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Economic growth and environmental pollution in West Africa: Testing the Environmental Kuznets Curve hypothesis

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A B S T R A C T

Several studies suggest that increased economic activities result in poor environmental quality while others argue otherwise, due to the demand for improved environmental quality as a result of higher incomes. This paper empirically tested the Environmental Kuznets Curve (EKC) hypothesis by analyzing the relationship between economic growth and environmental pollution (carbon dioxide emission, CO_2 and combustible renewable waste, CoWaste) using a panel dataset from 1970 to 2013 for selected West African countries with similar income status. This study is important in order to ascertain if economic growth really lead to a reduction in environmental pollution and at what income level would this be achieved. The results revealed that economic growth in the short-run significantly increases CO_2 emissions and CoWaste but does not significantly decrease CO_2 emission and CoWaste in the long-run. The non-significant relationship between economic growth and environmental pollution indicates the non-existence of EKC in West Africa. The results of the study further revealed a very low turning point at which CO_2 emission and CoWaste start to decrease; however, the non-existence of the EKC implies that the relationship between economic growth and environmental degradation in West African countries cannot be explained by an inverted U-shaped curve. The study recommends that West African economies should pursue efficiency improvement policy intervention to prevent environmental degradation.

Introduction

West African countries over the years have tried to develop their economies by shifting gradually from an agrarian economy to an industrialized one. This is not surprising since industrialization has been traditionally considered as the backbone for economic development (Peet, 1987). The increase in economic development has led to global warming with carbon dioxide (CO_2) as the main gas at the center of the debate. Heil and Selden (2001) opine that economic development is increasingly resulting in the emission of CO_2, with emission levels reaching 30 percent in the late 20th century. Shi (2003) suggest that high levels of pollutants in the atmosphere could lead to great disruption of the environment and create environmental problems. Studies suggest that the initial stages of economic development result in environmental pollution until a turning point is reached where an increase in per capita Gross Domestic Product (GDP) results in a decrease in environmental pollution (Grossman & Krueger, 1991; Panayotou, 2003; Selden & Song, 1994). This concept is known as the Environmental Kuznets Curve (EKC) and it is named after Kuznets (1955) who first hypothesized that income inequality increases to a maximum and then starts to decrease as per capita income increases. The term

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'Environmental Kuznets Curve' (EKC) was derived from a study done to assess the impact of economic development on environmental quality (Grossman & Krueger, 1991). The EKC hypothesis suggests that developing economies must face environmental degradation at the initial stages of economic development. Figure 1 presents the Environmental Kuznets Curve.

The dangers of global warming as a result of economic development have led researchers to determine if EKC actually exists for CO_2 and CoWaste. Nonetheless, these studies have found mixed results regarding EKC for CO_2 and CoWaste (Apergis & Payne, 2011; He & Richard, 2010; Payne, 2011; Sadorsky, 2009). In addition, most of the studies (for example, Adu & Denkyirah, 2017; Jalil & Mahmud, 2009; Olusegun, 2009; Omojolaibi, 2010) that were undertaken to assess the relationship between economic growth and environmental pollution failed to estimate the turning point or threshold at which pollution begins to decrease, and the relationship between CoWaste and CO_2, to determine if CoWaste leads to CO_2. Therefore the current study contributes to the literature by not only empirically testing the EKC hypothesis by analyzing the relationship between economic growth and environmental pollution (CO_2 and CoWaste), but further estimating the turning point at which CO_2 and CoWaste begin to decrease, and investigating the relationship between CoWaste and CO_2 emission to determine if CoWaste leads to CO_2 emission.

The West African sub-region in recent times has been moving from an agricultural-based economy to an industrialized one in its quest to attain high level of economic growth and development. With little or no finance for the citizenry to establish their own industries, advanced economies take advantage to set-up their industries to engage in environmentally hostile activities due to the weak environmental laws and policies in the sub-region, rendering West Africa a 'pollution haven'. This makes it very important to find out if environmental quality would be achieved after attaining high levels of economic growth as stated by the EKC hypothesis. Environmental pollutants (such as CO_2 and CoWaste) are important to West Africa because industrialization could increase their levels. Also, they are pollutants which every economy in the globe—not only West Africa—is trying hard to minimize.

This study is structured into five parts; firstly, the introduction which covers the background, problem statement, contribution to literature and justification; secondly, a literature review of several cross-country and country-specific studies which have been done to establish empirical evidence of EKC for environmental pollutants using different econometric models and different datasets; thirdly, the methodology which covers the data source, sampling criteria, and the method of data analysis including justification for the variables used in the study; fourthly, the results and discussion are presented; and finally, the conclusions and recommendations.

A limitation for the study is that data for certain variables which could have been used as control variables were not easily accessible. However, this does not affect the results in this case, since the tests carried out revealed that the variables and robust technique used in the study are appropriate.

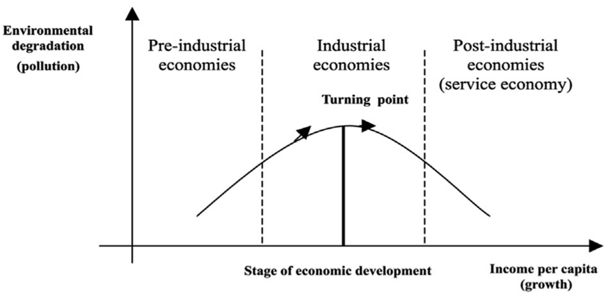

Figure 1 Environmental Kuznets Curve
Source: Panayotou (1993)

Literature Review

Several cross-country and country-specific studies have been done to establish empirical evidence of EKC for environmental pollutants using different econometric models and different datasets. These studies revealed conflicting or mixed results. A study done by Harbaugh, Levinson, and Wilson (2002) to determine the relationship between economic growth and environmental pollution reveal that EKC does not exist for environmental degradation. Daly (1977) asserts that despite rising incomes, the concentrations of pollutants, exploitation of natural resources, and accumulation of waste would result in environmental degradation and a decline in human welfare. A co-integration analysis by Olusegun (2009) using annual data of carbon dioxide per capita and GDP per capita from 1970 to 2005 found no evidence of EKC for CO_2 in Nigeria. Omojolaibi (2010) reports the non-existence of EKC for West Africa.

On the contrary, using a panel dataset of OECD countries and individual time series for each of the countries in the panel, Dijkgraaf and Vollebergh (1998) concluded that EKC existed for carbon emissions in the individual OECD countries but not as a whole. Jalil and Mahmud (2009) using the autoregressive distributed lag method in their study found that the relationship between carbon dioxide emissions and income per capita for China was an inverted U-shape. A vector error correction model was used by Lean and Smyth (2010) and the results revealed the existence of a non-linear relationship between carbon dioxide emissions and economic growth. Kaika and Zervas (2011), and Sanglimsuwan (2011) found an inverted U-shaped relationship for CO_2 emissions and economic development in a cross-country analysis. Narayan and Narayan (2010) in analyzing EKC for 43 developing countries used both time series and panel data estimation techniques. Their results revealed that in the long-run as income increase, CO_2 emission reduces.

The subject matter is inconclusive as studies have tried to overcome the limitations of earlier contributions by using new datasets, new functional forms, and more refined econometric techniques. Some researchers (Kaufmann, Davidsdottir, Garnham, & Pauly, 1998; Moomaw & Unruh, 1998; Suri & Chapman, 1998) have argued that an inverted U-shaped relationship between economic growth and environmental pollution (that is, the existence of EKC) is dependent on the explanatory variables used in the estimation model. However, López and Mitra (2000) for example, modified the equation to include corruption and found no existence of EKC.

Methods

Data Source and Sampling Criteria

This study employed secondary data which were mainly annual country data drawn from the period 1970–2013. The dataset was constructed to assess the existence of EKC. The empirical analysis and estimation were based on the use of panel data analysis. The data used for this study were sourced from the World Development Indicators (World Bank, 2014). The sampling criteria yielded a balanced dataset of seven West African countries with lower-middle income status (Ghana, Nigeria, Cote d'Ivoire, Togo, Benin, Burkina Faso and Gambia).

Data Analysis

Stationarity and Unit Root Test

The study employed panel analysis. According to Greene (2003), panel data are commonly used because they have the advantage of giving more information as the data consist of both cross-sectional information, which captures individual variability, and time series information, which captures dynamic adjustment. The first stage in undertaking panel data estimation is to test for the existence of unit roots in both the dependent and independent variables. The Augmented Dickey Fuller and Philip–Perron tests were employed to establish the non-existence of unit root within the variables. The augmented Dickey Fuller and Philip –Perron tests use a regression of the first differences of the series counter to the series lagged once, X_{t-1} and lagged difference terms. It may comprise a constant term α and a trend term Y_t as shown in Equation (1):

$$\Delta X_t = \alpha + \beta X_{t-1} + \sum\nolimits_{i=1}^{m} \gamma_i \Delta X_{t-1} + \varepsilon_t \tag{1}$$

where: Δ is a first-difference operator, m is the optimal lagged length, γ_i is the time trend, β is parameter estimate, α is the constant parameter and ε_t is the stationary random error. The test for a unit root has the hypothesis that $H_0 : \beta = 0$, $H_1 : \beta \neq 0$. The condition is that if the parameter is statistically not significant, then the hypothesis that X_t contains a unit root is rejected.

Theoretical Model

The panel data model can be estimated with either the fixed effects model (FEM), random effects model (REM), or the constant coefficient effects model (CEM). However, with regard to this work, the fixed and the random effects model were used to check the robustness of the results.

The framework for this panel study was developed by Verbeek (2004) and can be written as Equation (2):

$$y_{it} = \alpha_i + x'_{it}\beta + \varepsilon_{it} \tag{2}$$

where β denotes the partial effect of x'_{it}. x'_{it} is a k-dimensional vector of explanatory variables, not including a constant. The α_i captures the effects of those variables that are peculiar to the individual and that are constant over time. In the standard case ε_{it}, is assumed to be independent and identically distributed over individuals and time, with mean zero and variance σ^2_ε (Verbeek, 2004).

The Hausman test was used to decide whether to use FEM or REM. The null hypothesis underlying the Hausman test states that the REM is appropriate for interpretation of the results. If the null hypothesis is rejected, the conclusion is that REM is not appropriate and that we may be better off using FEM (Gujarat, 2004).

Empirical Model

The study adopts the model used by Athanasoglou, Delis, and Staikouras (2006) to set out the general model in a linear form as shown in Equation (3):

$$ENQ_{it} = c + \sum\nolimits_{k=1}^{k} \beta_k X_{it}^k + \varepsilon_{it} \tag{3}$$

where ENQ_{it} is the environmental quality (carbon dioxide emission and combustible renewable waste) of the countries i at time t, with $t = 1.....N$; $i = 1...T$, c is a constant term X_{it} and k explanatory variables and ε_{it} is the disturbances term.

The empirical model to assess the existence of EKC and its determinants is specified as Equation (4):

$$\begin{aligned} LENQ_{it} &+ \alpha_i + \beta_1 LNGDPCAPITA_{it} + \beta_2 LNPOPDENSITY_{it} \\ &+ \beta_3 LNOFFICIALER_{it} + \beta_4 LNTRADEOPENNESS_{it} \\ &+ \beta_5 LNGDPCAPITA^2{}_{it} + \nu_{it} + \mu_{it} \end{aligned} \tag{4}$$

where ν_{it} the unobserved country-specific effect and μ_{it} is the idiosyncratic error.

The current study followed Bloom, Canning, and Sevilla (2004), Afzal, Farooq, Ahmad, Begum, and Quddus (2010), and Dao (2012) to specify the empirical model. The dependent and independent variables were logarithmized to allow the parameters to be interpreted as elasticities. The definitions, notation, and the expected sign of the variables used in the model are shown in Table 1. Population density (POPDENSITY) is expected to have a positive relationship with carbon dioxide emission and combustible renewable waste. This can be deduced from the fact that an increase in population mounts pressure on the natural resource available, leading to high levels of pollution (Dinda, 2004; Jorgenson & Clark, 2013; Martínez-Zarzosa, Bengochea-Morancho, & Moreales-Lage, 2007; Shi, 2003). As a country opens up its borders and allows free trade, the probability of suffering from pollution levels is higher than in a country that does not open its borders to free trade (Akin, 2014; Halicioglu, 2008; Iwata, Okada, & Samreth, 2010; Lucena, 2005; Sharma, 2011). Trade Openness (TRADEOPENNESS) is expected to have a positive relationship with environmental degradation. GDP per capita (GDPCAPITA) is expected to have a positive relationship with CO_2 and CoWaste due to the fact that a country's GDP only rises as a result of the production of goods and services which leads

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Table 1
Definitions, notation and expected sign of the variables in the model

Variable	Measurement	Notation	a-priori Sign
Carbon dioxide (CO_2) emission	CO_2 from electricity and heat production (Million Metric Tons)	CO_2	No prediction
Combustible renewable waste	(Tonnes of oil equivalent)	COWASTE	No prediction
GDP per capita	GDP per capita current (current USD)	GDPCAPITA	Positive
GDP per capita squared	GDP per capita current (current USD)	$GDPCAPITA^2$	Negative
Population density	People Per km^2 of land area	POPDENSITY	Positive
Official exchange rate	(Local currency per USD, Period average)	OFFICIALER	Positive
Trade openness	(Imports + Export)/ GDP	TRADEOPENNESS	Positive

to increased pollution generation (Dijkgraaf & Vollebergh, 1998; Galeotti, 2007; Lipford & Yandle, 2010; Shafik & Bandyopadhyay, 1992). When a country attains higher levels of GDP, the citizens begin to demand environmental quality. As a result, policies are put in place to restrict the importation of goods and services that produce pollution. This study expected a negative relationship between the square of GDP ($GDPCAPITA^2$), and CO_2 and CoWaste (Castiglione, Infante, & Smirnova, 2015; Cole, 2003; Galeotti, Lanza, & Pauli, 2006; Schmalensee, Stoker, & Judson, 1998). This study was expected to have a positive relationship between the official exchange rate (OFFICIALER) and environmental degradation. This implies that as the local currency depreciates against the foreign currency, pollution levels will increase.

The Kuznets hypothesis exists if, $\beta_1 > 0$ and $\beta_5 < 0$ and the estimated turning point is specified as Equation (5);

$$\Delta = -\frac{\beta_1}{2\beta_5} \tag{5}$$

De Bruyn and Opschoor (1998) opine that the income turning point of this representation shown in Equation (5) of the inverted-U curve is obtained by setting the derivative of Equation (4) with respect to GDPCAPITA to zero, which produces Equation (6):

$$\Delta = e^{-\frac{\beta_1}{\beta_5}} \tag{6}$$

where Δ stands for turning point of GDPCAPITA, e is the natural logarithm operator, β_1 is the coefficient on the linear term and β_5 signifies the coefficient in the quadratic term (Adu, Domfeh, & Denkyirah, 2016). Several authors (such as Adu et al., 2016; Apere, 2014; Checherita & Rother, 2010) have employed the conventional threshold estimation technique. Though, the significance of the threshold value cannot be determined, econometricians believe that it is very simple to estimate. The current study also employed the same approach to estimate the threshold beyond which economic growth reduces environmental pollution (CO_2 emission and CoWaste).

Results and Discussion

Stationarity Test Results

Table 2 presents the results of the unit root and stationarity tests for the variables and shows that all the variables are integrated at order zero. This means that the variables are stationary (a series is said to be stationary if it does not vary over time, which implies that its values have constant variability) at levels (without differencing). All the variables were statistically significant at the 1% ($p < .01$) significance level.

Multicollinearity

The Variance Inflation Factor (VIF) approach was employed to test whether the regressors in the model were highly correlated. The VIF result is presented in Table 3. The empirical result indicated that none of the regressors were highly correlated because neither the mean VIF nor any of the respective VIFs of the regressors were greater than 10.

Estimation of Environmental Kuznets Curve for CO_2 and COWASTE

The results of the econometric analysis to establish whether EKC existed for CO_2 and CoWaste in selected West African countries is presented in Table 4. The Hausman test indicated that the random effect model is appropriate, implying that it is the model that best explains the relationship between the dependent variable and the explanatory variables.

The random effect model for CO_2 revealed that GDP per capita (GDPCAPITA), trade openness (TRADEOPENNESS) and official exchange rate (OFFICIALER) were statistically significant. GDP per capita and trade openness were statistically significant at 1% while official exchange rate was statistically significant at 5%. They were all consistent with the a-priori expectation of the study which indicated that the GDP per capita, trade openness, and official exchange rate cause CO_2 emission. The fixed effect model indicated that GDP per capita and official exchange rate were significant variables that influence CO_2 emission. GDP per capita was statistically significant at 5% while trade openness was statistically significant at the 10% significance level.

Adu and Denkyirah (2017), Dijkgraaf and Vollebergh (1998), Galeotti (2007), Lipford and Yandle (2010), and Shafik and Bandyopadhyay (1992) revealed that GDP per capita has a significant and positive effect on CO_2 emissions. It was noted that a country's environmental pollution increases as it develops by producing goods and services which increase its GDP per capita. The result indicates that trade openness leads to an increase in environmental pollution (CO_2 emission). Trade openness increases environmental pollution by increasing economic activities such as mining instead of the importation of energy-efficient technologies

Table 2
Augmented Dickey Fuller and Philip–Perron unit root tests

Augmented Dickey Fuller Test				
Variable	Constant without trend		Constant with trend	
	Level (5%)	First diff.	Level (5%)	First diff.
LNGDPCAPITA^2	−4.140279***	−4.250318***	−4.357949***	−4.646649***
LNGDPCAPITA	−4.061181***	−4.152270***	−5.139991***	−5.72496***
LNCO$_2$	−3.491276**	−3.793452***	−5.531623***	−6.631723***
LNPOPDENSITY	−6.115330***	−7.245340***	−8.159736***	−8.569787***
LNCOWASTE	−6.744399***	−6.924453***	−6.679536***	−7.568556***
LNTRADEOPENNESS	−7.977050***	−8.052126***	−7.900718***	−8.018924***
LNOFFICIALER	−5.539106***	−6.015626***	−5.470305***	−5.981547***
Philip–Perron Test				
	Constant without trend		Constant with trend	
	Level (5%)	First diff.	Level (5%)	First diff.
LNGDPCAPITA^2	−4.140279***	−4.250318***	−15.06249***	−15.97437***
LNGDPCAPITA	−4.061181***	−4.152270***	−4.646864***	−5.463621***
LNCO$_2$	−3.333454**	−3.988556**	−5.608850***	−6.839870***
LNPOPDENSITY	−3.960064**	−4.650011**	−3.612395**	−3.931199**
LNCOWASTE	−6.822726***	−6.944487***	−6.983999***	−7.673172***
LNTRADEOPENNESS	−7.932443***	−8.414043***	−7.855360***	−7.966480***
LNOFFICIALER	−5.586615***	−6.151615***	−5.490677***	−6.500811***

Note: Values in parentheses are standard errors. **$p < .05$, ***$p < .01$
Source: Authors' computation (2017)

Table 3
Multicollinearity test

Variable	VIF	1/VIF
GDPCAPITA	4.11	0.243054
GDPCAPITA^2	2.73	0.365829
POPDENSITY	2.33	0.429283
TRADEOPENNESS	1.08	0.924526
OFFICIALER	1.04	0.959603
Mean VIF	**2.26**	

Source: Authors' computation (2017)

which could reduce CO_2 emission. Akin (2014), Iwata et al. (2010), and Sharma (2011) revealed that trade openness leads to additional environmental pollution for developing countries. Official exchange rate had a positive and statistically significant effect on environmental pollution implying that depreciation of the local currency against a foreign currency increases the levels of CO_2 emission. Depreciation of the local currency against a foreign currency indicates a weak economy; therefore, a call for investors results in an increase in economic activities and subsequently increasing pollution levels. The population density was not statistically significant and contradicted the a-priori expectation. Although it was not significant, the result indicated that a population increase does not lead to CO_2 emission. Intuitively, this could imply that citizens may want to conserve their natural resources rather than exploiting them. The finding is consistent with Adu and Denkyirah (2017), and Omojolaibi (2010) who revealed a negative relationship between population density and CO_2 emission. Although the sign of the coefficient of GDP per capita was consistent with the study's hypothesis, it was not statistically significant. The result indicates that economic growth does not significantly reduce CO_2 emission. This means that there is no EKC for CO_2

Table 4
Estimation of environmental Kuznets equations for CO_2 and COWASTE

Independent variable	LNCO$_2$		LNCOWASTE	
	Fixed effects	Random effects	Fixed effects	Random effects
LNPOPDENSITY	−8.333 (34.577)	−15.273 (30.585)	−19.761 (14.453)	11.793 (17.230)
LNGDPCAPITA	0.376** (0.172)	0.651*** (0.119)	0.099 (0.076)	0.195*** (0.061)
LNGDPCAPITA^2	−0.070 (0.871)	−0.660 (0.853)	−0.133 (0.397)	−0.190 (0.485)
LNTRADEOPENNESS	0.602 (0.552)	0.957*** (0.191)	−0.412** (0.165)	0.233** (0.095)
LNOFFICIALER	0.617* (0.314)	0.768** (0.321)	0.056 (0.164)	−0.149 (0.217)
CONSTANT	6.887 (79.994)	16.259 (70.168)	49.129 (33.434)	−27.996 (39.900)
Turning point (USD)	**14.59**	**1.64**	**1.45**	**1.67**
R^2	0.548	0.588	0.520	0.630
F-stat (Prob)	2.55 (0.072)	49.88 (0.000)	16.54 (0.000)	39.900 (0.000)
Hausman Chi^2 (Prob)		1.21 (0.547)		1.62 (0.111)
Breusch Pagan LM Test		$chibar^2(01) = 15.59$ Prob > $chibar^2 = 0.0000$		$chibar^2(01) = 40.65$ Prob > $chibar^2 = 0.0000$

Note: Values in parentheses are standard errors. *$p < .10$, **$p < .05$, ***$p < .01$
Source: Authors' computation (2017)

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emission in West Africa. Adu and Denkyirah (2017), Muftau, Iyoboyi, and Ademola (2014), and Omojolaibi (2010) revealed that the Environmental Kuznets Curve does not exist for CO_2 emissions in West Africa.

The random effects model for the CoWaste revealed that GDP per capita and trade openness had a statistically significant effect on the production of CoWaste. GDP per capita was positive and statistically significant at 1% while trade openness was positive and statistically significant at 5%. They were all consistent with the a-priori expectation of the study which indicates that GDP per capita and trade openness lead to the production of CoWaste such as liquid biomass and industrial and municipal waste. The fixed effects model indicated that trade openness had a negative and statistically significant effect on CoWaste at the 5% significance level.

The result of GDP per capita having a positive effect on CoWaste indicates that as countries develop, their economic activities increase which leads to pollution of the environment. The result is consistent with the findings of Adu and Denkyirah (2017), and Apergis, Payne, Menyah, and Wolde-Rufael (2010). Furthermore, the results of this study revealed that trade openness increases economic activities such as mining of natural resources and leads to the production of CoWaste. This is consistent with the findings of Adu and Denkyirah (2017), and Sharma (2011) which revealed that trade openness creates additional environmental pollution for developing countries. The square of GDP had a negative but no significant effect on CoWaste production levels. This indicates there is no EKC for CoWaste in West Africa.

Table 4 presents the turning point for which CO_2 emission and CoWaste production would decrease. The turning point estimate for the fixed effects model using GDP per capita and GDP per capita squared was about USD 14.59 while that of the random effects model was USD 1.64 at 2000 constant prices for CO_2 emission. In the same vein, the turning points for the fixed effect and random effect models for CoWaste were USD 1.45 and USD 1.67 at 2000 constant prices, respectively. The turning points are the levels of income per capita at which CO_2 emission and CoWaste production levels begin to decrease. The low turning points imply that African countries may be turning the corner of EKC much faster than is expected. The results can also be interpreted as indicating that African countries do not need to wait for a higher threshold of per capita income to achieve environmental quality. The empirical result is consistent with the finding of Omotor and Orubu (2011) which revealed low turning points for selected African countries using panel data estimation models (random and fixed effects) and recommended that African economies should still pursue efficiency improvements in the form of active policy intervention in the face of market failures to prevent environmental degradation.

We further investigated the relationship between CoWaste and CO_2 emission, since CoWaste could lead to emission of CO_2. The result is presented in Table 5. The Hausman test indicates that the random effect model is appropriate, implying that it is the model that best explains the relationship between the dependent variable and the explanatory variables.

Table 5
Estimation of environmental Kuznets equations for CO_2

Variable	Fixed effects model	Random effects model
LNCOWASTE	−0.500 (0.323)	0.068 (0.302)
LNPOPDENSITY	−46.888 (40.665)	−38.174 (40.758)
LNOFFICIALER	1.222** (0.497)	0.858* (0.514)
LNTRADEOPENNESS	0.244 (0.568)	0.937*** (0.263)
$LNGDPCAPITA^2$	−0.152 (0.911)	−0.570 (0.940)
LNGDPCAPITA	0.483** (0.185)	0.645*** (0.162)
CONSTANT	95.819 (94.159)	68.865 (94.169)
Turning Point (USD)	**4.90**	**1.76**
R^2	0.163	0.568
F-stat (Prob)	3.63 (0.027)	36.77 (0.000)
Hausman Chi^2 (Prob)		1.83 (0.382)
Breusch Pagan LM Test		$chibar^2(01) = 14.64$
		Prob > $chibar^2 = 0.0001$

Note: Values in parentheses are standard errors. $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$
Source: Authors' computation (2017)

The results revealed that CoWaste positively influenced CO_2 emission, although it was not statistically significant. The total effect was that CoWaste does not significantly result in CO_2 emission. This could be due to the fact that the production levels of CoWaste in developing countries are minimal or not at levels which cause CO_2 emission as asserted by Adu and Denkyirah (2017). The addition of CoWaste in the equation still produced similar results for the independent variables as seen in Table 4. The random effect model for the CO_2 revealed that GDP per capita, trade openness, and official exchange rate had positive and statistically significant effects on CO_2 emission. Both the GDP per capita and trade openness were statistically significant at 1% while the official exchange rate had a 10% significance level. The square of GDP per capita was not statistically significant but had a negative relationship with CO_2 emission. This implies that even at higher incomes, environmental pollution does not decrease. The total effect of the square of GDP per capita indicates the non-existence of EKC for CO_2 in West Africa. This means as the sub-region develops, the citizens desire economic wealth over environmental quality and are more willing to accept higher CO_2 emission at higher income levels. Therefore, active steps are not taken to mitigate the negative impact of these toxic emission.

The turning points produced from GDP per capita and GDP per capita squared did not differ much from the turning points presented in Table 4. The result showed that emission of CO_2 reduces when the income levels in West Africa reach USD 4.90 (for the fixed effect model) and USD 1.76 (for the random effect model) at 2000 constant prices. This agrees with Omotor and Orubu (2011) who revealed very low turning points for CO_2 emission in Africa.

Conclusions and Recommendations

The panel estimation technique was used to determine if economic growth in the long-run significantly decreased CO_2 emission and CoWaste in West Africa. The results showed that economic growth in the short-run significantly increased CO_2 emission and CoWaste. However, economic growth in the long-run did not significantly

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decrease environmental pollution. This implies that even at higher income levels, environmental pollution does not significantly decrease. The non-significant relationship between economic growth and environmental pollution in the long-run indicates non-existence of EKC in West Africa. The turning points or thresholds at which CO_2 and CoWaste begin to decrease are very low, indicating that West African countries do not need to attain a higher threshold of per capita income in order to achieve environmental quality. Although there is a very low turning point for CO_2 emission and CoWaste in West Africa, the non-existence of EKC signifies that the relationship between economic growth and environmental degradation in West African countries cannot be explained by the inverted U-shaped curve. The study recommends that West African economies should still pursue efficiency improvement policies intervention to prevent environmental degradation.

Conflict of Interest

There is no competing interest regarding this manuscript.

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