



ECONOMIES OF WEST AFRICA REGION AND THE ENVIRONMENTAL KUZNETS CURVE: EMPIRICAL ASSESSMENT

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Abstract

This study examines the validity of the Environmental Kuznets Curve (EKC) in the developing economies of West Africa using a total of 32 cross sectional observations for each of the 16 countries of West Africa given a balance panel of 512 observations covering the periods 1980 through to 2012. The study estimated both the fixed effect and random effect model but however, the Hausman test shows that the estimates of the random effect are more consistent. The empirical results from this study provide evidence of the existence of the EKC for West Africa Countries as a group with income turning point ranging between US\$4,240.83 and US\$4,698.91. The study thus recommends that developing countries should not wait until they reach this high income turning point to reconcile economic growth and environmental improvement. The policy implication is that an induced environmental policy response is necessary for EKC to exist.

Keywords: Environmental Kuznets Curve, greenhouse effect, environmental sustainability, green economy

1. INTRODUCTION

Developing countries are preoccupied with the issue of poverty reduction, industrialization, economic growth and development as well as population problems. Achieving development through industrialization is their top priority with less emphasis on environmental sustainability. In the last few decades, the economic performance of West African countries has not been too impressive. The rate of growth in the countries has remained below the 7% threshold needed for effective poverty reduction within the framework of the MDGs. A protracted weak international demand for raw materials and a severe drop in their prices, the drying up of foreign direct investment and aid flows, and the reduction in remittances from nationals in the Diaspora during the financial crisis, have begun to make their effects felt. The dynamics created by these factors reduced the average growth rate to 3.2% per annum for West Africa in 2009 (UNECA, 2012).

The Abidjan Convention has as its objective to contribute to the highest possible degree of environmental protection, particularly through the imposition of regulatory measures governing human activities capable of creating a negative impact on the environment, or of sound natural resource management techniques. However, a status report on the effectiveness of environmental law in West Africa reveals a paradox: the proliferation of environmental protection rules is countered by the ineffectiveness of their executing mechanisms. There is no doubt as to the will of the West African decision-makers to incorporate environmental issues into their development policies. The Bamako and Abidjan Conventions attest to the awareness and will to push towards the attainment of sustainable development. However, the cost implications attached to this burning issue are high, and a heavy burden for countries already weakened by numerous problems. As a result, the

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environmental issue is not perceived, in practical terms, as a priority issue. The heavy additional cost of mitigating the ecological disaster in Africa is estimated at between 5 and 10% of GDP. The mechanisms of the carbon fund which are capable, in theory, of generating billions of dollars for investment in the developing world, presently ignore Africa.

The economies of Nigeria and Cape Verde seem to be of most concern with high levels of CO₂ emission per inhabitant (Orubu *et al.*, 2010). Going by the traditional development theories, it will be difficult if not impossible for West Africa countries giving their economic status to pursue environmental sustainability agenda at the expense of higher economic growth. The concept of EKC emerged in the early 1990's stemming from the works of Grossman and Krueger (1991) and Shafik and Bandyopadhyay (1992) but popularized by the World Bank in its World Development report 1992 (IBRD, 1992). This therefore raises the question whether or not the EKC is applicable to West Africa countries. Therefore, the main objective of this paper is to empirically verify the applicability of the EKC that there exists a relationship between Carbon dioxide (CO₂) emission, economic growth, energy consumption and population density in West Africa using a balance panel of the sixteen West Africa countries between 1980 and 2012.

2. LITERATURE REVIEW

Although the concept of EKC is a relatively recent phenomenon, there is a vast literature on it. The original Kuznets curve tries to establish the relationship between economic growth and income inequality. Grossman and Krueger (1991) pioneered its application to environmental issues. The study investigated the environmental impact of a North America Free Trade agreement. An EKC was estimated for Sulphur dioxide (SO₂) and Suspended Particles Matter (SPM). An inverted U-shaped EKC for both pollutants was confirmed. The income turning point was estimated to be around US\$4000 - US\$5000 for SO₂, while the concentration of SPM appeared to decline even at a low income level.

Stern (2002) used econometric model to decompose sulfur emission in 64 countries for the period between 1973 and 1990. The result provides evidence for the existence of the inverted U-shaped curve. Similarly, Vorgeteg and Egli (2005) also find evidence of the existence of the EKC based on time series data from Germany. The study investigated the relationship between several pollutants and per capita income. The pollutants were Sulphur dioxide (SO₂), Nitrogen oxide (NO₂), Carbon dioxide (CO₂), Carbon monoxide (CO), Ammonia (NH₃), Methane (CH₄), Particulate matter (PM) and methane volatile organic compound (NMVOC) for the period 1966 to 2002. There is however a controversy among those who accepted the notion of inverted U shaped EKC on the extent of the trade off and the actual income turning point. Dasgupta *et al.* (2002) reviewed the various views into three groups which are the conventional view, pessimistic view and the optimistic view. The conventional view depicts the standard inverted U shape with an income turning point occurring between US\$5000 and US\$8000 income per capita for air pollution measured by Sulphur dioxide and Particulate matter.

Apart from the above studies which confirmed the inverted U shape of the EKC, other studies such as Torras and Boyce (1998) find no relationship between development and environmental quality. They thus doubt the existence of the EKC or its inverted U-shape. In sum, the majority of the studies have confirmed the existence of the EKC and its shape, with different income turning points in relation to various pollutants. The motivation for this study stems from the fact that none of the studies exist for west Africa countries. This study is therefore aims at filling this gap and provides evidence or otherwise of the applicability EKC in West Africa countries and thus estimate income turning point if necessary.

3. FRAMEWORK AND MODEL SPECIFICATION

3.1. Theoretical framework

The theoretical underpinning of the inverted U-shaped EKC is the structural and technological changes that come with economic growth. “if there were no changes in the structure of technology of the economy, pure growth in scale of the economy would result in a proportional growth in pollution and other environmental impacts” (Stern, 2003). This is referred to as the scale effect. The traditional theories of development in theorizing the impact of development on the environment often hold technology constant. Thus the views of the theorist are based on the scale effect alone. However, according to Panayotou (2003), one of the proponents of the EKC, “at higher level of economic development, structural changes towards information intensive industries and service, coupled with increase environmental awareness, enforcement of environmental regulations, better technology and higher environmental expenditure, results in leveling off and gradual decline of environmental deregulation”.

Prominent among the theories is Andreoni and Levinson (2001). In their model, they gave two conditions that must hold for the EKC to occur:

- i. The marginal willingness to pay to clean up the last speck of pollution does not get to zero as income approach infinity
- ii. There must be increasing returns to scale in abatement.

It follows that pollution increase with consumption and decrease with increase in abatement technology. Assume further that pollution has a gross component that is proportional to consumption (C), and an abatement component that is of standard Cobb-Douglas production function ($I = C^\alpha E^\beta$). Therefore, the aggregate pollution function can be re-specified as:

$$P = C - C^\alpha E^\beta \dots\dots\dots (1)$$

Assume that the society has a given amount of resources given as (Y). This can be spent on either consumption (C) or pollution abatement effort (E). This means that the society is facing a budget constraint given as:

$$C + E = Y \dots\dots\dots (2)$$

Therefore, to derive the optimal levels of consumption and pollution, the pollution abatement effort must be maximized subject to the constraint in equation (2).

$$I = C^\alpha E^\beta \dots\dots\dots (3)$$

Subject to:

$$C + E = Y$$

Equation (3) can be transform as follows

$$\ln I = \alpha \ln C + \beta \ln E \dots\dots\dots (4)$$

The Langragian function is giving as

$$L = \alpha \ln C + \beta \ln E + \lambda (Y - C - E) \dots\dots\dots(5)$$

$$\frac{\partial L}{\partial C} = \alpha \frac{1}{C} - \lambda = 0 \dots\dots\dots(6)$$

$$\frac{\partial L}{\partial E} = \beta \frac{1}{E} - \lambda = 0 \dots\dots\dots (7)$$

$$\frac{\partial L}{\partial \lambda} = Y - C - E = 0 \quad \dots\dots\dots (8)$$

From equation (7) and (8)

$$\lambda = \frac{\alpha}{C} \quad \text{and} \quad \lambda = \frac{\beta}{E}$$

Therefore, $\frac{\alpha}{C} = \frac{\beta}{E}$

by cross multiplying,

$$\begin{aligned} \alpha E &= \beta C \\ E &= \frac{\beta}{\alpha} C \quad \dots\dots\dots (9) \end{aligned}$$

Or

$$C = \frac{\alpha}{\beta} E \quad \dots\dots\dots (10)$$

Substituting equation (10) into equation (4)

$$\begin{aligned} C + \frac{\beta}{\alpha} C &= Y \\ C \left(1 + \frac{\beta}{\alpha} \right) &= Y \\ C &= \frac{Y}{\left(1 + \frac{\beta}{\alpha} \right)} \\ C &= \left(\frac{\alpha}{\alpha + \beta} \right) Y \quad \dots\dots\dots (11) \end{aligned}$$

Also, substituting equation (11) into equation (4)

$$\begin{aligned} \frac{\alpha}{\beta} E + E &= Y \\ \left(\frac{\alpha}{\beta} + 1 \right) E &= Y \\ E &= \frac{Y}{\left(\frac{\alpha}{\beta} + 1 \right)} \\ \text{Therefore, equilibrium } E &= \left(\frac{\beta}{\alpha + \beta} \right) Y \quad \dots\dots\dots (12) \end{aligned}$$

Substitute equation (12) and (13) for C and E in equation (3) to obtain the society's optimal level of pollution.

$$\begin{aligned} P &= \left(\frac{\alpha}{\alpha + \beta} \right) Y - \left[\left(\frac{\alpha}{\alpha + \beta} \right) Y \right]^\alpha \left[\left(\frac{\beta}{\alpha + \beta} \right) Y \right]^\beta \\ P &= \left(\frac{\alpha}{\alpha + \beta} \right) Y - \left[\left(\frac{\alpha}{\alpha + \beta} \right) \right]^\alpha \left[\left(\frac{\beta}{\alpha + \beta} \right) \right]^\beta Y^{(\alpha + \beta)} \quad \dots\dots\dots (13) \end{aligned}$$

If $(\alpha + \beta) = 1$, then efforts spent on pollution abatement depicts a constant returns to scale and the pollution curve will be linear. On the other hand, if $(\alpha + \beta) > 1$, then pollution abatement depicts increasing returns to scale.

Let $\chi_1 = \left(\frac{\alpha}{\alpha + \beta} \right)$, $\chi_2 = \left[\left(\frac{\alpha}{\alpha + \beta} \right) \right]^\alpha \left[\left(\frac{\beta}{\alpha + \beta} \right) \right]^\beta$ and $(\alpha + \beta) = n$ where $n > 1$

Then equation 15 can be writing as

$$P = \chi_1 Y + \chi_2 Y^n \quad \dots\dots\dots (14)$$

If in equation (13), χ_1 is positive and χ_2 is negative then pollution will rise at a lower level of income and then fall at a higher income level. This will produce an inverted U shaped curve known as the EKC.

3.2. Empirical model and estimation method

Flowing from the above theoretical framework and following standard practice, the basic EKC equation can be specified in quadratic form as

$$(CO_2)_t = \chi_0 + \chi_1(GDPPC)_t + \chi_2(GDPPC)_t^2 + \epsilon_t \dots\dots\dots(15)$$

- CO₂ = Carbon dioxide emissions (metric tons per capita)
- GDPPC = GDP per capita PPP (constant 2005 international \$)
- t = time
- ε = stochastic error term

The validity of the EKC hypothesis demands that the coefficients of GDP per capita PPP must be positive and the square of GDP per capita PPP must be negative respectively, that is, $\chi_1 > 0$; $\chi_2 < 0$, and both must be statistically significant. If $\chi_1 > 0$ and statistically significant, while χ_2 is not statistically significant, then the environmental indicator may worsen as per capita income increase.

In the case of panel data (longitudinal data), equation (15) is re-specified as

$$(CO_2)_{it} = \beta_i + \delta_t + \chi_1(GDPPC)_{it} + \chi_2(GDPPC)_{it}^2 + \epsilon_{it} \dots\dots\dots(16)$$

- Where, $i = 1, 2, 3, \dots, n$ (representing number of countries)
- $t = 1, 2, 3, \dots, T$ (representing number of periods)
- $N = nT$ (for a balance panel)

The first two terms on the right hand side (β_i) and (δ_t) are intercept parameters that varies from across countries (i) and time (t). One basic advantage of the panel date over the cross-sectional or time series data is that the panel data combine the characteristics of cross-sectional and time series data. In this case, the differences across the units under investigation can be captured by differences in the intercept term. It is important to note that income per capita is not the only factor that influences environmental quality. Therefore, the above equation can be modified to take care of these factors. In this case, the augmented version of the above model can be express as

$$(CO_2)_{it} = \beta_i + \delta_t + \chi_1(GDPPC)_{it} + \chi_2(GDPPC)_{it}^2 + \sum D_{it} + \epsilon_{it} \dots\dots\dots(17)$$

Where D represent other variables that influences CO₂ emission such the population density (POPD) and energy consumption (ENERC). In this study, the selected variables include, population density, manufacture output (as % of GDP), and international environmental policy pressure. Dummy variable is used to capture the effect of international environmental policy pressure. Since most Africa countries had since 1995 signed various international environmental protection treaty, a value of 0 is assigned to periods up to 1995, while 1 is assigned to periods after 1995. In this case, there is possibility of local minimal or local maximum points. This type of behaviour will produce an EKC equation which assumes a cubic form. This is specified as follows:

$$(CO_2)_{it} = \beta_i + \delta_t + \chi_1(GDPPC)_{it} + \chi_2(GDPPC)_{it}^2 + \chi_3(GDPPC)_{it}^3 + \epsilon_{it} \dots\dots\dots(18)$$

In the above equation, if $\chi_1 > 0$; $\chi_2 < 0$ and, $\chi_3 > 0$; the EKC will have an N shape. This means that after the first turning points which result in declining environmental pollution, at a higher income level beyond that point, pollution will increase with increasing income level. The augmented version of equation (18) is specified below:

$$(CO_2)_{it} = \beta_i + \delta_t + \chi_1(GDPPC)_{it} + \chi_2(GDPPC)_{it}^2 + \chi_3(GDPPC)_{it}^3 + \sum D_{it} + \epsilon_{it} \dots\dots\dots(19)$$

This study estimates equations (18) and (19) using Ordinary Least Squared (OLS) technique. Their corresponding fixed and random effects formulations are also estimated. In applying the OLS techniques, it is usually necessary to assume that the error term is uncorrelated with the explanatory

variables. But according to Wooldridge (2000), in pooled OLS, estimates could still be biased if the error term (δ_i) in equation (19) correlate with the explanatory variables. This problem is therefore taking care of by the fixed and random effects estimations. Hence, the random and fixed effects estimations are considered superior to those of the OLS estimations. The OLS estimation is still useful as it provides a starting point and also forms the basis of comparison.

The basic difference between the fixed effect and random effect is the treatment of the unobserved effects captured by the constant terms in the above equations. The fixed effect assumed that the unobserved effects (δ_i) are correlated with the explanatory variables. Thus, the fixed effect model is obtained by taking the first difference or using fixed effect transformation to derive the *demeaned* data.

4. EMPIRICAL RESULTS

Equations (18) and (19) were estimated using gretl econometric package. The results are presented in the table below.

Table 1: Estimates of EK Equations for CO₂ from 1980 to 2012 (n = 512)

Regressors	Quadratic Form			Cubic Form		
	OLS results	Fixed effect results	Random effect results	OLS results	Fixed effect results	Random effect results
Constant	0.133*** (3.444)	0.290*** (3.930)	0.242*** (3.175)	0.0452 (0.917)	0.242*** (2.954)	0.187** (2.280)
GDPPC	0.0005*** (6.814)	0.0001* (1.751)	0.0002 (2.665)***	0.001*** (5.677)	0.0003** (2.023)	0.0002*** (2.697)
GDPPC ²	-1.200e ⁻⁰⁷ (4.382)***	-9.753e ⁻⁰⁹ (0.349)	-2.733e ⁻⁰⁸ * (1.707)	-5.561e ⁻⁰⁷ (3.556)***	-2.028e ⁻⁰⁷ (1.341)	-2.538e ⁻⁰⁸ * (1.697)
GDPPC ³				9.277e ⁻⁰¹¹ (2.829)***	3.965e ⁻¹¹ (1.299)	4.652e ⁻¹¹ (1.533)
POPD	0.00005 (0.1446)	0.0007 (1.339)	0.0006 (0.892)	-7.712e ⁻⁰⁵ (0.206)	0.001 (1.365)	0.0006 (0.885)
ENERC	-0.108*** (3.082)	-0.079** (2.139)	0.079** (2.280)	-0.113*** (3.265)	-0.085** (2.103)	-0.085** (2.455)
R ²	0.327	0.512		0.341	0.514	
Income turning point	\$2,404.17		\$4,698.91	\$1,470.10 (lower) \$2,545.11 (upper)		\$4,240.63
Hausman (Prob)			8.006 (0.155)			9.685 (0.138)

t-statistics are reported in parentheses under each coefficient estimate, and Hausman test statistic, the significance level for the variables are shown by asterisks. (***)for 1%, ** for 5% and * for 10%).

From the results summarized in the table 1 above, most variables met sign expectation. In the quadratic form, the coefficients of GDPPC and GDPPC² had the right signs. This is an indication of the existence of EKC for in West Africa. In the OLS results, the estimated income turning point is US\$2, 404.17, while that of the random effect model was US\$4,698.91. In the case of fixed effect model, the signs were also met but the impact of GDDPC² was not significantly different from zero even at 10% level. Given a total of 32 cross sectional observations for each of the 16 countries of West Africa given a balance panel of 512, for analytical purpose, the fixed and the random effects results are considered superior. Also, on the basis of the Hausman test result with a coefficient of 8.00626 and a P-value of 0.15589, the random effect estimates are consistent relative to the fixed effects estimates. Therefore, the income turning point is taking as US\$4,698.91.

In the cubic form, the OLS estimates provide evidence for two turning points indicating an N-shaped EKC. This means that CO₂ will initially raise up to a point corresponding to income level of US\$1,470, then begins to fall, but start rising again after income level of US\$2,545. However, this was not the case in the fixed effects and random effect version in which the impact of GDPPC³ were not significant in both cases. Also, comparing the estimates of the fixed and random effects, the random effect estimates were more consistent giving the Hausman coefficient of 9.685 with P-value of 0.138. Since the GDPPC³ was not significant, only one turning point is established at US\$4,240.63. The results also show that international environmental policy pressure has significant impact on carbon intensity in West Africa. The sign shows that it has an inverse relationship with carbon intensity. This imply that international environmental policy pressure have the potential of reducing carbon intensity in West Africa.

5. CONCLUSION

The empirical result from this study provides evidence of the existence of the EKC for West African Countries as a group. The income turning point is estimated to range between US\$4,240.83 and US\$4,698.91. This shows that West African Countries are still on the upward sloping region of the EKC. Hence carbon emission is still on the increase. The per capita income of Countries in West Africa is still far below this estimated income turning point and as such economic growth is still generally seen as the dominant policy objective in the region. This trend may continue until per capita income reaches a high level sufficient enough to induce development or procurement pollution abatement technology in production. It is important however, to advise at the juncture that developing countries in general should not wait until they reach this high income turning point to reconcile economic growth and environmental improvement. For any given pollutant, an EKC will only exist when policy measures are taken. The pollution income relation will be monotonically rising if the government remains inactive. The strongest link between income and pollution is via the induced policy response.

From the perspective of developing countries as evidenced in this empirical result, economic development is intricately tied to environmental degradation. And at this point when African countries are eagerly pursuing policies aimed at industrializing their economies. It would be unpopular to recommend a halt in the pursuit of economic development in order to save the environment. But it would be wise for government to mainstream the issue of the environment as part of the day to day policy formulation in order to fully address the balancing act between economic growth and environmental sustainability. This can be done in two ways; the first is support for programsthat provide public easily accessible information about polluters, pollution damages,local environmental quality and the cost of pollution abatement. The secondis support for development of stronger regulatory institutions and cost-effectivemeasures to reduce pollution. This support should be sustained for a long time as sustained support is critical, because institutionaldevelopment takes time. An induced environmental policy response is necessary for EKC to exist.

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Appendix 1: List of West African Countries used in the analysis

S/N	West African Countries
1	Benin
2	Burkina Faso
3	Cape Verde
4	Cote d'Ivoire
5	The Gambia
6	Ghana
7	Guinea
8	Guinea-Bissau
9	Liberia
10	Mali
11	Mauritania
12	Niger
13	Nigeria
14	Senegal
15	Sierra Leone
16	Togo

Appendix 2: Summary statistics, using the observations 1:01 - 16:32

Descriptive Statistics	Per Capita GDP (US\$)	CO ₂
Mean	502.02	0.31442
Median	383.77	0.23046
Minimum	64.356	0.04108
Maximum	3,797.8	4.2166
Standard deviation	416.02	0.31491
Skewness	3.7208	5.0801
Kurtosis	20.343	48.572