Testing the environmental Kuznets curve in selected West African countries: empirical evidence estimation

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Abstract: Environmental economics studied has become increasingly most popular in local and international community. In this paper, we empirically tested the environmental Kuznets curve hypothesis by analysis the relationship between growth of environmental quality and growth of per capita income. The panel estimation such as fixed effect and random effect were applied. From the results, the fixed effect model for growth for CO_2 revealed that growth for population density, growth of per capita income, growth of per capita income squared, growth of trade openness, growth of exchange rate, and growth of agriculture valued added were statistically significant. The results further indicated that growth of trade openness lead to an increases in growth of environmental quality. The growth of population density has positive and significant effects on the growth rate of environmental quality and has the a-priori expectation in our model.

Keywords: growth rate of environmental quality; CO_2 emission; growth rate of per capita income; panel estimation; growth rate.

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1 Introduction

Natural resources, climate change variables and pollution affect the environmental quality and that turn out to affect the economics growth of the country over time. This affects the majors keys sectors of the country, the service, the manufacturing and most importantly the agricultural sectors of the country As agriculture is the backbone of the economics of most west African countries and its act as the cornerstone to development

the environmental injustice causes by mostly human and nature causes the quality of life, standard of living and life expectancy to have negative impacts on growth in west Africa. It leads to high level of poverty, food insecurity of lack of rainfall and traditional ways of farming. The pollution causes by artificial means and deforestation, overgrasing, degradation, bushfire are causes more harm than good to artificial production. Natural resources intensity affect growth in Africa and that lead to lower sustainable development goals to achieve in the Africa. We must fight together to remove or reduces this myth in west Africa by ways and means of adaptation and mitigation of climate impact to new ways and management of resources we have for the future inter-generation to enjoy life and property of west African countries.

For instance, environmental; quality attracts lots of researchers' to investigate the damages caused by environment and it relationships with growth in economy and standard of living of the peoples. Most papers found negative link between environmental injustice like pollution, land degradation, deforestation, climate changes variables, to impact negatively with economic growth. The looking for better and most environmental quality topic worldwide attracts attention. The research problems in Western African countries can be regarded their level of rainfall, temperature, CO_2, agriculture, flooding, drought and renewable energy. However, this has impacted on their level of survival and negatively on the economics of West Africa countries. The study of the environment in West Africa is very important and very paramount to society growth and development. The African poverty dynamics rises as climate problems rise on the environment into chronic and transient poverty. The innovative ways of climate control on agriculture, services and manufacturing will go a long ways to sustain the economy of West Africa. As population rises, the growth rises, climate changes damages rises. As climate change damages rises so the economic growth will be used to solve the climate problems and poverty still will continue to rises (Beckerman, 1992). So without proper tools for adoption and mitigation strategy, West African countries will be bound to have vulnerable to pollution, drought, poverty starvation and even diseases.The empirical evidence of the presence of EKC for environmental quality using econometrics tools is used for this study. No Evidence of the existence of EKC was done by Omisakin (2009). Different scholars have different opinion. Using a time series and cross section for the OECD countries, Dijkgraaf and Vollebergh (1998) evidently that their existed for CO_2 emission in the individual OECD countries, but not the case of combined both at once. Using ARDL by Jalil and Mahmud (2009) found out that EKC had inverted *U*-shaped in china. A VECM found that existed of quadratic relationship between environmental quality and economic growth. The Inverted *U*-shape was create by many researchers involved and not restricted to Kaika and Zervas (2011). There is still a lot to be done on climate changes effects on growth through channelling under reviews, such as agriculture, manufacturing and industries, services sectors, pollution, degradation, burning, bushfire. There is lots of restriction as before and now, new data sets new technology, new research, new impact of climate change on both animals and plants. Most researchers especially Kaufmann et al. (1998), all indicated that inverted *U*-shaped between environmental quality and growth. Some added population and found out that population rises positively with pollution and negatively with economics growth (Dinda, 2004).

2 Materials and methods

2.1 Data source and sampling technique

This paper used the World Bank data from 1969–2017. The environmental quality was demonstrated to help us to assess the presence or non-presence of environmental Kuznets curve hypothesis. As of different country fixed effect model, the study applied employed panel data analysis. The sampling criteria is divided into two region in West Africa, Francophone and Anglophone speaking countries. The assumption is that the nine West African countries included in this studied had similar income status, similar demographic status, similar environmental pollution status and degradation and finally similar market structure.

2.2 Data analysis

The study used panel data analysis. Panel data analysis can be given concise treatment using matrices. We used econometrics books for details for panel data, including Greene (2000) and Semykina and Wooldridge (2010). As they put in this way, panel data is any data set that has both cross-sectional dimension and time-series dimension with the same cross-section units over time. By doing so we used co-integration testing.

2.3 Co-integration testing (Engle and Granger, 1987)

The notion of co-integration useful when two series are I(1), nevertheless a linear combination of one on the other is not spurious, but instead tell us somewhat about the long – run association between them. For the short- term dynamics, co-integration between two sequence also relates a particular kind of model. The co-integration equation given below:

If we have two I (1) processes, y_t and x_t, there is a coefficient β such that $y_t - \beta x_t$ is an I(0) process, which is always stationary. It means y and x are stationary or co-integrated and coefficient β, is co-integrated parameter.

$$S_t = y_t - \beta x_t \tag{1}$$

If we know β above in equation one, to test for co-integration will be regress S_t on y_t x_t. We will do DF test for co-integration in equation below: $y_t - \beta h_t$ is I(0).

$S_t = y_t - \beta x_t = (\delta - \beta\mu)t + (g_t - \beta h_t)$, which is trend stationary process.

According to Wooldridge for co-integration requires that there not be a trend, which means $\delta = \beta\mu$ for I(1) process with drift, it is possible that the stochastic parts that is g_t and h_t above are co-integrated, but the parameter β, that causes $g_t - \beta h_t$ to be I(0) does not eliminate the linear trend.

2.4 Theoretical model

The panel data models like this

$$y_{it} = \beta_0 + \beta_1 x_{it1} + \beta_2 x_{it2} + \beta_3 x_{it3} + \beta_4 x_{it4} +,,,,,,, + \beta_k x_{itk} + u_{it} \tag{2}$$

$$y_{it} = \beta_0 + \sum_{i=1}^{n} \beta_1 x_{itn} + u_{it} \tag{3}$$

A panel data method has two dimension, one is time series dimension and the other is cross-sectional dimension. The panel data contributes two most error mechanisms model as below:

$$u_{it} = e_t + v_i + \varepsilon_{it} \tag{4}$$

The u_{it}, the error term contains shocks that is the e_t that affects all observations for all *t* periods, v_i is city dependent, it affects all observation for cross-sectional unit for individual city for all *I*, and ε_{it} for all *I* and *t*. The two components of panel data to deal with in this paper are; fixed and random effect model.

The framework for this panel method study was established by Greene (2000), Afzal et al. (2010), Ahmed (2012) and Stern (2013) and can be re-rewritten as follows:

$$Y = X\beta + D\eta + \varepsilon \tag{5}$$

$$E\left(\varepsilon\varepsilon\right)^T = \sigma^2 I_n$$

The conditions for this paper on quality of environment on growth are that; $Cov\left(\varepsilon, CO_2, Combustible\, renewable\, energy\right) = 0, \forall\, RE \quad Cov\left(\varepsilon, CO_2, Combustible\, renewable\, energy\right) \neq 0, \forall\, FE$

The first assumption above is that unobserved fixed effect or error term is uncorrelated for the Random Effect model (RE) and correlated with Fixed Effect model (FE). From above equations, according to Russell *Y* and ε are *n*-vectors of elements y_{it} and ε_{it} for ε and D is an $n \times m$ matrix of dummy variables, where; $i = 1, \ldots, m$, $t = 1, \ldots, T$ for the matrix raw and column $J = 1, ..., m$. If row *i*=column *j* i.e., *i*=*j*. The β denoted the coefficients or elasticity of $x_{i1t}, x_{i2t}, x_{i3t}, x_{i4t}, x_{i5t}, ..., x_{itk}$ is a *k*-dimensional vector of Xs' and included the constant term and ε, which is ε_{it} is assume to be normal and iid with mean zero and $\sigma^2 I_n$ i.e., (0,1)=(0, $\sigma^2 I_n$).

Further, in order to make a clear decision whether we should choose between Fixed effect model and Random effect model. The only method that lead to that is Hausman test. The Hausman test is where the null hypothesis is that the preferred model is random effects in which the covariance between the error terms at time period *t* is uncorrelated with the error term i.e., $Co\left(\varepsilon, Xs'\right) = 0$. The alternative hypothesis which is fixed in which all the explanatory variables are correlated with the error term i.e., $Co\left(\varepsilon, X\right) \neq 0$.

How to perform Hausman Test

- *Step 1*: Run fixed effects and store the estimates
- *Step 2*: Run Random effect and store the estimates
- *Step 3*: Run Hausman fixed Random.

If the null hypothesis is rejected, it means fixed effect is more appropriate for the analysis than the random effect estimation.

2.5 Empirical model

To assess the presence of environmental Kuznets curve hypothesis, the study adopted the model as follows:

$$\begin{aligned} \text{Ln}EQ_{it} &= \beta_0 + \beta_1\ \text{LnPer}_{it} + \beta_2\ \text{Lnpden}_{it} + \beta_3 \ln \text{LnTO}_{it} \\ &\quad + \beta_4\ \text{LnEx}_{it} + \beta_5\ \text{LnA}r_{it} + \beta_6 \text{psq} + v_{it} + \varepsilon_{it} \end{aligned} \tag{6}$$

The variables above abbreviated below.

gen LnEQ=log(CO_2 emissionskgper2010USof)

gen LnG=log(GDP)

gen LnPer=log(GDPper)

gen psq=LnPer^2

gen LnA=log (Agri)

gen Lnpden=log (Populationden)

gen LnEx=log(OfEX)

gen LnTO=log(TradeOpeness)

The variables of this paper are logarithmised to allow the coefficients to be interpreted as rate of change of variables in elasticity form. $\ln EQ_{it}\left(CO_2\right)$ is the natural logarithm of environmental quality at time *t* and individual *i*, LnPer_{it}, is the natural logarithm of per capita income of the selected west African countries, Lnpden_{it} is the population density in natural logarithm form, openness is also in log form, LnEx_{it} is exchange rate is also in log form and we also squared per capital income with logarimised it. All at time *t* and individual *i*.

The pooled OLS estimator that is founded on time demeaned is called fixed effect estimator. The v_{it} and ε_{it} are unobserved country fixed effect and the error term in the model respectively. Fixed effect estimation, pooled OLS that has time demeaned variables is called fixed effect estimator.

The relationship between GDP Per capita and GDP per capita squared on the Environmental quality (CO_2 emissions as a prox) is the turning point to obtain the environmental Kuznets curve. The simple relationship we would test is as follows:

$$\text{Ln}EQ_{it} = a + \beta_1\ \text{LnPer}_{it} + \beta_2 Lnpsq + v_{it} + \varepsilon_{it} \tag{7}$$

Where: $\text{LnPer}_{it} = \log$ of the GDP per capita

$\text{Ln}Psq = \log$ of the GDP per capita Square

Understanding the existence of environmental Kuznets curve in our model, we first take the derivatives of environmental quality (CO_2 as a proxy) with respect to per capita income and we equate to zero. Therefore, to calculate the turning point of EKC = (coefficient of the linear term/(2*coefficient of the squared term)).It means that the coefficient of the per capita income divided by two times the coefficient of per capita income squared. After this calculations, we would check whether the resulting value falls

within the range of – gdp per capita or not. Thus, EKC exist at a point in which, $\beta_1 > 0$, coefficient for GDP per capita and $\beta_6 < 0$, coefficient for GDP per capita Squared. In order word the marginal propensity of GDP per capita and GDP per capita squared are negative and positive respectively.

The present study on EKC was closely followed the studied by Afzal et al. (2010).We added agriculture as a variable in the equation to see whether it influenza the existing of the environmental quality on growth of the 13 selected west African countries with similar income status. According to Dinda (2004) and Jorgenson and Clark (2013), population increases, CO_2 emission as pollution level rises. GDP per capita square had negative sign and positive sign for official exchange rate on environmental quality (Proxy CO_2) and trade openness i.e., export plus import divided by GDP impact negatively of growth (Iwatu et al., 2010).

3 Results and discussion of finding

3.1 Data and descriptive statistics

A brief descriptive of the data, the name of the variables, data sources and comment used in this study are presented in the Table 1 below:

Table 1 Data sources

Name of variable	*Source*	*Comment*
GDP Current(US$)	WDI	Current GDP $
CO_2 emission(EQ proxy)	WDI	CO_2 emissions $
Agriculture	WDI	Agriculture value added of $
GDP per capita	WDI	GDP per capita $
GDP per capita squared	WDI	GDP per capita square $
Real effect exchange rate	WDI	Real effect exchange rate
Trade openness	WDI	Total average rainfall
Population density	WDI	Total climate change variable

Note: WDI is world development indicator.

3.2 Descriptive statistics

From Table 2, the descriptive statistic of this paper indicated that the years has gaps. That make the number of observation to fluctuate overtime. We used panel estimation for 13 West African Countries with similar CO_2 emission per capita and with similar income status. We logarithmised the variables to interpret as elasticity or rate of change of variables. The descriptive statistic which contains the mean, the standard deviation, the maximum and the minimum for the selected West African Countries. The rate of change of quality of environment (proxy CO_2 emission per capita $) has negative mean and negative volatility of (1.24) and (0.49), respectively. The growth rate of openness has lowest mean of –17.7. The growth rate of per capita is 6.03 closer to the mean of growth rate of population density and growth rate of agriculture combined. The turning point in

which there is environmental Kuznets curve hypothesis exist, the squared of the environmental quality has standard deviation of 8.7.

Table 2 Descriptive statistics

Variables	*Observation*	*Mean*	*Standard deviation*
LnEQ	597	–1.240327	0.4868291
LnG	649	21.71916	1.681393
LnPer	649	6.025311	0.7129649
LnA	633	3.443186	0.3353611
Lnpden	650	3.496781	1.193989
Psq	649	36.81191	8.721851
LnTO	644	–17.69584	1.796891
LnEx	649	4.321505	3.165415

LnEx =Growth rate of exchange rate

LnTO = Growth rate of trade openness

LnA= Growth rate of Agricultural sector

LnEQ = Growth rate of Environmental quality

LnG = Growth rate of GDP

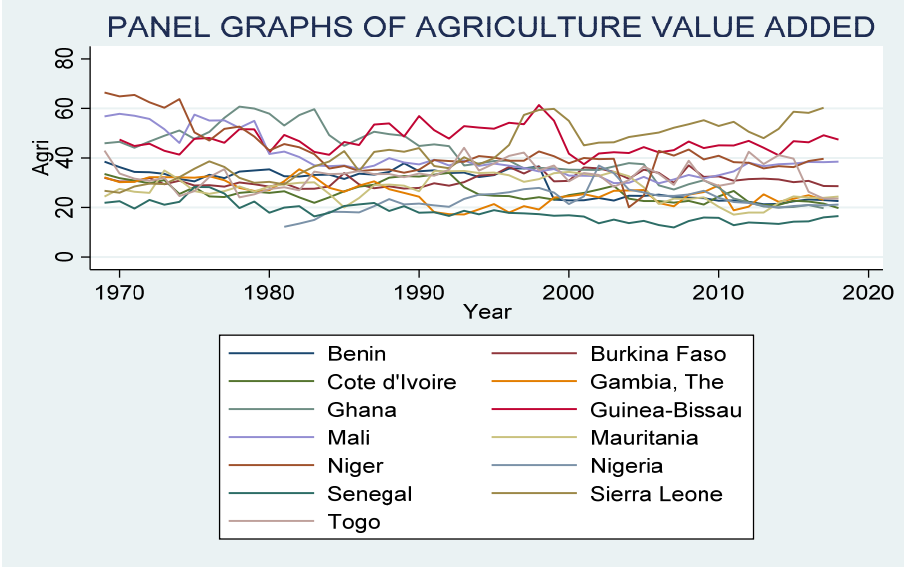
LnPer=Growth rate of per capita income

Lnpden=Growth rate of population density

Psq=growth rate of per capita income squared.

Sources: Authors' computation by using stata 13 for window.

Figure 1 Panel graph of agriculture valued added for selected West African countries



Note: Own evaluation

3.3 Correlation

From Table 3, the correlation is the relationship between variables under study. The growth rate of GDP and the growth rate of environmental quality has positive correlation of 10%. As CO_2 emission per capita rises, the rate of growth of GDP in the selected West African countries with similar income status also increases. The growth rate of agriculture has negative impacts on the growth rate of CO_2 per capita emission, on growth rate of GDP and growth rate of per capita income. This is due to the fact that in West African countries lower agriculture is due to lower rainfall. The exchange rate and trade openness has negative correlation with CO_2 emission per capita. The per capita income and per capita income squared has positive correlation with environmental quality. Meaning, in selected West African countries, the rate of growth of their income is due to quality of environment free from deforestation, pollution, erosion, drought, etc. It is due to high rainfall, quality of environment, high CO_2 emission per capita, and reforestation will lead to positive correlation with the environment up to close to 42% and 40%, respectively. The growth rate of GDP is due to inversely relationship with the growth rate of agriculture, growth rate of exchange rate and growth rate of trade openness. In the West African countries selected, growth of agriculture has negative impacts with the following variables; environmental quality, growth of GDP and growth of per capita income. This is revealed that in West African countries should do more on climate change mitigation and adaptation that hindrance the growth of agriculture.

Table 3 Correlation

Variables	*LnEQ*	*LnG*	*LnPer*	*LnA*	*LnTO*	*LnEx*
LnG	0.1009	–				
LnPer	0.4196	0.7612	–			
LnA	–0.3879	–0.432	–0.6156	–		
psq	0.4021	0.7677	0.9969	–0.620	–0.6617	0.0096
LnTO	0.0105	–0.9690	–0.6518	0.3366	–	
LnEx	–0.2109	–0.0002	0.0037	–0.078	0.0374	–

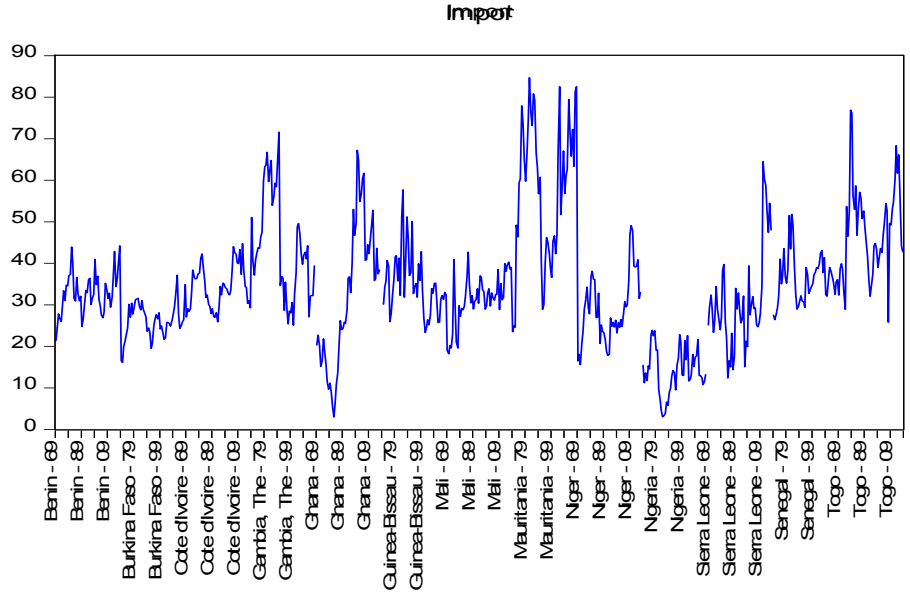
Source: Authors' computation by using stata 13 for Window.

3.4 Panel unit root test

The study covered from 1969–2016, with thirteen West African countries having similar income status. The questions that arises for panel unit root test-fisher type unit root test for the coefficients based on the augmented dickey – fuller tests. Does our data contains a unit root? How do we know the confidence level at which we can reject the null hypothesis or accept the alternative vice versa. For the growth of GDP is that all panel does not comprise a unit root. Given our results we failed to reject the null hypothesis. Since all the values in this test for growth rate of GDP are greater than 1%, 5% and 10%, we failed to test the null of exist the unit root. It indicates that there is unit root in our panels under the given test condition. This also answer the subsequent question, since the *p*-value tell us at which level of significance to reject or accept the null hypothesis. Table 4 contains all the variables with corresponding *t*-ratios and *p*-value with drift and trend. Only the intercept of the growth of GDP is statistically significant. The results of

econometric estimation is to identify whether growth rate of CO_2 emission per capita (proxy environmental quality) is existed for EKC in 13 selected West African countries with similar income status presented in table. The Hausman test indicated that the used of random effect is more appropriate when we used the effect of environmental quality on growth rate of per capita income and growth rate of per capita income squared. This was not the case when we regressed growth rate of EQ on the variables included per capita income and squared. According to Hausman test-chi-squared statistic, the used of fixed effect is more appropriate for our analysis.

Figure 2 Import of good and services



Note: Own evaluation

Table 4 Panel unit root test

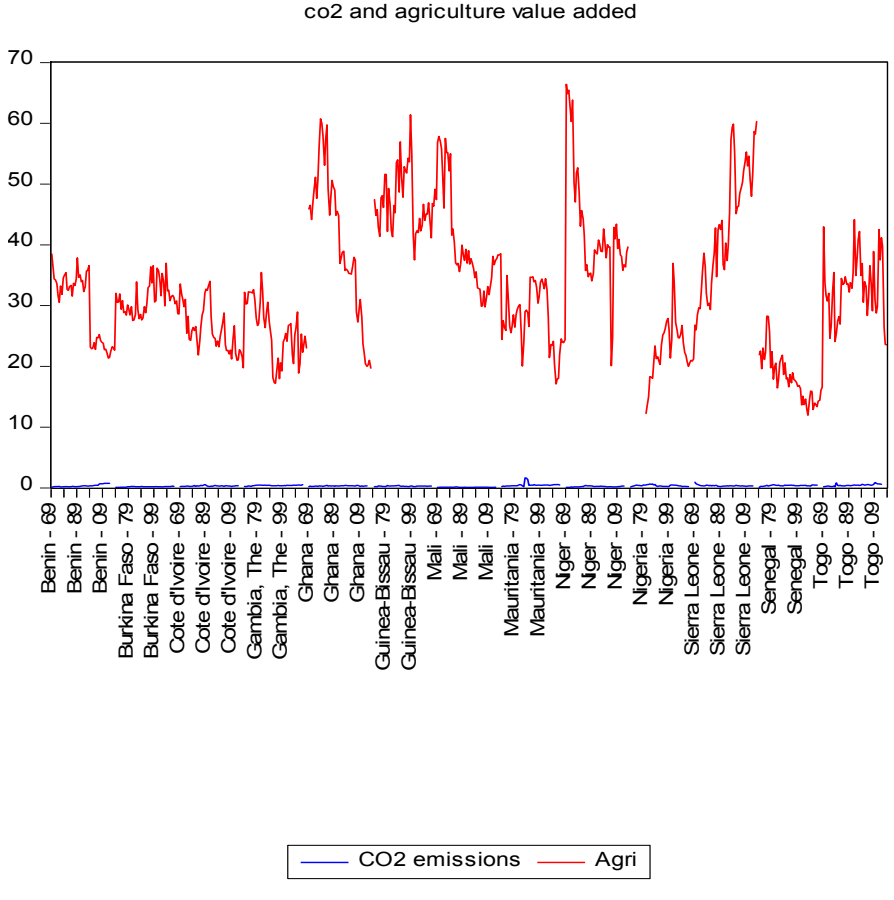
Variables	*T-Ratios*		*p-value*	
	Drift	*Trend*	*Drift*	*Trend*
LnEQ	–10.8544	–4.3755	0.0000***	0.0000***
LnPer	–5.7913	1.4098	0.0000***	0.0815*
LnG	–3.5710	–1.2007	0.0003***	0.1170
LnA	–8.3394	–2.5065	0.0000***	0.0073**
Lnpden	–4.2561	–23.1199	0.0000***	0.0000***
LnTO	–3.7190	–2.3539	0.0002***	0.0107*
Psq	–4.8720	–0.7478	0.0000***	0.2286
LnEx	–3.6441	–0.7281	0.0003***	0.2345

Notes: *, ** and *** denote significance at 10%, 5% and 1%; Own evaluation.

3.5 Fixed effect model

The fixed effect model for Carbon -dioxide exposed population density, per capita income, per capita income squared, trade openness, exchange rate, agriculture are significant. Only trade openness is not statistically significant associated with positive coefficient. The results further indicated that trade openness lead to an increases in environmental pollution by improving key economic activities such as mining, which may reduce CO_2 per capita emission in the selected West Africa countries. Akin (2014) revealed that trade openness leads to environmental pollution in developing countries. This in turn leads to highest CO_2 emission per capita in the environment and that can leads to lower life expectancy. According to our result GDP per capita and GDP per capita squared are all statistically significant at 1%, 5% and 10% and per capita income squared associated with negative sign. The GDP per capita is significant and positive. This is true because the EKC exist at a turning point in which $\beta_1 > 0$ and $\beta_6 < 0$ i.e., per capita income and per capita income squared respectively.

Figure 3 Environmental quality (CO_2 proxy) graph against agriculture valued



Note: Own evaluation.

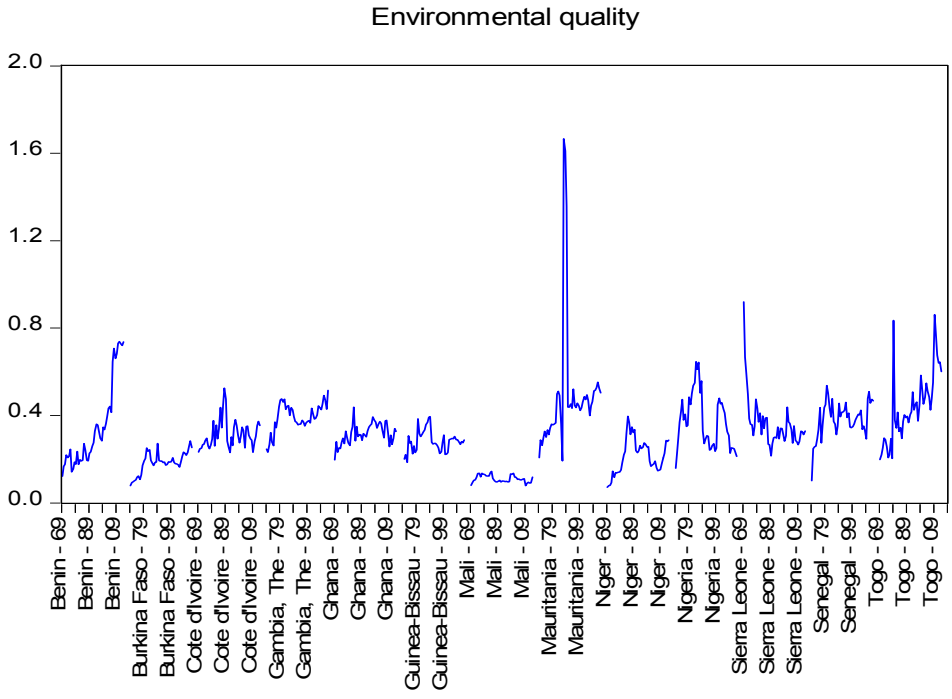
This results was reinforced by Adu and Denkyirah (2017), Aldy (2004) and Dijkgraaf and Vollebergh (1998) exposed in their studied that GDP per capita has important and optimistic influences on CO_2. Official exchange rate has important and related with negative sign. A percentage increases in exchange rate in these countries, CO_2 emission per capita reduces by 4.8%.This may be due to the fact that we selected more countries in our study than them. This implying that appreciation of the local currency against the major currency decreases at the level of CO_2 emission per capita. Our analysis indicated that exchange rate improvement for our domestic currency can lead to reduction in CO_2 emission per capita. We added agriculture as the predicted backbone of West African countries. Growth rate of agriculture has negative and statistically significant effect on environmental quality. An increases can lead to substantially reduction of 25.6% of CO_2 emission per capita. It means that as population increases, CO_2 emission rises approximately 34.64% in the selected West African countries. In addition, population rises can lead to improve people life, but cautious must be taken into account for quality of environment.

Table 5 Fixed effect model

	t-ratio Std. E	*P*-value Coef	*R-sq.=25%* Number of observation=584 Hausman prob. Chi-square=0.0431 *F*(12,565)=40.58
Constant	–5.27 (0.79)	0.000*** –4.17	
LnPer	4.46 (0.22)	0.000*** 0.998	
LnA	–3.78 (0.07)	0.000*** –0.26	
Lnpden	4.84 (0.07)	0.000*** 0.35	S* p=0.10, ** p=0.05, *** p=0.01 Sources: Author COMPUTATION BY using stata 13 for window
LnTO	0.41 (0.04)	0.684 0.02	
psq	–4.21 (0.018)	0.000*** –0.08	
LnEx	–4.94 (0.009)	0.000*** –0.05	

Random effect model results: The random effect model for CO_2 on growth rate of per capita and growth rate of per capita squared. We found out that both per capita squared and per capita are statistically significant and negative and positive sign respectively. This may be due to the fact that the first derivative with respect to EQ is negative. Even the intercept term, if all the variables become zero, EQ is statistically significant and negative sign. Without the other variables, the CO_2 emission in West African countries will be negative autonomous according to the result generated.

Figure 4 Environmental quality (CO_2 as a proxy)



Source: Own evaluation

Table 6 Random effect model

Variable	*Model (LnEQ)*		
Depedent variable LnA	*z*-ratio Std E	*p*-value Coef	Hausman chi-0.3320 *R*-squared=36% Number of observation=597
Constant	–8.59 (0.68)	0.000*** –5.84	* $p = 0.10$, ** $p = 0.05$, *** $p = 0.01$ Sources: Author computation by using stata 13 for window.
LnPer	5.99 (0.22)	0.000*** 1.345	
psq	–5.09 (0.019)	0.000*** –0.095	

Figure 5 Scattered plot for change in environmental quality again change in per-capital income

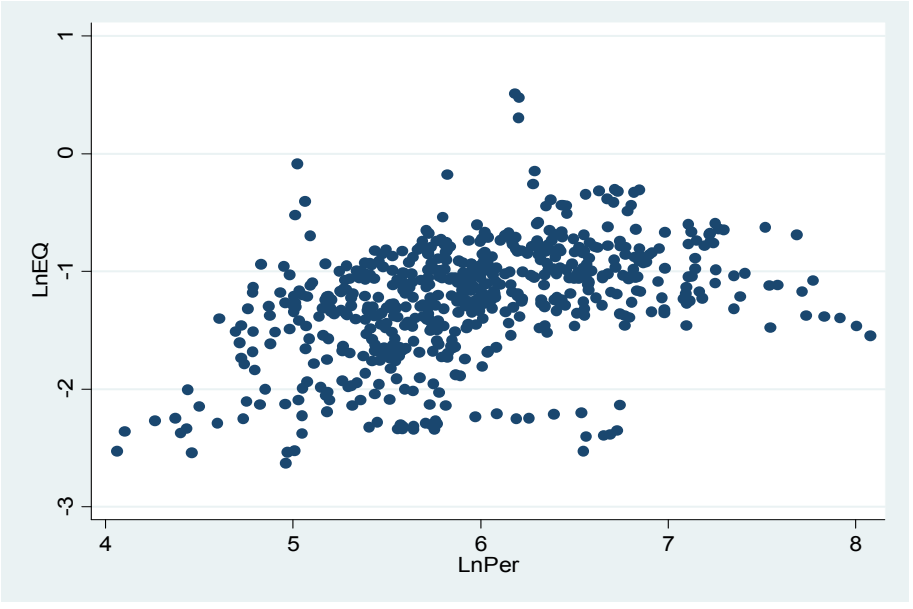
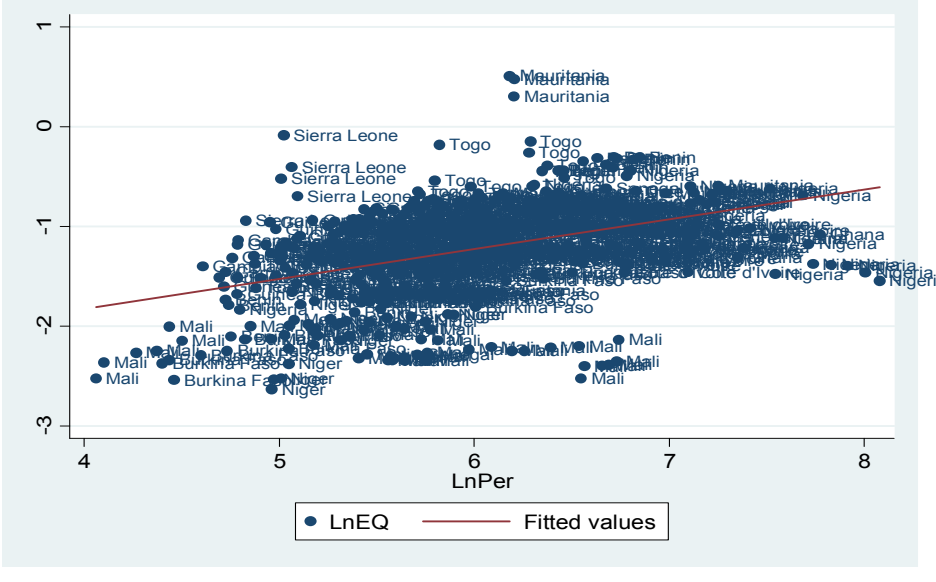


Figure 6 Scattered plot for change in environmental quality versus the fitted values



4 Conclusion and policy recommendation

The turning point estimation technique was used to determine at which rate the environmental Kuznets curve hypothesis exist. It exist at a point in which the coefficient of per capita income and the coefficient of per capita income square become positive and negative respectively. The results further indicated that trade openness lead to an increases in environmental pollution by improving key economic activities such as mining, which may reduce CO_2 per capita emission in the selected West Africa countries. Akin (2014) revealed that trade openness leads to environmental pollution in developing countries. This is true because the EKC exist at a turning point in which $\beta_1 > 0$ and $\beta_6 < 0$ i.e., per capita income and per capita income squared respectively.This results was supported by Adu and Denkyirah (2017) and Dijkgraaf and Vollebergh (1998) revealed in their studied that GDP per capita has significant and positive impacts on CO_2 emission per capital.

The policy recommendation is that the government of the country and its respective municipality should take account the following measures; replace disposable items with re-usable, pass on paper, conserve water and electricity, reduces plastic and paper waste, support local and environmental friendly to enable cost effectiveness, recycling materials that are waste product that will reduces pollution, save animals and plants, cut down consumption of energy and slow down global warming and finally, the government can steps forward to make more aware of the needs of the environment and climate change effect it leads to.

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