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Elasticity of CO2 emissions with Respect to Income, Population, and Energy Use: Time Series Evidence from African Countries

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Summary

This study examines the CO_2 emissions elasticity of income, population and Energy because it has become imperative for Africa to follow cleaner development pathways. The specified models, guided by the STIRPAT, EKC and EEO framework, are estimated by applying a dynamic regression technique. To minimise data attrition, different sample periods, between 1971 and 2013, are adopted for each 26 sampled African countries. The findings support the literature that environmental quality is a normal good in economies but do not support the neoclassical view that it is a luxury one. Economies in which a cleaner environment is found to be an inferior good are of higher threat to Africa's environment than economies where a cleaner environment is a normal good. African countries with positive population elasticity depict a threat to having a cleaner CO_2 environment in Africa. The study finds the EKC for 15 countries, the U-shaped relationship for six countries and a linear relationship for five countries. It, also, discovers that energy consumption, followed by affluence, is the primary driver of human-induced CO_2 emissions in African countries while the population is a lower impact-factor than affluence and recommended that CO_2 mitigation should relentlessly be made a regional, national and local focal issue.

Key words: CO_2 emissions; Energy-Emissions-Output; Environmental Impact Assessment; Environmental Kuznets Curve; Stochastic Impacts by Regression on Population, Affluence and Technology

JEL Classification: Q56

1. Introduction

Climate change is recognised as the greatest challenge of our time and carbon dioxide (CO_2) emission is the major driving force behind it (GEO4, 2007). Although Africa's average growth rate in CO_2 emissions was reduced from 3.09% during 1976-1995 to 2.52% during 1996-2015, its growth rate in emissions is above the world's average growth and its share of global emissions is higher than the previous decades (Canadell *et al.*, 2009). Africa's CO_2 per capita has been rising from 0.98 in 1976 to 1.08 in 1995 and 1.11 in 2015. Compared to other continents, Africa has a higher average growth rate in CO_2 per capita than Europe, North America and Oceania but a lower average growth rate in CO_2 per capita than

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Asia, Central America, Middle East and South America during 1996-2015 (www.globalcarbonatlas.org).

To its credit, Africa's average growth rate in CO_2 emissions to GDP dropped, and from being second in the ranking of continents (next to the Middle East), it now comes sixth, i.e. higher than Europe and North America and lower than others. In spite of this encouraging statistics on CO_2 emissions to GDP, the share of global cumulative atmospheric carbon for developing countries, including Africa, is likely to reach 50% by 2030 (Wheeler and Ummel, 2007). This indicates that unchecked emissions in Africa pose a threat (Wheeler and Hammer, 2010) and so it is imperative to follow cleaner development pathways.

Explaining the factors that determine emissions, Ehrlich and Holdren (1971) suggested that Population, Affluence and Technology influence emissions' environmental Impact (called the IPAT framework). This led Meadows *et al.* (1972) to argue that the world should transit to a steady-state economy by putting an end to economic growth. However, due to the strong correlation between income (affluence) and environmental protection, Beckerman (1992) maintains that the most certain way to reduce environmental abasement is by getting rich.

Although Beckerman's position is popularized by the World Bank's World Development Report (WDR) (1992), the report exposes the relevance of Ehrlich and Holdren's assumption by mentioning that rapid increase in population size (experienced in most African countries) may make it more difficult to address environmental problems like climate change. In support of this view, the UN Conferences on Trade and Development (UNCTAD) (2012) observed that with Africa's rising population, farm sizes have been declining and an increasing number of people are forced to cultivate virgin lands for farming and urban development, which causes organic CO_2 stored in trees and soil to be released into the atmosphere. Hence it is not surprising that a few years back Canadell *et al*. (2009) found an upward trend in Africa's average CO_2 emissions.

Due to access to energy-efficient technologies, this factor can either reduce or expand the degree of environmental impact (UNCTAD, 2012). This endorses Hamilton and Turton's (2002) conclusion that affluence and population are the main factors for the increasing CO_2 in Organization for Economic Cooperation and Development (OECD) countries. In furtherance of this debate, Liddle (2015) identified that some studies found that population has a greater environmental impact than affluence (e.g. Neumayer, 2004; Martínez-Zarzoso *et al.*, 2007; Liddle and Lung, 2010). Contrarily, recent studies like that of Pastpipatkul and Panthamit (2011) and Fang and Miller (2013) established that affluence has a higher environmental impact than population. This study identifies which statements are true for 26 African countries.

Earlier studies (e.g. Borcherding and Deacon, 1972; Bergstrom and Goodman, 1973) found that income elasticity for environmental quality is greater than one, while more recent ones (e.g. Imber *et al*., 1991; Carson *et al.*, 1996) detected an income elasticity that is less than one. Unlike the more recent studies, Dietz and Rosa (1997) introduced a stochastic framework and obtained the CO_2 emissions elasticity of income and population that are greater than but close to unity. York *et al.* (2003) found a roughly proportional effect of population on the environment. Shi (2003) supports the more recent studies and York *et al.* (2003) on income elasticity and calls into question the findings of Dietz and Rosa (1997) that population elasticity is greater than but not approximately one. Applying a more robust estimation technique, Neumayer (2004) found that emissions change less proportionately with income and proportionately with population.

Some recent studies do not agree with the above-mentioned studies. Fan *et al*. (2006) found both elasticities to be less than one. At the provincial level, Pastpipatkul and Panthamit (2011) obtained unitary and less than unitary emissions elasticity of income and population. Although Fang and Miller (2013) agree with Dietz and Rosa (1997) on emissions elasticity of population, they found income elasticity to be greater than one. However, Liddle (2015) supports Shi (2003) on income and population elasticity to be less and more proportional, respectively.

This study takes into account the wealth of the literature on panel analysis, the endogeneity of data and the non-linearity of the models, and makes the following contributions: [a] Country-specific analysis is conducted; [b] Models are specified using three theoretical frameworks; and [c] A time series robust estimation technique is applied. This paper is organised into four sections. The next section makes an overview of the literature on environmental impact, the methodology is presented in section three, the estimated results are discussed in section four and the paper is concluded in the last section.

2. Literature Review

Studies in the literature are based on the framework of Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) (e.g. York *et al*., 2003; Martínez-Zarzoso *et al*., 2007), Environmental Kuznets Curve (EKC) (e.g. Jorgenson and Clark, 2013), STIRPAT and EKC (e.g. Neumayar, 2004), and STIRPAT and Kaya identity on intensity variables (e.g. Liddle, 2015). To consider a different perspective, this study applies the STIRPAT, EKC and Energy-Emissions-Output (EEO) frameworks. These frameworks have income in common, though they share some uncommon features (York *et al*., 2003).

Criticizing the IPAT framework for not explaining the non-proportional effects of the determinants and omitting other factors of interest, Dietz and Rosa (1997) and York *et al*. (2003) proposed a more elaborate approach called the STIRPAT (specified in equation 1).

$$I = \alpha P^{\beta} A^{\gamma} T^{\delta} \varepsilon \quad (1)$$

The term *I* is the environmental impact, α is the constant term, *P* is the population with coefficient β, *A* is affluence with coefficient γ, *T* is a vector of variables including technology with coefficient δ and ε is the error term. If the natural log of equation 1 is obtained as equation 2, the equation is expressed as a log-linear model. The STIRPAT framework is, perhaps, the most widely utilised environmental impact theory in the literature on the effect of population on CO_2 emissions and it consistently shows that income and population has a non-negative effect on emissions.

$$lnI = \alpha + \beta lnP + \gamma lnA + \delta lnT + \mu \quad (2)$$

The EKC is widely used to examine the effect of income on CO_2 emissions. It is due to neoclassical economists' argument that economic growth contributes to environmental problems and increasing income should yield increase in the demand for environmental quality (Martinez-Alier, 1995). That is, a cleaner CO_2 environment is a luxury good affordable only for rich societies (York *et al*., 2003) as the demand for a cleaner CO_2 environment rises more proportionately with the increase in income. If emissions elasticity of income is less than one but non-negative then a cleaner CO_2 environment is a necessary good with its demand rising less proportionately as income increases. Meanwhile, a negative emissions elasticity of income means that a cleaner CO_2 environment is an inferior good as its demand falls as income rises.

To illustrate this point, the following case is suggested: if public transport is considered indispensable in a society then as income increases people would not shy away from trekking/riding the bus/train/bicycle, which in turn implies that cleaner CO_2 environment is seen as a normal good. If owning a car is considered to be a status symbol while trekking/riding the bus/train/bicycle are interpreted as a sign of poverty, then as income increases people would trade off trekking/riding the bus/train/bicycle for buying cars. This would lead to a dirtier environment and accordingly make the cleaner CO_2 environment an inferior good.

The EKC is specified in equation 3 as an inverse-U-shaped relationship between income (*Y*) and environmental degradation (*E*).[1] The model expresses that as income increases environmental degradation goes up at first, and income reaches a point at which environmental degradation starts to decline. Since the paper aims to obtain the elasticity of the stimulus variables for the response variable, the natural log of equation 3 is obtained as the log-quadratic model in equation 4.

$$E = \beta_0 + \beta_1 Y + \beta_2 Y^2 + \varepsilon \quad (3)$$

$$lnE = \beta_0 + \beta_1 lnY + \beta_2 lnY^2 + \varepsilon \quad (4)$$

Although the EKC model is based on the presumption that the emissions elasticity of population is one (Neumayer, 2004) and it could be removed via division (Dinda, 2004), Ehrlich and Holdren (1971) argued that population has a disproportional impact on the environment and Panayotou (2000) claimed that a higher population may result in higher emissions for a given income per capita.

Except for Shahbaz *et al.* (2011) who found the EKC for South Africa, country-specific study in the EKC literature on African countries (e.g. Boopen and Vinesh (2010) for Mauritius; Alege and Ogundipe (2013) for Nigeria; Onafowora and Owoye (2013) for Nigeria and South Africa) did not find the inverted-U-shape relationship between income and CO_2 emissions.

Relying on the findings of Kraft and Kraft (1978) on the causality that exists between economic growth and energy consumption[2], the EEO model is introduced by Ang (2007) to have a comprehensive estimate that considers the CO_2 emissions-income relationship and energy-income causality. The EEO model is presented in equation 5, where *E* is the environmental indicator, *Y* is income, *Ec* is energy consumption and ε is the error term.

3. Methodology

Given that, once emitted, CO_2 can persist for over 100 years (Cunha-e-Sá, 2008), the log-linear model in equation 6 is a dynamic STIRPAT model on the EEO. Where CO_2 (metric tons per capita) is the environmental indicator in country i; CO_{2it-1} is a period lagged of CO_2 emissions; Y is income/affluence in country i proxy with GDP per capita measured in constant 2010 U.S. dollars; P is the population for country i; the share of industry in GDP is used as a proxy for technology in country i; Ec is energy consumption per capita in country i and μ is the error term.

$$lnE = \beta_0 + \beta_1 lnY + \beta_2 lnY^2 + \beta_3 lnEc + \varepsilon \quad (5)$$

$$lnCO_{2it} = \beta_0 + \beta_1 lnCO_{2it-1} + \beta_2 lnY_{it} + + \beta_4 lnP_{it} + \beta_5 lnI_{it} + \beta_6 lnEc_{it} + \mu_{it} \quad (6)$$

$$lnCO_{2it} = \beta_0 + \beta_1 lnCO_{2it-1} + \beta_2 lnY_{it} + + \beta_3 lnY_{it}^2 + \beta_4 lnP_{it} + \beta_5 lnI_{it} + + \beta_6 lnEc_{it} + \mu_{it} \quad (7)$$

[1] The coefficients of income and squared income are expected to be positive and negative to obtain the inverse-U-shape. If reversed signs are obtained, then the relationship between income and degradation will be U-shaped.

[2] Increase in economic growth leads to increasing energy consumption which is associated with an increase in carbon emissions (Kraft and Kraft 1978).

The second model specified is the log-quadratic model in equation 7 and it is a dynamic combination of the STRIPAT, EKC and EEO models where the squared income term is introduced and the definitions remain the same. The squared income depicts what happens to CO_2 emissions as income further increases. If the log-linear model is significant, β_2 is the emissions elasticity of income ($\in y$). If the log-quadratic model is significant, the $\in y$ is calculated as (Shafik and Bandyopadhyay, 1992):

$$\in y = \beta_2 + 2\beta_3 lnY \quad (8)$$

The estimation of equation 6&7 yields the short-term elasticity. Since the EKC is expected to convey a long-run relationship, the long-term elasticity is obtained as the short-run elasticity divided by $(1-\beta_1)$.

The panel Ordinary Least Squares (OLS) method has been applied by Dietz and Rosa (1997); Shi (2003); Fan *et al.* (2006). More robust estimation methods like Panel Corrected Standard Error (PCSE) (Neumayer, 2004), difference Generalized Method of Moments (GMM) (Fang and Miller, 2013); and Common Correlated Effects Mean Group (CMG) and Augmented Mean Group (AMG) Estimator (Liddle, 2015) have also been employed in the panel study literature. Thus, unlike studies on African countries[3], this study contributes by estimating equations 6&7 with a more robust technique called the Single-Equation Instrumental Variables (IV) regression (GMM estimator) which is heteroscedasticity and autocorrelation consistent (HAC) to take care of the argument of nonlinearity in modelling (Itkonen, 2012) its time series data.

The IV regression is adopted to resolve the bias of the lag of CO_2 emissions (CO_{2it-1}) (see Rabe-Hesketh and Skrondal, 2012). As a result, whether the error term has (or does not have) an effect on CO_{2it-1}, the coefficients of other explanatory variables in both models become inconsistent, given that they are either too small or insignificant when empirical methods like OLS and ECM are employed (Achen, 2001). Unlike the previously applied estimation methods, the IV regression also resolves likely endogeneity in the models by capturing the effect of an endogenous variable(s) on CO_2 only due to induced instruments (Stock and Watson, 2015). Since the specified models are single equation regressions and not a simultaneous equation, the identified exogenous variables that correlate with identified endogenous variables, the untransformed data of the endogenous variables (where applicable) and the lags of endogenous variables that do not correlate with the error term are used as instruments.[4]

Likewise, the IV regression is preferable to the Hansen GMM (another dynamic estimation method) as long as heteroscedasticity is absent (Baum *et al.*, 2003). The test of Pagan and Hall (1983), designed specifically to detect the presence of heteroscedasticity in IV regression, is conducted as a diagnostic test in addition to the Hansen's J over-identification test for misspecification. Before the IV regression, the Augmented Dickey-Fuller (ADF) unit root test and the Engle-Granger cointegration test are conducted. This is conducted to test whether the long-run estimates obtainable from the IV regression estimates are reliable. The data for all the variables are sourced

[3] Boopen and Vinesh (2010) = vector autoregression (VAR) & OLS; Shahbaz et al. (2011) autoregressive dynamic lag (ARDL) & error correction model (ECM); Alege and Ogundipe (2013) = fractional cointegration approach; Onafowora and Owoye (2013) = ARDL & unrestricted ECM.

[4] The problematic variable(s) varies from country to country but lnCO2t-1 is generally instrumented and it is the only problematic variable for most of the countries. Examples of countries with more than one problematic variable are Sudan and Zambia (lnY), Togo (lnP), Senegal (lnEc), Benin, Egypt, Namibia and Zimbabwe (lnY & lnP), Congo Republic (lnY & lnEc), and Tunisia (lnP and lnEc).

from the World Bank's World Development Indicators. Due to the shortage of data, different time periods (between 1971 and 2013) have been selected for the sampled 26 African countries (see Table 1).

4. Empirical Results and Discussion

The ADF unit root test and the Engle-Granger cointegration test are presented in Table 1. The study variables are mostly integrated at first difference (I(1)) for all the sampled countries, except for Algeria which is integrated at level (I(0)) for all the variables. GDP per capita, population and the share of industry in GDP are integrated at second difference (I(2)) under a few

Table 1. Unit Root Test and Cointegration test

	lnCO$_2$	lnY	lnP	lnI	lnEc	Cointe- gration Test	Critical Values: @1%	@5%	@10%
Algeria (1971-2013)	-4.621* I(0)	-3.25** I(0)	-9.553* I(0)	-3.785* I(0)	-4.054* I(0)	-5.805* I(0)	-3.634	-2.952	-2.610
Angola (1985-2013)	-8.005* I(1)	-5.642* I(2)	-6.163* I(1)	-8.246* I(1)	-5.001* I(1)	-5.902* I(0)	-3.743	-2.997	-2.629
Benin (1971-2013)	-7.417* I(1)	-6.211* I(1)	-3.720* I(1)	-6.639* I(1)	-6.514* I(1)	-3.670* I(0)	-3.641	-2.955	-2.611
Botswana (1981-2013)	-6.555* I(1)	-4.513* I(1)	-10.25* I(0)	-4.819* I(1)	-6.951* I(1)	-3.886* I(0)	-3.709	-2.983	-2.623
Cameroon (1971-2013)	-3.33** I(0)	-4.163* I(1)	-5.545* I(0)	-5.386* I(1)	-4.531* I(1)	-4.674* I(0)	-3.641	-2.955	-2.611
Congo Dem. Rep. (1971-2013)	-5.502* I(1)	-6.988* I(2)	-6.763* I(1)	-6.452* I(1)	-7.222* I(1)	-3.821* I(0)	-3.641	-2.955	-2.611
Congo Rep. (1971-2013)	-6.661* I(1)	-3.729* I(1)	-3.970* I(0)	-6.426* I(1)	-6.367* I(1)	-3.848* I(0)	-3.641	-2.955	-2.611
Cote d'Ivoire (1971-2013)	-8.088* I(1)	-4.266* I(1)	-20.16* I(0)	-7.614* I(1)	-7.133* I(1)	-4.492* I(0)	-3.641	-2.955	-2.611
Egypt (1971-2013)	-7.823* I(1)	-3.558* I(1)	-3.935* I(0)	-5.155* I(0)	-5.786* I(1)	-4.747* I(0)	-3.641	-2.955	-2.611
Ethiopia (1981-2013)	-6.668* I(1)	-3.926* I(1)	-5.801* I(0)	-4.635* I(1)	-8.125* I(2)	-2.66*** I(0)	-3.716	-2.986	-2.624
Gabon (1971-2013)	-6.612* I(1)	-3.22** I(0)	-5.186* I(1)	-8.602* I(1)	-6.120* I(1)	-4.206* I(0)	-3.641	-2.955	-2.611
Ghana (1971-2013)	-9.220* I(1)	-4.110* I(1)	-8.179* I(1)	-5.333* I(1)	-5.875* I(1)	-5.089* I(0)	-3.641	-2.955	-2.611
Kenya (1971-2013)	-6.570* I(1)	-5.669* I(1)	-12.76* I(0)	-6.683* I(1)	-5.433* I(1)	-3.176** I(0)	-3.655	-2.961	-2.613
Mauritius (1976-2013)	-4.843* I(1)	-5.329* I(1)	-7.202* I(0)	-2.89** I(1)	-5.068* I(1)	-4.391* I(0)	-3.675	-2.969	-2.617
Morocco (1980-2013)	-6.435* I(1)	-12.25* I(1)	-12.97* I(0)	-10.72* I(1)	-6.317* I(1)	-4.190* I(0)	-3.702	-2.980	-2.622
Mozambique (1980-2013)	-3.11** I(0)	-3.624* I(1)	-5.381* I(1)	-3.781* I(0)	-4.899* I(0)	-3.948* I(0)	-3.696	-2.978	-2.620
Namibia (1991-2013)	-5.924* I(1)	-3.761* I(1)	-4.279* I(0)	-4.799* I(1)	-6.952* I(1)	-4.336* I(0)	-3.750	-3.000	-2.630

[5] Angola, Congo Democratic Republic (DR.) and Tanzania under GDP per capita; Ethiopia and Nigeria under the share of industry in GDP and population, respectively.

Nigeria (1981-2013)	-5.438* I(1)	-4.197* I(1)	-3.860* I(2)	-5.910* I(1)	-5.354* I(1)	-2.61*** I(0)	-3.716	-2.986	-2.624
Senegal (1980-2013)	-2.92** I(0)	-6.294* I(1)	-4.557* I(1)	-7.553* I(1)	-4.700* I(1)	-3.748* I(0)	-3.702	-2.980	-2.622
South Africa (1971-2013)	-5.815* I(1)	-4.136* I(1)	-6.110* I(0)	-4.790 I(1)	-5.974* I(1)	-6.432* I(0)	-3.641	-2.955	-2.611
Sudan (1971-2013)	-8.343* I(1)	-4.616* I(1)	-5.330* I(0)	-5.726* I(1)	-9.822* I(1)	-3.09** I(0)	-3.641	-2.955	-2.611
Tanzania (1990-2013)	-4.135* I(1)	-7.697* I(2)	-6.112* I(1)	-4.793* I(1)	-2.84*** I(1)	-3.27** I(0)	-3.750	-3.000	-2.630
Togo (1971-2013)	-3.477* I(0)	-6.439* I(1)	-6.394* I(1)	-7.093* I(1)	-6.689* I(1)	-5.594* I(0)	-3.641	-2.955	-2.611
Tunisia (1971-2013)	-8.326* I(1)	-9.255* I(1)	-6.750* I(0)	-3.445* I(0)	-9.922* I(1)	-6.900* I(0)	-3.641	-2.955	-2.611
Zambia (1971-2013)	-5.910* I(1)	-5.047* I(1)	-6.643* I(0)	-5.881* I(1)	-8.122* I(1)	-4.639* I(0)	-3.641	-2.955	-2.611
Zimbabwe (1971-2013)	-6.557* I(1)	-4.304* I(1)	-8.405* I(0)	-6.516* I(1)	-5.280* I(1)	-3.36** I(0)	-3.641	-2.955	-2.611

Source: Author using Stata 14

*Notes: The statistic and diagnosis are presented for each test. Statistic significant at 1%, 5% & 10% are indicated as *, ** & ***, respectively. Diagnosis I(0), I(1) & I(2) means integration at level, first difference and second difference, respectively.*

sampled countries.[5] A long-term relation has been identified for the variables for all the sampled countries, which suggests that the long-term estimates obtained from the IV regression estimates are reliable.

Table 2 presents the estimated results of the log-linear and log-quadratic models in equation 6&7 as short-run effects and the obtained results after dividing the short-run coefficients with $(1-\beta_1)$ as long-run effects under each country's time series data. On the Table, contrary to the expectation that population has a non-negative elasticity on emissions; this study found that 13 African countries have negative population elasticity ($\in p$) for CO_2 emissions. This implies that these countries[6] have economies of scale on the response of emissions to increase in population size. Meanwhile, emissions are found to grow faster than the population in eight countries[7] because they have positive $\in p$. Some uniform results have been obtained that support other studies while others are multiform. Like Liddle's (2015) findings, Angola and Mauritius have found emissions elasticity of population that are greater than one in the short and long run. Ethiopia, Ghana, Sudan and Togo have emissions elasticity of population that is less than one in the short and long run. These findings are consistent with Fan *et al.* (2006) and Pastpipatkul and Panthamit (2011). The study obtained conflicting results (i.e. positive and negative $\in p$) for Congo DR., Egypt and Morocco and statistically insignificant results for Algeria and Cote d'Ivoire.

Contrary to the findings in the literature, the study also found five African countries in the sample with negative income elasticity ($\in y$) for CO_2 emissions. The negative $\in y$ means that a cleaner CO_2 environment is an inferior good as income rises in these countries[8] in the short and long run. Seventeen sampled African countries have positive $\in y$, which supports

[6] Botswana, Cameroon, Congo Republic, Gabon, Kenya, Mozambique, Namibia, Nigeria, Senegal, South Africa, Tanzania, Zambia and Zimbabwe

[7] Angola, Benin, Ethiopia, Ghana, Mauritius, Sudan, Togo and Tunisia

[8] Kenya, Mauritius, Morocco, Nigeria and South Africa

Table 2. Estimated Results test

	β_0	$lnCO_{2it-1}$	lnY_i	lnY_i^2	lnP_i	lnI_i	$lnEc_i$	R^2	Pagan-Hall Test	Hansen's J overid. Test
ALGERIA (1971-2013)										
Short-run	-0.064 (0.839)	-0.447* (0.056)	0.160** (0.064)	----	0.075 (0.065	-0.849* (0.093)	0.356* (0.054)	0.34	3.044 [0.218]	1.533 [0.957]
Short-run	28.01 (37.30)	-0.577* (0.063)	-6.281 (8.933)	0.382 (0.539)	-0.059 (0.091)	-0.798* (0.108)	0.554* (0.078)	0.24	3.035 [0.219]	1.518 [0.823]
€y for Short-run log-quadratic			-0.018							
Long-run	-0.044		0.111”	----	0.052	-0.587”	0.246”			
Long-run	17.76		-3.983	0.242	-0.037	-0.506”	0.351”			
€y for Long-run log-quadratic			-0.011							
ANGOLA (1985-2013)										
Short-run	-41.79* (3.906)	-0.719* (0.066)	1.266* (0.168)	----	4.358* (0.406)	-1.049* (0.259)	-5.819* (0.989)	0.68	1.349 [0.509]	1.755 [0.416]
Short-run	-147.1* (39.73)	-0.721* (0.072)	26.45* (9.936)	-1.602** (0.635)	3.860* (0.428)	-0.670* (0.254)	-3.726* (1.049)	0.69	2.179 [0.336]	1.522 [0.467]
€y for Short-run log-quadratic			1.126”							
Long-run	-24.31”		0.736”	----	2.535”	-0.610”	-3.385”			
Long-run	-85.47”		15.37”	-0.931”	2.243”	-0.389”	-2.165”			
€y for Long-run log-quadratic			0.653”							
BENIN (1971-2013)										
Short-run	-54.73* (3.598)	-0.348* (0.063)	4.535* (0.793)	----	1.013* (0.178)	-0.11*** (0.059)	1.338* (0.139)	0.89	1.762 [0.414]	1.507 [0.681]
Short-run	-260.9* (74.30)	-0.383* (0.096)	65.80* (23.49)	-5.116* (1.840)	2.050* (0.105)	0.296* (0.057)	2.473* (0.117)	0.90	3.488 [0.175]	1.503 [0.826]
€y for Short-run log-quadratic			-0.319”							
Long-run	-40.60”		3.364”	----	0.751”	-0.082”	0.993”			
Long-run	-188.6”		47.58”	-3.699”	1.482”	0.214”	1.788”			
€y for Long-run log-quadratic			-0.231”							
BOTSWANA (1981-2013)										
Short-run	-10.17* (2.944)	0.300* (0.066)	0.295*** (0.174)	----	-0.622** (0.315)	-0.338* (0.084)	2.860* (0.197)	0.89	5.956 [0.051]	1.664 [0.893]

Short-run	-22.15* (5.057)	0.318* (0.080)	3.451* (1.275)	-0.189* (0.071)	-0.592** (0.271)	-0.394* (0.095)	2.655* (0.150)	0.90	5.899 [0.052]	1.706 [0.945]
€y for Short-run log-quadratic			0.291”							
Long-run	-14.53”		0.421”	----	-0.889”	-0.483”	4.086”			
Long-run	-32.48”		5.060”	-0.277”	-0.868”	-0.578”	3.893”			
€y for Long-run log-quadratic			0.427”							
CAMEROON (1971-2013)										
Short-run	16.84** (6.763)	-0.206* (0.074)	1.109* (0.265)	----	-1.005* (0.225)	1.936* (0.335)	-2.739* (0.492)	0.28	1.824 [0.402]	1.674 [0.892]
Short-run	-465.4* (58.37)	-0.302* (0.089)	154.9* (16.13)	-10.88* (1.129)	-3.451* (0.327)	4.000* (0.367)	-7.551* (0.824)	0.15	0.671 [0.715]	2.157 [0.707]
€y for Short-run log-quadratic			1.579”							
Long-run	13.96”		0.920”	----	-0.833”	1.605”	-2.271”			
Long-run	-357.5”		118.9”	-8.356”	-2.651”	3.072”	-5.800”			
€y for Long-run log-quadratic			1.213”							
CONGO DR. (1971-2013)										
Short-run	-38.29* (2.826)	-0.147* (0.051)	1.732* (0.101)	----	0.414* (0.067)	-0.375* (0.038)	3.199* (0.475)	0.97	1.008 [0.604]	1.428 [0.921]
Short-run	-78.14* (2.578)	-0.407* (0.039)	23.76* (0.906)	-1.769* (0.077)	-0.471* (0.074)	0.210* (0.053)	0.506* (0.172)	0.98	2.341 [0.310]	1.259 [0.974]
€y for Short-run log-quadratic			1.711”							
Long-run	33.38”		1.510”	----	0.361”	-0.327”	2.789”			
Long-run	-55.54”		16.89”	-1.257”	-0.335”	0.149”	0.360”			
€y for Long-run log-quadratic			1.216”							
CONGO REPUBLIC (1971-2013)										
Short-run	-5.785* (0.981)	0.622* (0.033)	0.775* (0.141)	----	-0.129** (0.059)	-0.191* (0.056)	0.351* (0.072)	0.59	3.186 [0.203]	1.395 [0.498]
Short-run	-447.4* (111.3)	0.288* (0.042)	113.4* (28.91)	-7.194* (1.855)	-0.447* (0.172)	-0.398* (0.107)	1.475* (0.166)	0.45	0.972 [0.615]	1.746 [0.782]
€y for Short-run log-quadratic			0.641”							
Long-run	-15.30”		2.050”	----	-0.341”	-0.505”	0.929”			

Long-run	-628.4”		159.3”	-10.10”	-0.628”	-0.559”	2.072”			
∈y for Long-run log-quadratic			0.900”							
COTE D’IVOIRE (1971-2013)										
Short-run	-11.81* (1.810)	-0.830* (0.102)	1.955* (0.149)	----	-0.132 (0.081)	1.249* (0.202)	-0.907* (0.110)	0.21	1.175 [0.556]	1.601 [0.901]
Short-run	-187.5* (35.54)	-0.453* (0.149)	49.05* (8.679)	- 3.214* (0.563)	0.027 (0.181)	0.256 (0.213)	-0.25*** (0.147)	0.55	0.902 [0.637]	3.631 [0.727]
∈y for Short-run log-quadratic			1.881”							
Long-run	-6.454”		1.068”	----	-0.072	0.683”	-0.496”			
Long-run	-129.0”		33.76”	-2.212”	0.019	0.176”	-0.172”			
∈y for Long-run log-quadratic			1.295”							
EGYPT (1971-2013)										
Short-run	-19.65* (1.014)	-1.330* (0.082)	2.410* (0.201)	----	0.138** (0.063)	-0.127* (0.038)	0.115 (0.109)	0.95	2.296 [0.317]	1.276 [0.735]
Short-run	22.99 (14.40)	-1.248* (0.141)	-6.79*** (3.702)	0.607* (0.233)	-0.532* (0.175)	-0.054 (0.082)	0.719** (0.324)	0.94	0.594 [0.743]	1.478 [0.687]
∈y for Short-run log-quadratic			2.152”							
Long-run	-8.433”		1.034”	----	0.059”	0.055”	0.049			
Long-run	10.23		-3.020”	0.270”	-0.237”	-0.024	0.320”			
∈y for Long-run log-quadratic			0.957”							
ETHIOPIA (1981-2013)										
Short-run	-12.23* (1.121)	0.525* (0.039)	0.170* (0.048)	----	0.060** (0.029)	0.111* (0.031)	1.419* (0.210)	0.87	1.021 [0.600]	1.736 [0.884]
Short-run	-100.3* (21.04)	0.393* (0.054)	19.46* (4.660)	-1.803* (0.434)	0.138* (0.042)	-0.09*** (0.049)	7.207* (1.350)	0.87	1.078 [0.583]	2.026 [0.917]
∈y for Short-run log-quadratic			-0.106”							
Long-run	-25.75”		0.358”	----	0.126”	0.234”	2.987”			
Long-run	-165.2”		32.06”	-2.970”	0.227”	-0.148”	11.87”			
∈y for Long-run log-quadratic			-0.175”							
GABON (1971-2013)										
Short-run	41.34* (7.229)	-0.107 (0.169)	-0.852* (0.191)	----	-2.231* (0.359)	0.615* (0.207)	-0.44*** (0.247)	0.86	0.794 [0.672]	1.157 [0.561]

Short-run	-89.44* (27.18)	-0.084 (0.099)	22.89* (6.049)	-1.217* (0.319)	-1.381* (0.136)	0.370* (0.115)	0.152* (0.056)	0.95	4.820 [0.089]	1.369 [0.504]
∈y for Short-run log-quadratic			0.256”							
Long-run	37.34		-0.769	----	-2.015	0.556	-0.397			
Long-run	-82.51		21.12	-1.123	-1.274	0.341	0.140			
∈y for Long-run log-quadratic			0.236							
GHANA (1971-2013)										
Short-run	-12.75* (0.555)	-0.194* (0.024)	0.644* (0.039)	----	0.370* (0.025)	0.033** (0.016)	0.118** (0.055)	0.75	3.220 [0.199]	1.664 [0.893]
Short-run	-17.42** (8.555)	-0.200* (0.036)	1.921 (2.285)	-0.092 (0.164)	0.383* (0.037)	0.02*** (0.012)	0.124** (0.055)	0.75	3.174 [0.205]	1.854 [0.933]
∈y for Short-run log-quadratic			0.655							
Long-run	-10.68”		0.539”	----	0.310”	0.028”	0.099”			
Long-run	-14.52		1.601	-0.077	0.319”	0.017”	0.103”			
∈y for Long-run log-quadratic			0.546							
KENYA (1971-2013)										
Short-run	-11.91* (0.722)	0.682* (0.035)	-0.556* (0.132)	----	-0.076* (0.024)	-0.17*** (0.092)	2.792* (0.173)	0.69	2.312 [0.315]	1.607 [0.900]
Short-run	-19.17 (41.25)	0.695* (0.039)	1.546 (11.99)	-0.155 (0.879)	-0.074* (0.024)	-0.179** (0.087)	2.813* (0.178)	0.69	1.679 [0.432]	1.611 [0.952]
∈y for Short-run log-quadratic			-0.555							
Long-run	-37.45”		-1.748”	----	-0.239”	-0.535”	8.780”			
Long-run	-62.85		5.069	-0.508	-0.243”	-0.587”	9.223”			
∈y for Long-run log-quadratic			-1.820							
MAURITIUS (1976-2013)										
Short-run	-55.66* (6.122)	-0.079** (0.036)	-0.673* (0.206)	----	3.429* (0.511)	0.356* (0.060)	1.958* (0.230)	0.99	0.694 [0.707]	1.475 [0.688]
Short-run	-38.13* (2.406)	0.073* (0.022)	2.609* (0.794)	-0.165* (0.044)	1.216* (0.264)	0.237* (0.061)	1.606* (0.126)	0.99	2.833 [0.243]	1.421 [0.922]
∈y for Short-run log-quadratic			-0.153”							
Long-run	-51.58”		-0.624”	----	3.178”	0.330”	1.815”			

Long-run	-41.13”		2.814”	-0.178”	1.312”	0.256”	1.732”			
∈y for Long-run log-quadratic			-0.165”							
MOROCCO (1980-2013)										
Short-run	-8.508* (0.824)	-0.299* (0.033)	-0.08*** (0.046)	----	0.09*** (0.051)	-0.239* (0.039)	1.435* (0.054)	0.99	0.551 [0.759]	1.744 [0.942]
Short-run	-19.62* (2.785)	-0.136* (0.032)	4.610* (1.212)	-0.305* (0.078)	-0.346** (0.136)	-0.131* (0.029)	1.481* (0.050)	0.99	0.170 [0.918]	4.464 [0.485]
∈y for Short-run log-quadratic			-0.011”							
Long-run	-6.550”		-0.062”	----	0.069”	-0.184”	1.105”			
Long-run	-17.12”		4.058”	-0.268”	-0.305”	-0.115“	1.304”			
∈y for Long-run log-quadratic			-0.01”							
MOZAMBIQUE (1980-2013)										
Short-run	12.34** (5.083)	0.769* (0.050)	1.205* (0.156)	----	-1.367* (0.298)	-0.182* (0.067)	0.634* (0.199)	0.87	0.296 [0.863]	1.495 [0.474]
Short-run	142.7* (46.49)	0.919* (0.148)	-24.51* (7.596)	2.352* (0.698)	-3.192** (1.555)	0.707** (0.314)	-4.713* (1.682)	0.79	0.145 [0.930]	1.581 [0.454]
∈y for Short-run log-quadratic			1.146”							
Long-run	53.42”		5.216”	----	-5.918”	-0.788”	2.745”			
Long-run	1761.7”		-302.6”	29.04”	-39.41”	8.728”	-58.19”			
∈y for Long-run log-quadratic			14.15”							
NAMIBIA (1991-2013)										
Short-run	0.968 (1.673)	0.110* (0.042)	0.856* (0.209)	----	-1.087* (0.220)	0.10*** (0.059)	1.143* (0.264)	0.84	5.048 [0.080]	1.580 [0.454]
Short-run	42.37 (32.73)	-0.204* (0.045)	-9.623 (7.871)	0.612 (0.469)	-1.274* (0.137)	0.216* (0.052)	2.035* (0.189)	0.84	3.736 [0.154]	2.073 [0.557]
∈y for Short-run log-quadratic			0.595							
Long-run	1.088		0.962”	----	-1.221”	0.112”	1.284”			
Long-run	35.19		-7.993	0.508	-1.058”	0.179”	1.690”			
∈y for Long-run log-quadratic			0.494							
NIGERIA (1981-2013)										
Short-run	-13.28* (1.442)	0.737* (0.021)	-0.266* (0.050)	----	-0.365* (0.081)	-0.111** (0.047)	3.387* (0.285)	0.65	2.002 [0.368]	1.778 [0.879]

Short-run	-86.83* (9.324)	0.699* (0.035)	19.86* (2.484)	-1.360* (0.168)	-0.192** (0.084)	-0.242* (0.050)	2.844* (0.609)	0.67	2.541 [0.281]	1.906 [0.862]
∈y for Short-run log-quadratic			-0.099"							
Long-run	-50.49"		-1.011"	----	-1.388"	-0.422"	12.88"			
Long-run	-288.5"		65.98"	-4.518"	-0.638"	-0.804"	9.449"			
∈y for Long-run log-quadratic			-0.33"							
SENEGAL (1980-2013)										
Short-run	-7.758* (0.763)	0.134* (0.050)	0.622* (0.254)	----	-0.15*** (0.078)	0.727* (0.228)	0.545* (0.197)	0.35	0.656 [0.721]	1.835 [0.766]
Short-run	42.22 (155.8)	0.073 (0.097)	-13.56 (46.54)	1.178 (3.448)	-0.303** (0.132)	1.118* (0.270)	-0.710* (0.255)	0.25	1.544 [0.462]	1.759 [0.881]
∈y for Short-run log-quadratic			2.456							
Long-run	-8.958"		0.718"	----	-0.173"	0.839"	0.629"			
Long-run	45.54		-14.63	1.271	-0.327"	1.206"	-0.766"			
∈y for Long-run log-quadratic			2.649							
SOUTH AFRICA (1971-2013)										
Short-run	-4.253* (0.234)	0.129* (0.022)	-0.037* (0.011)	----	-0.142* (0.011)	-0.034** (0.016)	1.157* (0.027)	0.96	0.567 [0.753]	1.554 [0.817]
Short-run	-13.02* (1.729)	0.079* (0.016)	1.732* (0.365)	-0.101* (0.021)	-0.102* (0.012)	0.024 (0.015)	1.181* (0.023)	0.96	0.179 [0.915]	2.033 [0.845]
∈y for Short-run log-quadratic			-0.044"							
Long-run	-4.883"		-0.042"	----	-0.163"	-0.039"	1.328"			
Long-run	-14.14"		1.881"	-0.110"	-0.111"	0.026	1.282"			
∈y for Long-run log-quadratic			-0.048"							
SUDAN (1971-2013)										
Short-run	-26.91* (2.973)	0.499* (0.077)	0.759* (0.159)	----	0.237** (0.099)	0.165* (0.017)	2.742* (0.323)	0.85	0.593 [0.744]	1.850 [0.763]
Short-run	23.09** (10.79)	0.588* (0.038)	-14.10* (3.483)	1.046* (0.247)	0.367* (0.056)	0.221* (0.020)	2.814* (0.182)	0.90	1.595 [0.451]	1.957 [0.582]
∈y for Short-run log-quadratic			0.253"							
Long-run	-53.71"		1.515"	----	0.473"	0.329"	5.473"			

Long-run	56.04”		-34.22”	2.539”	0.891”	0.536”	6.830”			
∈y for Long-run log-quadratic			0.615”							
TANZANIA (1990-2013)										
Short-run	-5.119 (3.587)	0.479* (0.049)	1.089* (0.362)	----	-0.934* (0.267)	-0.729* (0.089)	2.582* (0.354)	0.90	0.027 [0.987]	0.425 [0.935]
Short-run	60.68* (17.92)	0.533* (0.081)	-26.12* (6.642)	2.006* (0.494)	0.016 (0.12)	-0.876* (0.083)	4.254* (0.674)	0.93	0.127 [0.939]	1.858 [0.762]
∈y for Short-run log-quadratic			-0.720”							
Long-run	-9.825		2.090”	----	-1.793”	-1.399”	4.956”			
Long-run	129.9”		-55.93”	4.296”	0.034	-1.876”	9.109”			
∈y for Long-run log-quadratic			-1.542”							
TOGO (1971-2013)										
Short-run	-26.66* (7.111)	-0.408* (0.137)	1.150** (0.498)	----	0.688** (0.334)	0.227* (0.081)	1.053* (0.280)	0.33	0.239 [0.887]	1.740 [0.783]
Short-run	136.4** (67.69)	-0.404** (0.187)	-51.60** (23.63)	4.221** (1.924)	0.914** (0.445)	0.151** (0.067)	0.805** (0.369)	0.36	0.535 [0.765]	2.928 [0.711]
∈y for Short-run log-quadratic			1.500”							
Long-run	-18.93”		0.817”	----	0.489”	0.161”	0.748”			
Long-run	97.15”		-36.75”	3.006”	0.651”	0.108”	0.573”			
∈y for Long-run log-quadratic			1.069”							
TUNISIA (1971-2013)										
Short-run	-38.05* (3.142)	-0.869* (0.134)	0.681* (0.176)	----	2.025* (0.230)	1.079* (0.133)	-0.349* (0.126)	0.92	1.332 [0.514]	1.320 [0.724]
Short-run	-36.15* (6.488)	-0.239* (0.066)	5.939* (1.368)	-0.349* (0.077)	0.439* (0.113)	0.555* (0.058)	0.436** (0.183)	0.98	2.466 [0.291]	1.930 [0.749]
∈y for Short-run log-quadratic			0.475”							
Long-run	-20.36”		0.364”	----	1.083”	0.577”	-0.187”			
Long-run	29.18”		4.793”	-0.282”	0.354”	0.448”	0.352”			
∈y for Long-run log-quadratic			0.383”							
ZAMBIA (1971-2013)										
Short-run	-13.38* (4.777)	-0.221* (0.064)	0.491* (0.082)	----	-0.705* (0.184)	0.108* (0.027)	2.976* (0.422)	0.97	2.617 [0.270]	1.856 [0.762]

Short-run	24.00* (7.499)	0.458* (0.131)	-10.25* (2.457)	0.736* (0.173)	-0.084** (0.041)	0.037** (0.015)	1.871* (0.615)	0.98	1.419 [0.492]	1.619 [0.805]
∈y for Short-run log-quadratic			0.157”							
Long-run	-10.96”		0.402”	----	-0.577”	0.088”	2.437”			
Long-run	44.28”		-18.91”	1.358”	-0.155”	0.068”	3.452”			
∈y for Long-run log-quadratic			0.290”							
ZIMBABWE (1971-2013)										
Short-run	-14.81* (1.394)	-0.276* (0.063)	0.914* (0.094)	----	-0.116* (0.041)	0.579* (0.107)	1.268* (0.239)	0.86	2.767 [0.251]	1.576 [0.665]
Short-run	-42.62* (6.885)	-0.238* (0.064)	9.376* (2.191)	-0.617* (0.159)	-0.112* (0.040)	0.565* (0.091)	1.089* (0.233)	0.87	0.566 [0.754]	1.512 [0.679]
∈y for Short-run log-quadratic			0.780”							
Long-run	-11.61”		0.716”	----	-0.091”	0.454”	0.994”			
Long-run	-34.43”		7.574”	-0.498”	-0.090”	0.456”	0.880”			
∈y for Long-run log-quadratic			0.630”							

Source: Author using Stata 14
*Note: *, ** & *** represent 1%, 5%&10% statistical significance of estimated values. Figures in ( ) are standard errors and those in [ ] are the probability values. Estimates with " are significant long run values.*

the literature that a cleaner CO_2 environment is a normal commodity in the short and long run. The results of seven of these countries, consistently, depict ∈y that is less than one which implies that a cleaner environment is a necessity in the short and long run.[9] These findings support the more recent studies, Shi (2003), Fan *et al.* (2006) and Liddle (2015).

Three countries have ∈y that is greater than unity, which shows that environmental quality is a luxury in the short and long run.[10] These findings reconfirm the early studies and those of Fang and Miller (2013). The remaining countries with normal cleaner CO_2 environment have different elasticity interpretation in the short and long run. For example, Angola's environmental quality depicts luxury in the short run and necessity in the long run (others are Cameroon, Congo Republic, Egypt, Sudan, Senegal and Togo). Inconsistent results (i.e. positive and negative ∈y) have been found for Benin, Gabon, Ethiopia and Tanzania.

The EKC has been found for 15 out of the 26 sampled African countries[11] (these findings support Shahbaz *et al.* (2011) on South Africa and contrast Boopen and Vinesh (2010) on Mauritius; Alege and Ogundipe (2013) on Nigeria; and Onafowora and Owoye (2013) on Nigeria and South Africa). The U-shape relationship has been

[9] Algeria, Botswana, Ghana, Namibia, Tunisia, Zambia and Zimbabwe
[10] Congo DR., Cote d'Ivoire and Mozambique
[11] Angola, Benin, Botswana, Cameroon, Congo DR., Congo Republic, Cote d'Ivoire, Ethiopia, Gabon, Mauritius, Morocco, Nigeria, South Africa, Tunisia and Zimbabwe

established for six countries[12] while a linear relationship between income and emissions has been established for the remaining five countries[13]. This study supports WDR (1992) and UNCTAD (2012) that technology can either reduce or expand the degree of environmental impact. Industrial activities contribute to emissions in 12 countries[14] while they limit emissions in 10 countries[15] in the short and long run. This may be due to lack of energy-efficient technologies or an uncontrolled industrial-use of carbon-related resources in the 12 countries. The results on how the share of industry in GDP affects CO_2 emissions in Benin, Congo DR., Ethiopia and Mozambique are found to be varying under the models.

Energy consumption is the main source of CO_2 emissions in 19 countries in the short and long run. This implies that fossil fuel was largely used to generate energy in these countries.[16] Eight of these countries are found to have inefficient energy consumption as their long-run effects on CO_2 emissions are higher than their short-run effects.[17] Meanwhile, energy consumption limits emissions in three countries in the short and long run. Thus, Angola, Cameroon and Cote d'Ivoire have been consuming more of renewable (or low-carbon) energy.[18] Conflicting results are found for Gabon, Mozambique, Senegal and Zimbabwe.

Unlike Hamilton and Turton (2002), who found affluence and population as the main factors increasing CO_2 emissions, and Shi (2003) and others, who found that population has a greater environmental impact than affluence, this study has identified energy consumption as the main driving factor for CO_2 emissions in 16 countries[19]; affluence is the main driving factor in nine countries[20]; technology is the main driving force in four countries[21]; and population is the main driving force in three countries[22]. Using the number of countries, these results support Pastpipatkul and Panthamit (2011) and Fang and Miller (2013) that affluence has a higher environmental impact than population.

The Pagan-Hall heteroscedasticity tests conducted do not reject the null hypothesis that 'the disturbance in the models is homoscedastic' at 10% and 5% significant level for all the countries. Hansen's J over-identification tests do not reject the null hypothesis of 'over-identification restrictions of the instruments used are valid' at 10% significant level. These diagnostic tests inform that there is no model misspecification.

5. Conclusion

The CO_2 emissions elasticity of income and population for 26 African countries has been examined in this paper. Using

[12] Egypt, Mozambique, Sudan, Tanzania, Togo and Zambia
[13] Algeria, Ghana, Kenya, Namibia and Senegal
[14] Cameroon, Cote d'Ivoire, Gabon, Ghana, Mauritius, Namibia, Senegal, Sudan, Togo, Tunisia, Zambia and Zimbabwe
[15] Algeria, Angola, Botswana, Congo Republic, Egypt, Kenya, Morocco, Nigeria, South Africa and Tanzania
[16] Algeria, Benin, Botswana, Congo DR., Congo Republic, Egypt, Ethiopia, Ghana, Kenya, Mauritius, Morocco, Namibia, Nigeria, Sudan, South Africa, Tanzania, Togo, Zambia and Zimbabwe
[17] Botswana, Congo Republic, Ethiopia, Kenya, Nigeria, South Africa, Sudan and Tanzania
[18] These findings speak to these facts: Côte d'Ivoire has the third largest hydro-power plants system in West Africa (AfDB, 2013) and Angola's liquefied natural gas (LNG) is one of the world's largest gas flaring reduction projects (UNECA, 2012). However, Nigeria and Ghana have the first and second largest hydro-power plants in West Africa, Nigeria has an LNG plant, Kenya is the world leader in the number of solar power systems installed per capita (Allied Crowds, 2015), Ethiopia uses a geothermal plant and six wind projects to generate over 1000 kilowatts (Babatunde, 2014), etc. are facts not supported by the findings.
[19] Algeria, Benin, Botswana, Congo DR., Congo Republic, Ethiopia, Kenya, Mauritius, Morocco, Namibia, Nigeria, South Africa, Sudan, Tanzania, Zambia and Zimbabwe
[20] Benin, Congo DR., Congo Republic, Cote d'Ivoire, Egypt, Ghana, Mozambique, Senegal and Togo
[21] Cameroon, Gabon, Senegal and Tunisia
[22] Angola, Mauritius and Tunisia

the STIRPAT, EKC and EEO framework, the study has identified technology and energy consumption as additional indicators of environmental impact on income and population. The study found that the response of emissions to population growth has a limiting effect in some countries and a contributory one in others. The study confirms that the perception of a cleaner CO_2 environment is not the same in all countries. Generally, the results do not support the neoclassical view that environmental quality is a luxury good in economies. Rather, the findings support the literature that environmental quality is seen as a normal good. African countries with positive population elasticity pose a threat to having a cleaner CO_2 environment in Africa. The few economies with low demand for environmental quality, i.e. a cleaner CO_2 environment is considered to be an inferior good, can be deemed to be a bigger threat to the continent's environment than the economies that regard it as a normal good.

Furthermore, the study found the EKC for 15 countries, the U-shaped relationship for six countries and a linear relationship for five countries. Technology is a relevant mitigating factor in 10 countries while other countries need to move towards cleaner technologies and away from high-carbon technologies. Energy consumption is generally a contributory factor to emissions in Africa, given that it is a limiting factor in only Angola, Cameroon and Cote d'Ivoire.

In the first part, this paper summed up the findings in the literature pertaining to the main factors of environmental impacts, namely affluence and population. However, the results obtained in this study has established that energy consumption, followed by affluence, is the primary driving force behind human-induced CO_2 emissions in African countries, while population is a factor with a lower impact than affluence (except in Angola, Mauritius and Tunisia). Hopefully, CO_2 emissions in African countries will be reduced in the nearest future by implementing the measures envisaged in the following documents: the continuous integration of low-carbon strategies into regional, national and local development plans; the orientation of individual, household and firms' activities that contributes to CO_2 emissions and alternative activities; and the African Renewable Energy Initiative (AREI), announced in Paris in 2015, which has the goal to build new and additional renewable energy generation plants by 2020 (Climate Council 2015).

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