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Growth Thresholds and Environmental Degradation in Sub-Saharan African Countries: An Exploration of Kuznets Hypothesis

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Abstract

This study investigates the presence of environmental Kuznets curve (non-linear relationship between pollution and the per capita income) in Nigeria, Ghana, Cote d'Ivoire, Mali and Senegal and Gabon. In the study, pollution is regressed on per capita income, squared per capita income, trade intensity, foreign direct investment and population density price. Panel estimation technique and ordinary least square were used to obtain required estimates for all selected countries and individual economies. The study established the presence of environmental Kuznets curve for these countries at group and individual level. It also revealed that the value of turning point in pollution level corresponding to per capita income is varying among countries. From the result, the threshold GDP per capita (constant 2005 US$) is approximately $758 for Nigeria, $7060 for Gabon, $585 for Ghana, $1014 for Cote d'Ivoire, $390 for Mali and $675 for Senegal. The declining trend of pollution with regards per capita income could be attributed to introduction of environmental friendly products, structural changes in the industrial sector of these countries that involve more output per primary resources.

Keywords: Income, environment, Kuznets curve, pollution, Africa.

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Introduction

In 1999, there was a protest in World Trade Organisation (WTO) meeting in Seattle by some group who claimed that trade liberalization is incompatible with sustainable

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development. Following this protest, many economies, especially, developed ones, initiated environmental conservation reforms. Countries started conserving energy and diversifying away from pollution-intensive products. Consequently, the world pollution intensity of production began to decline (OECD, 2004). Apart from declining global pollution intensity, studies also show that this pollution intensity varies across economies. While most developed nations are experiencing low pollution intensity, some developing countries exhibit increasing pollution intensity (Aggarwal, 2001; Ashraf *et al*., 2010).

One of the outcomes of environmental conservation policies is the emergence of Environmental Kuznets Curve (EKC) hypothesis. The EKC hypothesizes that environmental conditions deteriorate at low level of income and they improve as countries reach the middle-income level of development, and improve greatly as countries reach the higher bracket of development (Grossman and Krueger, 1995; Stern and Common, 2001) might be presence for developing countries given the abundance of environmental resources in these countries and the relative term of trade faced by these countries. By this claim, it might be that pollution intensity function in these countries is linear and non-linear as inverted U shape.

Many developing countries, especially the sub-Saharan African countries, are living through that part of the Environmental Kuznets curve where environmental conditions are deteriorating with economic growth due to their low level of income (Antweiler *et al.*, 2001; Feridun *et al.*, 2006), less stringent environmental regulations (Qureshi, 2006), poor term of trade which expedites inordinate natural resource degradation, and causes ecological poverty (Aggarwal, 2001).

There are three different channels through which income influences the environment and shape the EKC of a country. They are the scale effect, the composition and technique effects (Lopez, 1994; Grossman and Krueger, 1995; Antweiler *et al.*, 2001; and Copeland and Taylor, 2003). The impact of income on environmental quality in different countries differs based on the relative strength and direction of scale, composition and techniques effects created by different countries characteristics and trading partners and these are important considerations in trade- environment nexus (Anteweiler *et al.*, 2001; Capeland and Taylor, 2004).

Scale effect refers to increased pollution due to expanded economic activity and the greater consumption made possibly by more wealth. Composition effect refers to a change in the share of polluting goods in GDP, which may come about because of a price change favoring their production (Angela, *et al*., 2003; McCarney and Adamowicz, 2006). The technique effects refer to a change in the amount of emissions per unit of output across sectors. It involves the use of different methods of production that have different environmental impacts due to the possibility of substitution between different inputs (Grossman and Krueger, 1993; Lopez, 1994; Antweiler e*t al*, 2001).

It was argued that at lower income level, the scale effect outweighs the composition and technique effects, creating a positive relation between income growth and environmental damage. At some higher level of income, however, the both composition and technique effects outweigh the scale effect. Thereafter, increased income leads to a

net reduction in environmental damage and thus, pollution intensity declines (Antweiler*et al.*, 2001; McCarney and Adamowicz, 2006).

Many empirical studies have investigated the existence of an inverted U shaped relationship between trade liberalization and environmental degradation in developed countries, using cross- country and time series data. Different estimation techniques have been applied to investigate this relationship. However, evidences on the relationship between income and environment are mixed **(**Arrow *et al.*, 1995, Janicke *et al.*, 1997; Ekins, 1997; Mani and Wheeler, 1998; Stern and Common 2001; Cole, 2004). Also, while there sizeable empirical studies on EKC in developed countries, there is scanty empirical studies on this area in sub-Saharan Africa. Dearth of empirical works in this region might lead to the inability of policy makers in these countries to make guided environmental policies that could further sustainable economic development. In addition, no study known to us has estimated per capita income associated with the turning point of environmental curve in Sub-Saharan Africa. Thus, this study examines the existence of EKC in selected Sub-African countries and investigates the level of per capital income associated with turning point of environmental curve in these countries.

Materials and method

The methodology used for this study was adapted from Abdulai and Ramcke (2009). They examined the relationship between income and pollution and also determine the existence of EKC hypothesis for some developed and developing countries. In this study, similar approaches were adopted to examine the impact of income and trade on environmental degradation in selected Sub-Saharan African countries. This study, however, went further to determine the per capita income associated with declining pollution in these countries. The sample countries include six West African countries - Nigeria, Ghana, Cote d'Ivoire, Mali and Senegal and Gabon. The study covered the period from 1980 to 2013 based on data availability.

To determine the income thresholds for individual countries, just as in Stern (2003) and Abdulai and Ramcke (2009), the level of pollution is estimated as a function of per capita income. Trade, FDI and population density are included in this pollution function. The econometric specification is based on the following model;

$$\ln POLL_{it}=\beta_0+\beta_1 \ln GDP_{it}+\beta_2(\ln GDP_{it})^2+\beta_3 \ln FDI_{it}+\beta_4 \ln TRA_{it}+\beta_4 \ln POP_{it}+\xi \quad (1)$$

Where poll is the level of pollution being tested; GDP is per capita income; FDI is foreign direct investment; TRA is trade intensity or level of openness; POP is population density; β_0 is the intercept; β_i are the coefficients, and ξ is error term. Subscripts i and t represent country and year respectively.

Panel estimation technique was used to equation 1 in order to derive general growth threshold income per capita that associates with diminishing or increasing pollution (carbon emission). However, the non-linearity specification of pollution function would be tested by examining the significance of $\log GDP^2$.

Equation (1) is a complex function and as per capita GDP grows higher, equation 1 implies that pollution has diminishing effects. That is, pollution will reach a point of

saturation, and it will thereby reverse its trend. However, since our interest was to ascertain the behavior or trend of an individual country, because it was expected that in some countries the diminishing effects of income on pollution may take different values of per capita GDP, equation 1 will be run for individual country and it is specified as follows;

$$\ln POLL_t = \beta_0 + \beta_1 \ln GDP_t + \beta_2 (\ln GDP_t)^2 + \beta_3 \ln FDI_t + \beta_4 \ln TRA_t + \beta_5 \ln POP_t + \xi \quad (2)$$

Equation 1 and 2 are non-monotonic pollution functions that take note of non-linearity property of the function. The sign and significance of the coefficient of $(\ln GDP)^2$ would indicates the shape of the function and from the per capita income thresholds required for the function to reaches its maximum/minimum point can be calculated.

This is derived by finding the critical point of equation 2 as follows.

$$\ln POLLt = \beta_0 + \beta_1 \ln GDPt + \beta_2 (\ln GDPt)^2 + \beta_3 \ln FDIt + \beta_4 \ln TRAt + \beta_5 \ln POPt + \xi 0 \quad (2.1)$$

$$\delta \ln POLL_t / \delta \ln GDP_t = \beta_1 + 2\beta_2 \log GDP_t = 0 \quad (3)$$

From equation 3, $\log GDP_t = -\beta_1 / 2\beta_2$

The trade-off point or the diminishing effects of income on pollution in the above dynamic function are simply the first derivative with respect to per capita income. Thus $\exp(-\beta_1/2\beta_2)$ is the turning point income that could be at the maximum (minimum) point of an inverted U shaped (U shaped) pollution curve depending on the sign of the β_1 and β_2.

Data and sample

Dataset for this work are secondary annual data spanning from 1981 to 2013 for six selected countries in West Africa. All data for the study were sourced from the World Bank development indicator (2014). Pollution was proxied by quantity of carbon dioxide (CO_2) emissions (Kt). Income per capita was proxied by GDP per capita at 2005 constant dollar price. Foreign direct investment was represented by FDI net inflows. Trade intensity was captured as sum of import and export divided by GDP. Population density was captured by people per square kilometer of land area.

Result and discussion

Table 1 Descriptive analysis

	Ghana		Nigeria		Gabon	
	Carbon Emission	GDP per capita	Carbon Emission	GDP per capita	Carbon Emission	GDP per capita
Mean	5802.383	455.1675	68758.15	687.0374	3298.338	6919.690
Maximum	9578.204	766.0508	104696.5	1055.837	6633.603	8107.357
Minimum	2559.566	320.7723	34917.17	494.2390	80.67400	5974.685
Standard deviation	2302.241	112.6966	19998.55	177.2388	1851.282	612.1880

The tables 1 and 2 show the properties of carbon emission and per capita income of the six selected countries in terms of mean, standard deviation, minimum and maximum.

Table 2 Descriptive analysis

	Senegal		Cote d'Ivoire		Mali	
	Carbon Emission	GDP per capita	Carbon Emission	GDP per capita	Carbon Emission	GDP per capita
Mean	4261.435	720.8386	6546.969	1067.807	497.7627	385.1104
Maximum	7656.545	805.8050	9160.166	1468.625	649.9000	498.4751
Minimum	2453.223	635.0104	4466.406	892.9972	359.3660	295.2484
Standard deviation	1475.241	50.95788	1159.635	152.7529	88.09429	65.97590

The mean of carbon emission and per capita GDP for the six selected countries generally are 14860.84 and $1705 respectively. Among the selected countries, Nigeria has the highest carbon emission (104696.5) followed by Ghana (9578.2), Cote d'Ivoire (9160.17) and Senegal (7656). Mali has the least carbon emission among the selected countries. It is unsurprising that Nigeria has the highest carbon emission among these countries since she is the highest oil producer among them coupled with her large population (about 180 million) which more than population of the remaining five countries put together.

In terms of average per capita income, Gabon also has the highest average per capita income among the six selected African countries with average per capita income of $6919.69. This is followed by Cote d'Ivoire ($1067.81) and Senegal ($720.84). Mali has the smallest per capita income among the selected countries with per capita income of $385.11. The average per capital income of Ghana stood at $455.17. It could be deduced from above that per capita income does not directly relate with level of environmental pollution. This is obvious from the fact that Gabon who has the highest per capita income among the selected six countries possesses least carbon emission besides Mali, while Nigeria with fourth highest income among the group has the highest record of carbon emission. The amount of carbon emitted in Nigeria in 2005 (104696.5) is more than threefold of carbon emitted in all the other five countries put together.

Estimation of income per capita threshold

The table 3 shows the panel estimation of pollution function. The coefficients in the two estimations are all significant at 5 percent critical level. The coefficient of determination of the two estimations are very high (0.799 and 0.948 respectively) and the all the included independent variables are jointly significant in influencing the dependent variable (CO_2 Emission). Hausman test was used to test for the need for random effect estimation. Random effect estimation was rejected based on the test as reported in table 4 below.

Table 3: Panel Estimation Result
Dependent Variable: CO_2 Emission

	Pooled OLS	Fixed Effect
Constant	11.1143 (2.6461)	33.6219 (5.3978)
LnGDP	-2.9589 (-2.2428)	-10.0901 (-5.0834)
$LnGDP^2$	0.2317 (2.6821)	0.7660 (5.7753)
LnFDI	0.0108 (2.8857)	-0.0822 (-2.8879)
LnTRA	0.3509 (2.4765)	0.2034 (2.5038)
LnPOP	1.3172 (18.2106)	0.5218 (3.6151)
R^2	0.7997	0.9509
Adjusted R^2	0.7946	0.9484
F-statistic (Prob.)	158.0974 (0.000)	374.4144 (0.000)
Threshold Income Per capita	$590	$725

Note: t-statistic is in bracket

The pooled ordinary least square and fixed effect results are similar except for foreign direct investment (FDI) which has a negative sign in the fixed effect panel estimation. This implies that FDI has a negative effect on level of carbon emission in the selected West African countries. The result corroborates the pollution haloes hypothesis for the selected that states that FDI could have a beneficial effect on environment through the transfer of environmental friendly production techniques from developed countries to developing countries (Aliyu 2005).

The fixed panel estimated results indicate that CO_2 emission and trade openness are positively related. Thus, the greater the degree of trade openness in the sub-region, the higher would be CO_2 emission. The result implies that foreign trade affect environmental quality in the selected West Africa. Most of the imports to these countries are pollution intensive commodities such as second hand appliances, clothes, automobiles etc. The finding is consistent with that of Machado (2000); McCarney and Adamowicz (2006) and Feridun *et al.*, (2006) who found a positive link between foreign trade and CO2 emission, implying that trade openness contributes positively to environmental deterioration developing countries.

From the table 3, the estimated coefficients on the income variables, based on fixed effect, imply an elasticity of carbon dioxide emissions (pollution) with respect to changes in the level of income of 10.09. This suggests that higher levels of economic activities lead to lower incidence of CO_2 emission and consequently to environmental pollution and degradation. This result shows that with increasing economic growth, these countries were able to afford environmental friendly technologies that bring about lower pollution (Antweiler *et al.*, 2001).

Population intensity has a significant positive effect on CO_2 emission in this sub-region. This suggests that higher population growth rates increase the level energy consumption which generates increased CO_2 emission and consequently leading to environmental pollution. The growth rate of population in the selected countries, especially Nigeria, is one of the highest in the world. Higher population density exerts pressure on resources and consequently on the quality of the environment. This finding corroborates that of Muftau *et al.* (2014).

The coefficient of $LnGDP^2$ is positive and indicates an inverted U shaped pollution curve (EKC) for the countries altogether. The linearity hypothesis of the pollution function is strongly rejected in the two estimations since the coefficient of $lnGDP^2$ is statistically significant at 5 percent critical level. The result, therefore, confirms the presence of environmental Kuznets curve (EKC) and non-linear relationship between per capita income and environmental pollution. Consequently, income per capita associated with declining/ rising pollution can be determined. Our result is consistent with the findings of Grossman and Krueger (1991), Cole *et al*. (1997), List and Gallet (1999), and Stern and Common (2001).

The threshold per capita GDP that is consistent with declining pollution level for the countries on the average is $590 and $725 based on pooled ordinary least square (OLS) and fixed effect panel estimation respectively- a level of per capita income that has been attained by all the selected countries except Mali.

Table 4: Hausman Test of Random effect

Correlated Random Effects - Hausman Test			
Equation: Untitled			
Test cross-section random effects			
Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	595.633983	5	0.0000

Before the estimation the individual country pollution function, XY line of per capita income and pollution level was constructed to ascertain the nature of relationship between income and pollution. The graphs below show XY line for the six selected countries (Nigeria, Ghana, Gabon, Cote d'Ivoire, Mali and Senegal). In the figures 1, 2, 3, 4, 5, 6 the relationship between per capita income and carbon emission is non-linear for all countries.

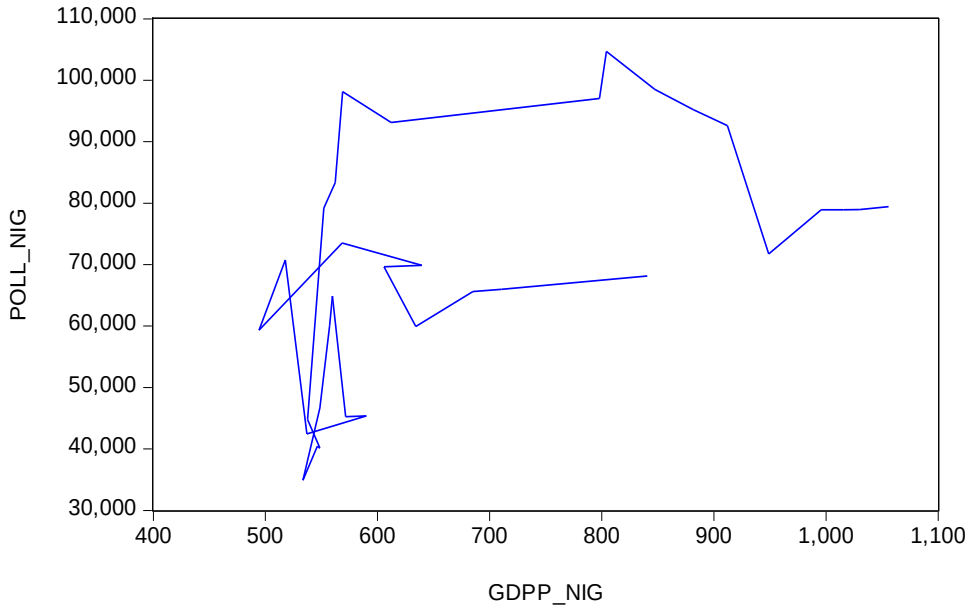

Figure 1 Relationship between per capita income and pollution level in Nigeria

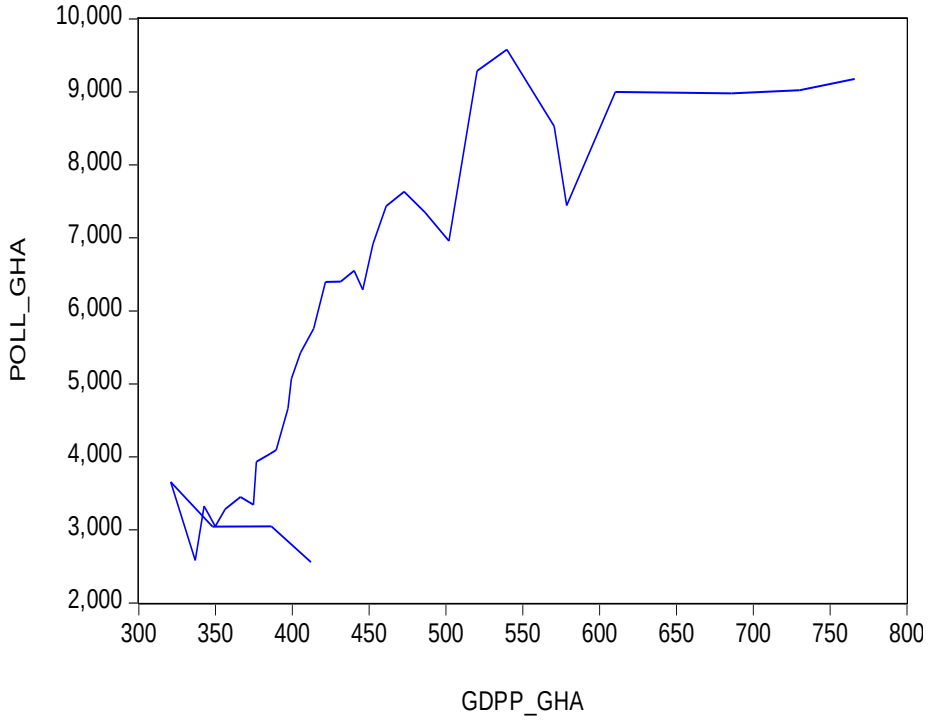

Figure 1 Relationship between per capita income and pollution level in Ghana

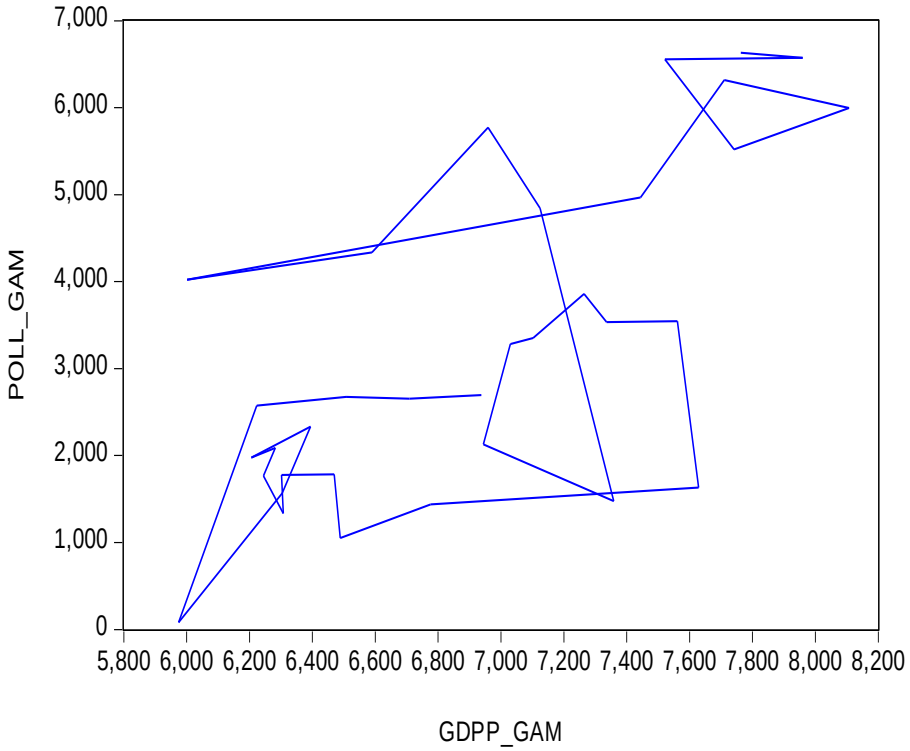

Figure 2 Relationship between per capita income and pollution level in Ghabon

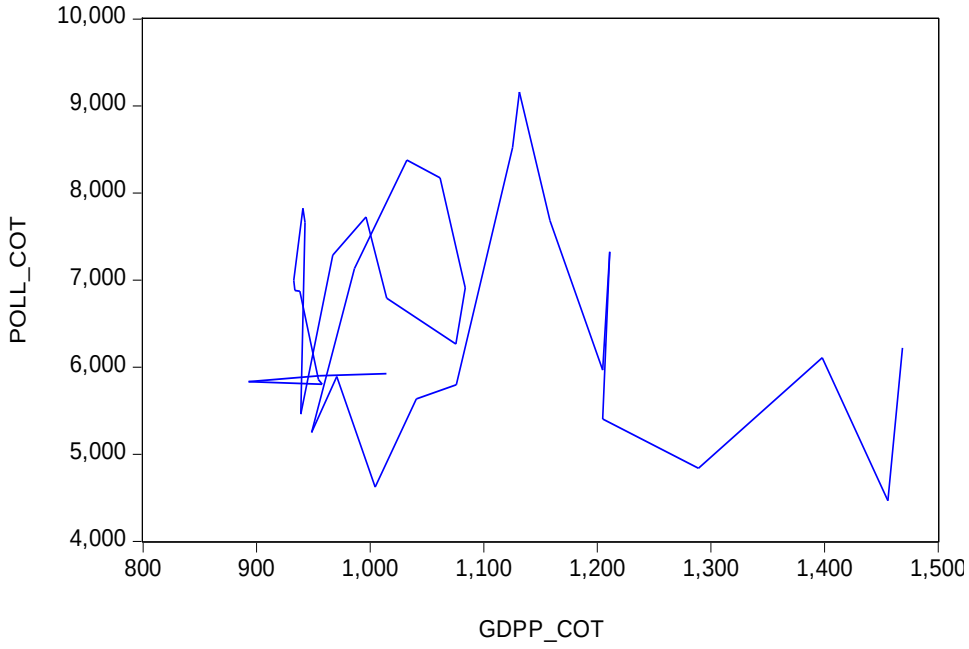

Figure 3 Relationship between per capita income and pollution level in Cote d'Ivoire

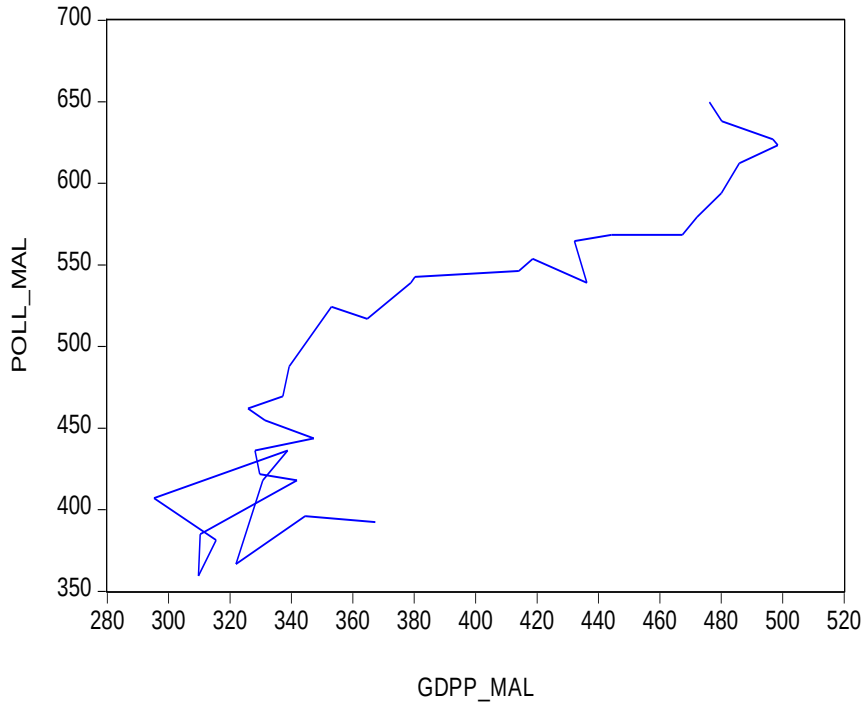

Figure 4 Relationship between per capita income and pollution level in Mali

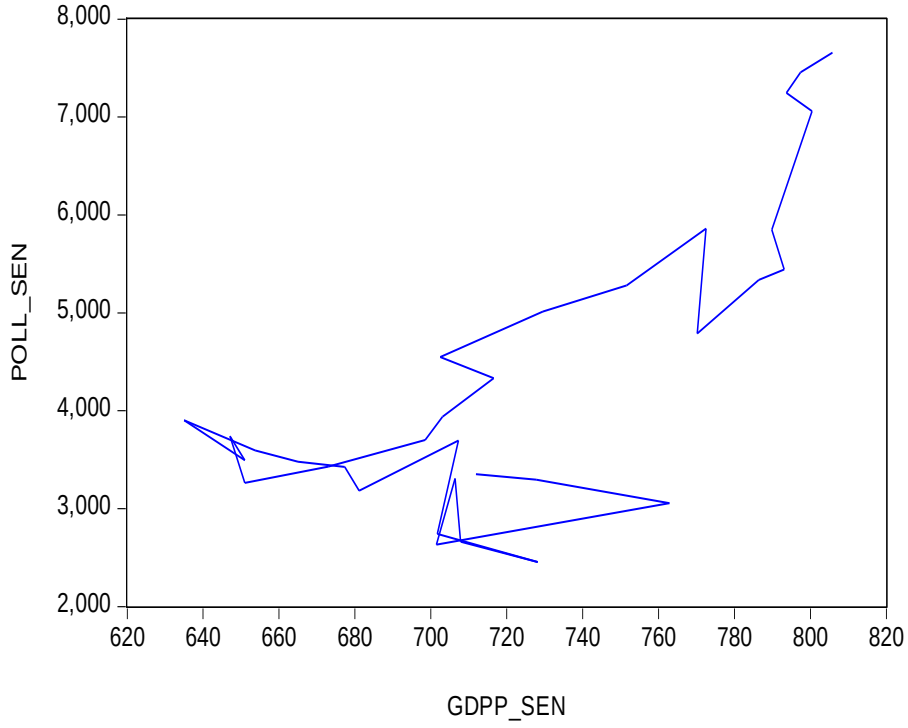

Figure 4 Relationship between per capita income and pollution level in Senegal

Table 5 reports the OLS result of individual countries. In the result, $lnGDP^2$of all countries, besides Ghana, is statistically significant at 5 percent critical level. This confirms non-linearity assumption at individual country level. The non-monotonic pollution function signifies the shift in structural changes towards environmental friendly policies in the individual countries. This is what is termed technique effect. As per capita income reached a certain level, individual country could possibly afford better technologies and produce environmental friendly products.

The estimation results indicated that the per capita income consistent with the Environmental Kuznets Curve differs between panel estimation and individual country estimation. Although, the panel estimation shows that all the selected country, except Mali, have attained the threshold per capita income, however, there were exceptions to these main findings.

The individual country result shows that all the six countries have attain the per capita income threshold corresponding to changing pollution trend.

From the result, the threshold GDP per capita (constant 2005 US$) is approximately $758 for Nigeria, $7060 for Gabon, $585 for Ghana, $1014 for Cote d'Ivoire, $390 for Mali and $675 for Senegal.

Table 5: Individual country result
Dependent Variable: Carbon Emission

Independent Variables	Gabon	Ghana	Nigeria	Cote d'Ivoire	Mali	Senegal
Constant	-3246.422 (-2.2004)	-16.8625 (-1.0149)	-150.0304 (-2.6676)	-156.8021 (-1.8202)	-63.6682 (-4.6151)	668.5964 (2.7114)
Log(GDP)	733.6482 (2.1974)	5.3989 (0.9791)	47.8345 (2.7881)	48.6436 (1.9866)	22.8719 (4.8973)	-204.0410 (-2.7140)
$Log(GDP^2)$	-41.3903 (-2.1882)	-0.4238 (-0.9427)	-3.6072 (-2.7411)	-3.5139 (-2.0106)	-1.9186 (-4.8517)	15.6570 (2.7313)
Log(FDI)	0.00574 (1.2964)	-0.0009 (-1.9207)	-0.00137 (-0.3478)	0.00997 (3.1302)	0.0013 (1.8181)	-0.0069 (-2.0491)
Log(TRA)	1.4831 (1.0475)	-0.14287 (-2.6139)	-0.2532 (-1.5872)	-0.0992 (-0.3506)	0.1353 (2.0236)	0.2492 (1.6673)
Log(POP)	-2.1521 (-2.9425)	2.0652 (7.9096)	0.7944 (2.2486)	-0.6513 (-1.4607)	0.5720 (6.0035)	0.8789 (7.3827)
R^2	0.5364	(0.9582)	0.5085	0.3793	0.9673	0.9070
Adjusted R^2	0.4536	0.9506	0.4205	0.2685	0.9615	0.8904
F-statistic (Prob)	6.4791 (0.0004)	127.9136 (0.0000)	5.7886 (0.0008)	3.4224 (0.0154)	165.8114 (0.0000)	54.6109 (0.0000)
Threshold Income Per capita	$7060	$583	$758	$1014	$390	$675

Note: t-statistic is enclosed in parentheses

These countries attained the threshold per capita income at different periods. Gabon, Cote d'Ivoire and Senegal attained the threshold income earlier than Nigeria, Mali and Ghana.

Also, while individual country results show Nigeria, Ghana, Gabon, Mali and Cote d'Ivoire have and inverted U shaped pollution function and showed evidence for emissions reduction, Senegal, on the other hand, has a U shaped pollution function and shows evidence for increasing carbon emission.

Conclusion

In this study, the threshold income level that is associated with turning point of pollution level was investigated for six West African countries between 1980 and 2013. Apart from this, the study also examined the non-linear relationship between pollution and income level. The study reveals that all the six selected countries altogether tend to have an inverted U shaped environmental curve with per capita income level of $725 as threshold.

However, at individual level, each country's environmental curve exhibits different shape. While environmental curve for Nigeria, Gabon, Mali, Cote d'Ivoire and Ghana has an inverted U shape, environmental curve for Senegal is U shaped. Also value of turning point in pollution level corresponding to per capita income is varying among countries. It was also shows that all countries studied experience the reduced pollution level as they experience higher growth, except for Senegal whose pollution level is increasing with income. Thus, it can be said that environmental conservation policies in all the selected countries except Senegal, are yielding result. These policies should be further pursued. The sources of declining pollution might be attributed to introduction of environmental friendly products, structural changes in the industrial sector of these countries that involve more output per primary resources, and change in consumers' attitude towards environmental pollution. Senegal, on the other hand, has to examine her environmental policies more profoundly in order to turn around her level of environmental pollution.

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