Environmental degradation, energy consumption, population growth and economic growth: Does Environmental Kuznets curve matter for Nigeria?

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Abstract

This paper investigates the relationship between CO2 emissions, energy consumption, population growth and economic growth in Nigeria during the period 1980-2012. The paper adopts autoregressive distributed lag (ARDL) bounds testing approach for cointegration with structural breaks and Toda-Yamamoto non-granger causality approach. Based on the result, there is no evidence of unidirectional causality running from CO2 emissions and energy consumption to economic growth and strong unidirectional causality running from CO2 emissions, energy consumption and economic growth to population growth was found. The long run and short run estimates show that energy consumption and population growth have strong and positive impact on CO2 emissions in the long-run and short run whereas economic growth impact weakly and negatively on CO2 emissions in the short-run. The inverted U-shaped environmental Kuznets curve (EKC) hypothesis is supported graphically and analytically in the long run with a turning point of 4.87. This means Nigeria has reached the required level of per capita real GDP to get an inverted U-shaped EKC. The main policy prescriptions among others is that Nigeria government should increase environmental taxation in order to reduce the rate of fossil fuel used by individuals which may lead to a reduction in per capital CO2 emissions.

Introduction

Nigeria is one of the developing countries in the world with per capital GDP (gross domestic product) of $5606.56 after being adjusted by Purchasing Power Parity (PPP) in 2014. Nigeria being the 21st largest economy in the world in terms of nominal GDP, the 20th largest in terms of purchasing power parity and the largest economy in Africa, still struggling to leverage the country's vast wealth in fossil fuels in order to displace the poverty that affects about 33% of its population (CIA World Fact Book). The use of fossil fuels causes CO2 emissions and CO2 emissions are those released from the burning of fossil fuel, manufacture of cement, energy consumption, carbon dioxide produced during consumption of solid liquid, gas fuel and gas flaring which form indicators for environmental degradation. According to World Bank, CO2 emission (kt) in Nigeria was reported as 95756.37kilogram in 2008.

Nigeria's primary energy consumption was about 108 million tonnes of oil equivalent (Mtoe) in 2011, most of which comes from fossil fuels and hydropower. Nigeria's energy consumption will increase by 56% in 2040 due to its rapidly growing population (Energy Information Administration (EIA), 2013). Currently, Nigeria is targeting to increase its electricity production from 4,000MW to 10,000MW and gas production from 26,000 to 46,000 megawatts to meet its energy needs in the next few years.

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Nigeria's population growth rate (annual %) was last measured at 2.63 in 2017 according to the World Bank. The population growth rate results from a surplus (or deficit) of birth over deaths and the balance of migrant entering and leaving a country. It may be positive or negative. The growth rate is a determinant of how great a burden would be imposed on a country by the changing needs of its people for infrastructure (e.g. food, water, electricity), and jobs (CIA world Fact book). Hence, as population grows, energy consumption increases and the rate of CO2 emissions from energy consumption also rises.

The nexus between CO2 emissions and economic growth gives rise to Environmental Kuznets Curve (EKC). According to Kuznets (1955), economic growth increases, carbon dioxide increases as well until some threshold level of economic growth is reached after which this emission starts to decline. The EKC hypothesis postulates that the relationship between economic growth and CO2 emissions is an inverted U-shaped e.g. Grossman and Krueger's (1991). That is CO2 emissions level increase as economy grows, but begins to decrease beyond a turning point as economic growth continues to increase.

Against this background, the relationship between CO2 emissions, energy consumption, population growth and economic growth, has been a serious research area in the developing and developed countries of the world. Several authors have explicitly addressed the issue of the relationship between CO2 emissions, energy consumption, population growth and economic growth but the conflicting empirical findings are yet to be resolved. Omri (2013) found in 14 Middle East and North Africa (MENA) countries that there is bidirectional causal relationship between economic growth and CO2 emissions and between energy consumption and economic growth in the region as a whole. Jaunky (2010) findings disapproved Omri (2013) by investigating EKC hypothesis for 36 high income economies (including Bahrain, Oman, and UAE), found unidirectional causality running from GDP per capita to CO2 emissions per capita in both long- and the short- run. Saidi and Hammami (2015) found using 58 countries (Europe and North Asia, Latin America and Caribbean, sub-Saharan, North African and Middle Eastern) that population growth, CO2 emissions and economic growth have a significant and positive effect on energy consumption. Achike and Onoja (2014) findings for Nigeria support Saidi and Hammami (2015) that fossil fuel energy is exogenously determined by economic growth rate. Cowan et al (2014) showed that no evidence of Granger causality between GDP and CO2 emissions in India and Brazil. Also, they found a one-way Granger causality running from GDP to CO2 emissions in South Africa. They further found that no evidence of Granger causality between GDP and CO2 emissions in India and China and between electricity consumption and CO2 emissions in Brazil, Russia, China and South Africa. Akpan and Akpan (2012) found similar result for Nigeria that economic growth is associated with increase CO2 emissions while an increase in electricity consumption leads to an increase in CO2 emissions. Jebli and Youseff (2015) disagrees with Saidi and Hammami (2015) and showed that the inverted U-shaped EKC hypothesis is supported graphically and analytical in the long-run for Tunisia.

The existing empirical studies have focused on the relationship between CO2 emissions, energy consumption, population growth and economic growth in countries and regions like Brazil, India, China, Russia, Tunisia, South Africa, Europe and North Asia, Latin America, Caribbean, sub-Saharan African countries, North African and Middle Eastern etc. There are few empirical studies in Nigeria such as Akpan and Akpan (2012), Achike and Onoja (2014), Omojolaibi (2010), Alege and Ogundipe (2013), etc. To the best of our knowledge, the gap in the literature surveyed showed that no Nigeria specific case studies have examined the relationship between CO2 emissions, energy consumption, population growth and economic growth and extensively test for the EKC hypothesis in Nigeria. The need to address this issue is pertinent because it will show the specific impact of economic growth on CO2 emissions and the implication of population growth rate on CO2 emissions. In addition, it will give an insight of the relationship that exists between CO2 emissions, energy consumption, population growth and economic growth.

The objective of the study is to empirically investigate the dynamic causal relationship between CO2 emissions, energy consumption, population growth and economic growth in Nigeria and to also test whether the inverted U-shaped EKC hypothesis is verified or not for Nigeria during the considered period 1980 -2012.

Data description[3]

This study focuses on the relationship between CO2 emissions (E), energy consumption (EN), population growth (P) and economic growth (Y) in Nigeria over the period spanning from 1980 to 2012. The data used in the study are from the world development indicator (WDI, 2013-CD-ROM) and US energy information administration (EIA). The variables used are CO2 emissions (measured in metric tons per capital), energy consumption (measured in kilogram (kg) of oil equivalent per capita), population growth (measured in growth rate) and economic growth (measured in per capita RGDP constant 2000 US$). The descriptive statistics mean, median, standard deviation, Kurtosis, and minimum & maximum for the variables are presented in Table 1. We can see that the average of CO2 emissions is 0.6194 metric ton per capita from 1980-2012 in Nigeria. The mean of per capita RGDP, per capita RGDP square, energy consumption, and population growth during the period are 8.19, 67.10, 6.60 and 2.60, respectively. The average and median values are quite closer which indicate symmetric nature of the data.

The correlation coefficient is reported in Table 2. The correlation between CO2 emissions and economic growth is negative. The relation between population growth and CO2 emissions is positive. CO2 emissions are negatively related to the square of per capita RGDP. The correlation between economic growth and energy consumption is negative. Energy consumption is positively correlated to economic growth. Population growth and energy consumption are negatively related.

EKC Hypothesis

EKC hypothesis can be specified as follows:

$$E = f(Y, Y^2, w) \qquad (1)$$

Where E is an environmental pollution indicator (CO2 emissions per capital), Y is income (per capita RGDP) and W are other explanatory variables that may influence environmental degradation in Nigeria. The long run quadratic EKC model is estimated to study the relationship between the variables. The log linear estimation model is as follow:

$$E = \alpha_0 + \alpha`_1 Y_t + \alpha_2 Y_t^2 + \alpha_3 EN + \alpha_4 P + \varepsilon_t \qquad (2)$$

Where t is the period and ε is the disturbance term. Values of the income coefficients (αs) ndicate different functional form, where $\alpha 1=\alpha 2=0$ Indicates a level relationship, $\alpha 1<0$ and $\alpha 1<0$ and $\alpha 2=0$ indicate a monotonically decreasing linear relationship,

[3]Note that all the data are rescaled using logarithm except CO2 emissions and population growth which are already in logarithm form.

$\alpha 1>0$ and $\alpha 2=0$ indicate a monotonically increasing linear relationship, $\alpha 1<0$ and $\alpha 2>0$ representing U-shaped relationship and $\alpha 1>0$ and $\alpha 2<0$ indicate an inverted u-shaped relationship, hence the EKC. The turning point of per capita real income is $Y^{*}=-\alpha 1/|2\alpha 2|$. f the variable Y is measured in logs then exp(Y*) will yield the monetary value representing the peak of the EKC.

Unit root tests[4]

The result of unit root tests with and without accounting for a structural break is respectively reported in Table 3 and Table 4. The result of augmented Dickey Filler (ADF) and Phillip Perron (PP) is mixed in a few cases but the common suggestion of the two unit root tests both in constant and constant & trend is that in level, most of the variables are non-stationary while in first difference, all the variables are stationary. According to ADF and PP tests, series E, Y and Y^2 have unit root at levels. ADF test shows that series P is stationary at level in both constant and constant & trend unlike PP test. Also, the two unit root tests show that series EN is stationary at level in constant for both ADF and PP tests.

The Zivot-Andrew (1992) unit root test gives the information about the integration and structural breaks properties, which interest most policymakers. The null hypothesis of unit root break reveals that the variable is non-stationary; the alternative hypothesis indicates that the variable is stationary at one-time break point. The result from Zivot-Andrew unit root test with intercept show that, at level and first difference all the variables with structural breaks are stationary.

Cointegration test[5]

Following the unit root test, the study further test for the instability of the long-run relationship between the CO_2 emissions and energy consumption, population growth and economic growth. The test statistics LC are reported in Table 5. The results show that, at 5% and 10% levels of significance, there is not enough evidence to accept the null hypothesis of stability in the long-run equations of energy consumption and population growth, since most of the LC statistics are significant at the 5% level and 10% except per capital RGDP and per capital RGDP square. The findings will change if the test results are considered at 1% significance level. All the long run relationships are stable at 1% level of significance.

The next step is to conduct the threshold cointegration test by Gregory and Hansen (1996). This provides alternative approaches, which test, are based on the regime change and a development over the usual residual-based cointegration test. The test is presented in the Table 6.The result of the GH threshold cointegration indicates that the statistics obtained by the modified ADF, Zt*, and Za* (Engle and Granger (1987) and Phililps and Ouliaris (1990)) seem to give invariant results. The result indicates that for Za* the null hypothesis of no cointegration was rejected for the variables. The result suggests that allowing for structural change in the cointegration relation, the series move together in the long run and they share a common stochastic trend although in the short run the series may diverge from each other. In the presence of structural breaks, such cointegration relationship can be used in making forecast while other statistics (ADF and Zt*) accept the null hypothesis of no cointegration.

Since the results of the unit root tests validate the use of ARDL estimation therefore, ARDLmodel is run. ARDL bounds test for cointegration is reported in Table 7. The Akaike information criterions (AIC) select the lag order of the ARDL estimation. The ARDL bound test shows that the computed F-statistics is greater

[4]This study used the ADF and Phillips Perron (PP) models to test unit root without structural breaks and Zivot and Andrews (1992) was used to test for unit root with breaks .

[5]This study employs Gregory and Hansen (1996) cointegration test. The tests are extensions of the ADF, $Z\alpha$ and Zt tests for cointegration that incorporate a break in the cointegrating relationship. In addition, This study employs the ARDL bound testing approach as an estimation technique

than the upper critical bound at 5% level of significance, as CO2 emissions is used as dependent variable. This result shows that there is no cointegrating vector, which refuse to confirm the existence of the long-run relationship between the variables.

The estimated long run and short run elasticities or the marginal impact of energy consumption, population growth and economic growth on CO2 emissions are reported in Table 8. The result shows that energy consumption and population growth are statistically significant at 1% level in the short run while in the long run, the result revealed that population growth is statistically significant at 1% level and energy consumption at 5% level of significance. Energy consumption and population growth have positive impact on CO2 emission in Nigeria, which suggest that a 1% increase in energy consumption and population growth increase CO2 emissions directly by 667% and 177%, 648% and 250% in the long-run and short-run. The result corroborates Saboori and Sulaiman (2013), who found positive relationship between energy consumption and CO2 emission in Singapore, Philippines, Malaysia, Thailand and Indonesia.

The relationship between economic growth and CO2 emissions supported EKC hypothesis stipulating an inverted U-shaped curve in the long-run. This shows that a 1% increase in economic growth is linked to a 274% rise in CO2 emissions, while the nonlinear term of economic growth seems to confirm the delinking of CO2 emissions after the threshold level of real GDP per capita and also confirmed graphically in Fig 1 which show an inverted U-shaped from 1998-2010. This result is similar to Omojolaibi (2013) for the West Africa case. However, the result is contrary to Alege and Ogundipe (2013), who showed that the non-existence of EKC hypothesis in Nigeria. This difference in results may occur as result of the difference in variable used, data used and period considered. Now, we can obtain the estimated turning point regarding per capital real income $(Y^{*}= (-\alpha_1/|2\alpha_2|))$. Based on the result the turning point is calculated in logarithms. The turning point is 4.87.

In the short run, the relationship between economic growth and CO2 emissions does not support EKC hypothesis, as the linear and nonlinear terms of per capital real GDP have a negative and positive impact on CO2 emissions. The results in the long-run and short-run are consistent with Boluk and Mert (2015), Lee, S and Oh, D.-W (2015), Jebli and Youssef (2015) Saboori and Sulaiman (2013) which they found inverted U-shaped and non-inverted U-shaped in different time horizon. The estimated lagged error term (ECTt-1) is negative (-2.61426) and it is statistically significant at 1% level which suggests long-run relationship between the variables and it confirms that the deviation of the variables from short run to long-run equilibrium is adjusted by 261.426% per year.

The residual diagnostic tests applied to the model show that there are no evidence of serial correlation, heteroskedasticity, and residual are normally distributed. For the CUSUM and CUSUM of squares test in Fig.2, the tests statistic is not outside the critical boundary of 5% level of significance. Thus, the null hypothesis of parameter stability is accepted at 5% significance level showing the stability of the coefficients. The intuition is that the structural break does not affect the model estimation. The bootstrap distribution of the resample residual after 10000 repetitions in Fig 3, shows a smooth distribution and signifies that the results of the long run estimate of ARDL model is stable.

Granger causality test[7]

The technical way to overcome the pitfall ensuing from using the traditional method for causality tests when series are individually integrated but non-cointegrated is nevertheless available under Toda-Yamamoto Granger non-causality test. Toda-Yamamoto Granger non-causality test is used since Hansen (1992) instability tests do not support the presence of structural change at 5% significance level and the GH cointegration test suggests that there is a long-run (equilibrium) relationship between CO2 emissions, energy consumption, population growth and economic growth in Nigeria. The TY test is employed to investigate the causal relationship between CO2 emissions, energy consumption, population growth, and economic growth in Table 10. The highest order of integration (dmax) of the variable was initially determined using the results from Zivot-Andrew unit root test. The optimum lag length (P) without serial autocorrelation selected by means of Akaike information criterion (AIC) and Schwarz information criterion (SIC) is reported in Table 9

The results of TY test are reported in Table 10. The results are quite interesting because this is the first study interested in the causal relationship between CO2 emissions, energy consumption, population growth and economic growth in Nigeria. The results show that there is strong unidirectional causality running from CO2 emissions to economic growth. Thus, an increase in CO2 emissions affects economic growth in Nigeria. The finding is consistent with Tiwari (2011) who found unidirectional causality running from CO2 emissions to economic growth in India. The results also show that there is bidirectional causality between CO2 emissions and non-linear term of per capita real GDP.

There is no causal relationship running from energy consumption to economic growth, which indicated that energy consumption cannot cause economic growth in Nigeria. This finding is contrary to Bastola and Sapkota (2015) who found unidirectional causality running from economic growth to energy consumption in Nepal. Also, contrary to Omir (2013) who found that there is unidirectional causal linkage from CO2 emissions to energy consumption in Middle East and North Africa (MENA). The TY test also reported that there is strong bidirectional causality between energy consumption and the non-linear term of per capita real GDP. Furthermore, there is a strong unidirectional causality running from CO2 emissions, energy consumption, economic growth and non-linear term of per capita real GDP to population growth.

Therefore, an increase in CO2 emissions, energy consumption, and economic growth will increase the rate of population in Nigeria. The long run analysis fails to establish causal linkage from economic growth to CO2 emissions, energy consumption to CO2 emissions and economic growth to energy consumption but there may still be short-run temporary effects.

Conclusion and Policy prescriptions

This paper incorporates energy consumption and population growth as interesting variables to study their causal relationship with per capita CO2 emissions and per capita real GDP, and to verify the EKC hypothesis for Nigeria using data over the period 1980-2012. The paper employed the Zivot-Andrews structural break unit root test, Gregory and Hansen cointegration test, the ARDL bounds testing approach to cointegration, and the Toda-Yamamoto long run non granger causality test. Generally, the results suggest a robust long-run relationship among the variables. An inverted U-shaped relationship between CO2 emissions and income was found in the long

[7] Toda and Yamamoto (1995) approach is a development over the traditional Granger-causality test. The procedure is a methodology of statistical inference, which make parameter estimate valid. In this study, we use a multivariate VAR (p +dmax) including CO2 emissions, energy consumption, population growth and economic growth, following Yamada (1998) and Esso (2010).

run according to ARDL estimation model. Therefore our result support EKC hypothesis for Nigeria in the long run. However the study prescribes that as economy grows in the long run, Nigeria should increase environmental taxation in order to reduce the rate of fossil fuel (exhaustible or non-renewable energy) used by individuals leading to a reduction in per capita CO2 emissions and an inverted U-shaped EKC. Also, the government of Nigeria should strengthen their environmental laws in order to control environmental problem that may occur from carbon dioxide emissions.

The results of TY non granger causality test show the absence of unidirectional causality running from economic growth to CO2 emissions while strong unidirectional causal linkage is shown running from CO2 emissions to economic growth. This implies that for Nigeria to achieve sustainable development, there is need for emission policies to be enhanced and for more investment in pollution reduction strategies. Also, there is no evidence of unidirectional causality running from CO2 emissions to energy consumption and energy consumption to economic growth. Thus, while protecting environmental health, the Nigerian government must continue to encourage the use of energy most especially renewable energy such as biogas, solar, wind etc. There is strong bidirectional causality between population growth and CO2 emissions, energy consumption and economic growth. This implies that future growth in population is expected to increase energy use, per capita CO2 emissions and economic growth. To achieve sustainable development, Nigeria should try as much as possible to stabilize the population growth rate by controlling birth rate through the different advisory agencies in the country.

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Appendix

Table 1

Summary of descriptive statistics on CO_2 emissions, energy consumption, population growth and economic growth in Nigeria (1980-2012).

Variables	Average	Median	Skewness	Kurtosis	SD	Min	Max	JB
E	0.619399	0.645019	-0.097061	1.889509	0.175145	0.322040	0.924785	1.747453
EN	6.598864	6.595977	0.106610	2.403924	0.019982	6.555561	6.637309	0.551058
Y	8.189722	8.140356	0.774626	2.757046	0.172710	7.925344	8.584335	3.381415
Y^2	67.10047	66.26540	0.810284	2.801818	2.851826	62.81107	73.69081	3.665089
P	2.598640	2.568834	0.926049	2.954643	0.099013	2.495284	2.861355	4.719448

Note: SD and JB are standard deviation and Jarque-Bera.

Table 2

Correlation Matrix

Variables	E	EN	Y	Y^2	P
E	1.000000				
EN	0.181562	1.000000			
Y	-0.207743	-0.176826	1.000000		
Y^2	-0.205812	-0.181535	0.999939	1.00000	
P	0.306706	-0.472608	0.629383	0.63311	1.00000

Table 3

Augmented Dickey Fuller and Phillips-Perron unit root tests without structural break

variables	ADF t-stat		PP t-stat	
	Constant	Constant & Trend	Constant	Constant & Trend
Level				
E	-2.254980	-2.12848	-2.243646	-2.12861
EN	-3.020562**	-2.92786	-3.108548**	-3.01663
Y	0.771199	-1.61552	0.100505	-3.41620*
Y^2	0.853309	-1.50713	0.168991	-3.33146
P	-4.512258***	-4.30489**	-2.530002	-2.88423*
First difference				
ΔE	-6.47419***	-6.44272***	-6.46005***	-6.48535***
ΔEN	-5.75622***	-5.72477***	-7.09247***	-8.62819***
ΔY	-5.26641***	-5.62407***	-5.40503***	-5.75352***
ΔY^2	-5.26206***	-5.65642***	-5.39353***	-5.78443***
ΔP	-3.26836**	-6.02958***	-3.99855***	-3.49413*

***, **, and * Indicates significant at the 1% level, 5% and 10% level

Table 4

Zivot-Andrew unit root tests with structural break

Variables	Level		First difference	
	T-stat	Year of Break (T_B)	T-stat	Year of Break (T_B)
E	-5.33901(0)***	2000	-6.96927(0)*	1996
EN	-3.80500(0)**	2007	-6.07408(0)	1996
Y	-1.60524(4)**	1994	-3.29321(4)**	1993
Y^2	-1.53260(4)**	1994	-3.33319(4)**	1993
P	-2.15677(2)*	1993	-11.1402(1)*	2002

Note: ***, **, and * Indicate significant at the 1%, 5% and 10% levels. Lag order is shown in parenthesis,

Table 5

Hansen (1992b)'s instability test results: 1980-2012.

Dependent Variables	EN	Y	Y^2	P
L_c Statistics	0.698341	0.423947	0.437329	0.542394
	(0.034500)*	(0.150400)	(0.139700)	(0.077100)**

Note: * and ** indicates significance, i.e. rejection of the null hypothesis of stability at 5% and 10% level. L_C tests are performed by Eviews 9. Numbers in parenthesis are p-values. We use C and @TREND as deterministic regressors, and no lags.

Table 6

Gregory and Hansen (1996) Cointegration Test Results: 1980-2012

Dependent Variables:			EN	Y	Y^2	P
	Level Shift C	ADF*	-3.04914(2)	-3.48563(0)	-3.45631(0)	-3.18835(2)
			[1985]	[2002]	[2002]	[1986]
		Z_α^*	-19.6151**	-15.9427**	-15.9159**	-15.0645**
			[1988]	[1988]	[1988]	[1988]
		Z_t^*	-3.99507*	-3.54173*	-3.51172*	-3.10746*
			[1988]	[2002]	[2002]	[1988]
	Level Shift with Trend C/T	ADF*	-5.14283(0)	-5.14925(0)	-5.14548(0)	-5.06025(0)
			[2001]	[2001]	[2001]	[2001]
		Z_α^*	-30.4022**	-30.4879**	-30.4637**	-29.893**
			[2001]	[2001]	[2001]	[2001]
		Z_t^*	-5.38325*	-5.23164*	-5.22781*	-5.14122*
			[1988]	[2001]	[2001]	[2001]
	Regime Shift C/S	ADF*	-3.02598(0)	-3.84233(0)	-3.83238(0)	-3.37596(2)
			[1995]	[2001]	[2001]	[2005]
		Z_α^*	-18.6823**	-15.2337**	-15.2031**	-15.0623**
			[1988]	[1988]	[1988]	[1988]
		Z_t^*	-3.70416*	-3.95177*	-3.94079*	-3.10804*
			[1988]	[2001]	[2001]	[1988]

Note: * and ** denote significance, i.e. rejection of the null hypothesis of no cointegration at 5% and 1% levels, respectively. Numbers in (.) are lag order to include in equations which was set as in Perron (1997). Time breaks are in [.] 5% critical values for level shift, level shift with linear trend, regime shift models based on Gregory and Hansen (1996).

Table 7

ARDL bounds test for cointegration

F-statistics	AIC:ARDL (4,4,4,3)			4.331495
F-critical values	1%		5%	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
K=4	3.74	5.06	2.86	4.01

Note: ARDL bounds test is performed by Eview 9.

Table 8

Long run and short run estimate ARDL model

Dependent Variables: E	AIC: ARDL (4,4,4,3)			
	Coefficient	Standard error	t-Statistics	P-values
Long run estimates				
EN	6.672566***	1.019681	6.543779	0.0012
Y	2.735467	16.11074	0.169792	0.8718
Y^2	-0.28044	0.986262	-0.284349	0.7875
P	1.774156***	0.37518	4.728811	0.0052
Constant	-51.7254	62.15597	-0.832188	0.4432
Short run estimates				
ΔEN	6.481381***	1.197754	5.411277	0.0029
ΔY	-161.671*	74.1031	-2.1817	0.0809
ΔY^2	9.886722*	4.548408	2.173666	0.0818
ΔP	25.01052**	9.183664	2.723371	0.0416
ECT_{t-1}	-2.61426***	0.647311	-4.03865	0.0099

R^2=0.986 Adj R^2=0.921

F-stat=15.166 P (F-stat) =0.003

Norm test= 1.317(0.518) Hetero test=1.574(0.325) Durbin-W=2.61

LM test=5.450(0.3096)

Note: ***, ** and ** indicate statistical significance at the 1%, 5% and 10% levels respectively. The ARDL estimation model is performed by Eview 9.

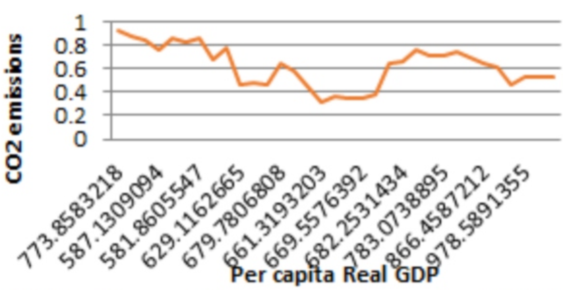

Fig1. Plot of per capital CO_2 emission and real GDP.

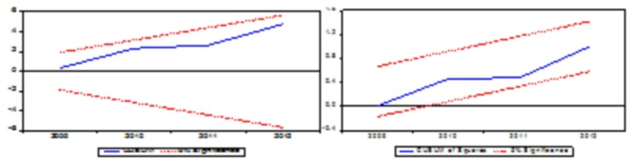

Fig2. CUSUM and CUSUM of squares plot of recursive residual.

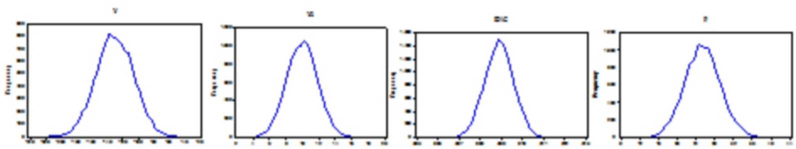

Fig3. Bootstrap distribution of the resample residual after 10000 repetitions

Table 9

VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	222.3345	NA	2.13E-13	-14.98858	-14.7528	-14.91475
1	379.0509	248.5847	2.49E-17	-24.07248	-22.658	-23.62949
2	424.7037	56.67239	7.10E-18	-25.4968	-22.9037	-24.68466
3	498.5339	66.19265	4.00E-19	-28.86441	-25.0926	-27.68311
4	573.3479	41.27668*	4.41e-20*	-32.29986*	-27.34930*	-30.74940*

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level) FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion

Table 10

Toda-Yamamoto non-causality test results: 1980-2012

Dependent Variables	E	EN	Y	Y^2	P
E	-	5.095992	6.463092	6.303784	4.100322
		(0.2776)	(0.1671)	(0.1776)	(0.3926)
EN	6.847303	-	3.014633	2.945961	7.709231
	(0.144200)		(0.5554)	(0.5669)	(0.1028)
Y	63.76953	32.9104	-	54.05974	65.77875
	(0.0000)***	(0.0000)***		(0.0000)***	(0.0000)***
Y^2	61.27037	31.7731	52.28172	-	63.02423
	(0.0000)***	(0.0000)***	(0.0000)***		(0.0000)***
P	22.72574	32.9002	27.45623	27.24853	-
	(0.0001)***	(0.0000)***	(0.0000)***	(0.0000)***	

Note: lag length were determined based on Akaike information criterion (AIC) and Schwarz information criterion (SIC), ***, ** and *** denote significance i.e. rejection of null hypothesis of no causality at 1%, 5% and 10% levels, respectively. *P*-values are presented in parenthesis.