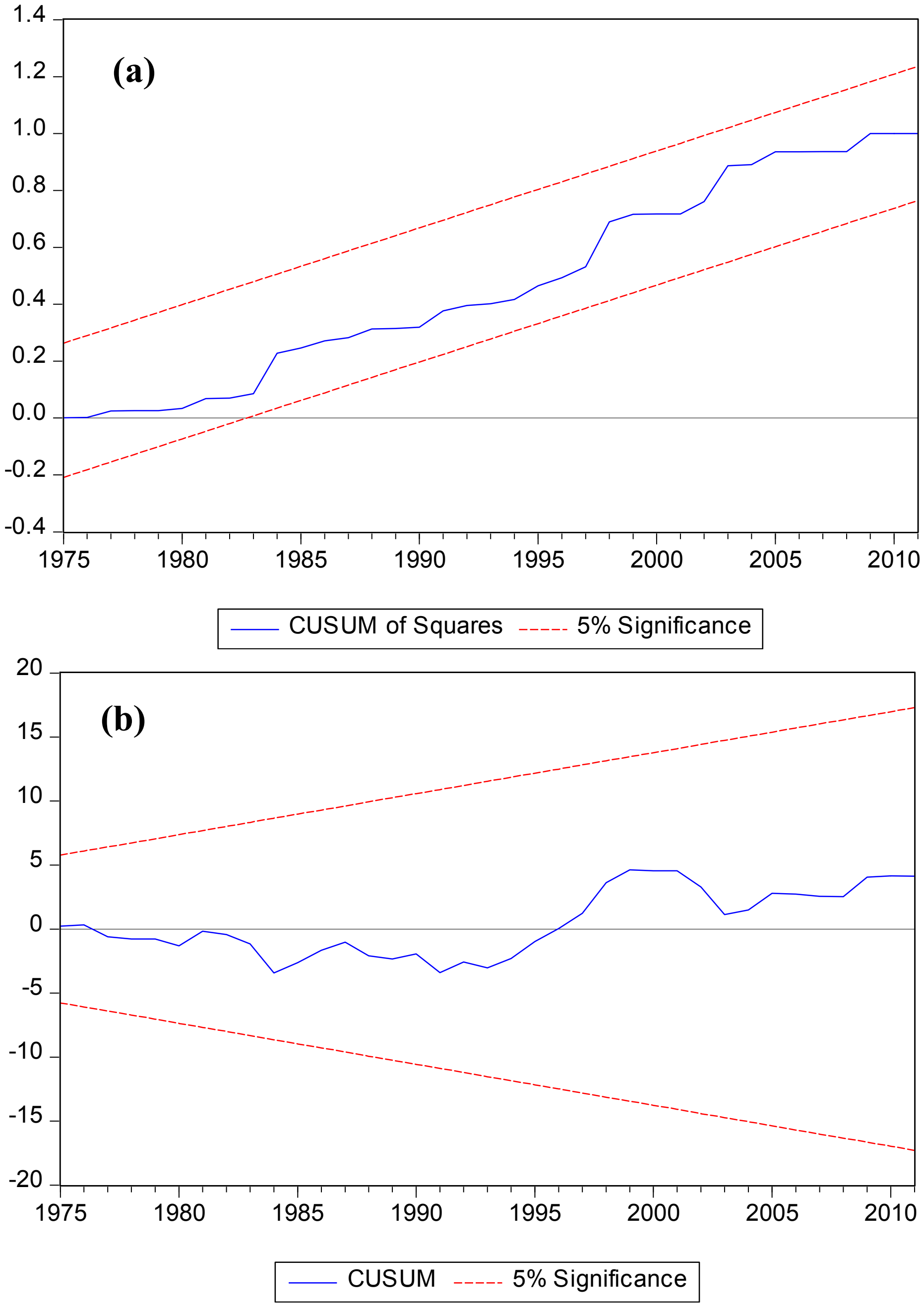

Figure 4. (**a**) CUSUM of Squares and (**b**) CUSUM of the Residuals

6. CONCLUSION AND POLICY RECOMMENDATIONS

In this study, an attempt was made to investigate the Kenya case of a multivariate causality of carbon dioxide emissions by employing a time series data spanning from 1961-2011 using the ARDL method of cointegration analysis. The study further analyzed the direction of causality using the Granger-causality test and the variance decomposition based on Cholesky's technique in order to analyze each random innovation affecting the variables in the VAR.

The ARDL model shows a long-run and a short-run equilibrium relationship running from food production index, financial development, GDP per capita, industrialization and urbanization to carbon dioxide emissions. The long-run elasticities show that, a 1% increase in financial development increases carbon dioxide emissions by 0.28%, a 1% increase in GDP per capita increases carbon dioxide emissions by 1.32% and a 1% increase in urbanization decreases carbon dioxide emissions by 1.14%. The higher effect of per capita GDP and financial development on carbon dioxide emissions in Kenya is due to the higher depletion and degradation of natural resources for industrial purposes in order to achieve the 2030 development strategy of reaching a middle income country status of US$1,000 per capita GDP with an accelerated economic growth of 6% [75]. As a global menace, Kenya is experiencing higher levels of urbanization in two industrial hubs namely Nairobi and Mombasa; the former been industrial and services hub for the local and regional markets while the later been a costal industrial hub for the emerging global markets. Nevertheless, Kenya is making the best out of urbanization to improve the labour force leading to an accelerated growth in economy and literacy which serves as a way of mitigating climate change and its impact through awareness creation.

Moreover, there was evidence of a unidirectional causality running from financial development to carbon dioxide emissions, food production index to carbon dioxide emissions, GDP per capita to carbon dioxide emissions, industrialization to carbon dioxide emissions, urbanization

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to carbon dioxide emissions, food production index to GDP per capita, industrialization to GDP per capita and urbanization to GDP per capita.

The innovation accounting based on the Cholesky's technique of variance decomposition shows that 20% of future shocks in carbon dioxide emissions are due to fluctuations in financial development. In addition, 9% of future shocks in financial development are due to fluctuations urbanization, 22% of future shocks in food production index are due to fluctuations in carbon dioxide emissions, 16% of future shocks in GDP per capita are due to fluctuations in financial development, 43% of future shocks in industrialization are due to fluctuations in GDP per capita and 22% of future shocks in urbanization are due to fluctuations in food production index.

The evidence from the long-run and short-run equilibrium relationship, the Granger-causality and the innovation accounting have policy implications for Kenya. All fast-growing developing economies are rapidly urbanizing, therefore Kenya should transform the rate of urbanization into good use through the creation of decent jobs and a strong labour force to increase economic productivity. Achieving higher levels of economic growth and productivity through technological improvements, innovation and creativity, diversification and high-value added to raw materials is a requirement for Kenya to achieve the middle-income status by 2030.

Finally, as extreme levels of carbon dioxide emissions affect food production index, efforts by the Government of Kenya that promotes sustainable agriculture through modern technologies and improved agricultural techniques would boost Kenya's economic productivity, promote food security while mitigating climate change and its impacts.

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