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Energy Consumption, ICTs Development and Environmental Quality among ECOWAS

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Abstract: Relationships among energy consumption, environmental issues and other macroeconomic variables provide an extensive literature for a large number of studies across the world. Existing studies have explored the nature and direction of the linkage between energy consumption, income, electricity price, inflation, exchange rate and trade openness. However, relationship among ICT development, energy consumption and environmental quality has received little attention particularly among Economic Community of West African States. This study investigated the dynamic linkages among energy consumption, ICT development and environmental quality using the panel of 6 countries in West Africa using data from U.S. Energy Information Administration (EIA) and World Development Indicators and Generalized Method of Moments (GMM). It was found that carbon dioxide emissions increased energy consumption. Also, mobile telephone subscription had negative but insignificant relationship with environmental quality and fixed line subscription has significant negative impact on environmental quality within the period under study. In addition, environmental damage increased as economies of these selected countries grew, hence, there is no inverted U-shape relationship found between economic growth and environmental quality. The results obviously would facilitate the policy planners to formulate related policies in line with carbon free economy thereby enhancing sustainable development in selected countries.

Keywords: Energy consumption; Mobile Subscriptions; Fixed line subscriptions; Carbon emissions

JEL Classification: Q4; L86; Q2

1. Introduction

The potentials of technologies in impacting key variables like carbon emission and energy consumption in the economy have been documented (Moyer and Hughes, 2012). Greenhouse gas emission (GHG) has been identified as one of the major

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contributors to climate change. Thus, the need to reduce global warming became imperative so as to mitigate environmental challenges (Apergis et al., 2010).

Kuznets (1955) hypothesized a relationship among different ways relating per capita income with environmental degradation. To Kuznet, as economic activities increase, there is also an increase in pollution, though; the increase in pollution may be above the per capita income. Such continual increase in income propels growth which brings about improvement in environment. Kuzinet hypothesis indicated a u-shaped curve between environment and income (Niu & Li, 2014). However, Gatotti et al (2009) posited that the limit theory presented the reverse of the above scenario, implying that environmental challenges could have affect on the economy to the point to the of shrinking the economy. The impact of such challenges could be felt in terms of waste of natural resources, quality of life and pollution.

Moreover, it has been confirmed that during the early stage, growth naturally precedes environmental degradation, though, an economy has to be rich in order to benefit from decent environment (Beckerman, 1992). The framework of information technology emphasized by Schumpeter in Field (2004) showed that technologies in form of innovation, invention and diffusion have capabilities to transform the economic and or environmental atmospheres of nations.

Endogenous theory as analyzed by incorporating technology as a variable in the system of how market economy functions (IPCC, 2007; Weitzman, 1997). Importance of technological change has also been analyzed vial reduction in environmental pollution, end of pipe technology and efficiency. However, Yeh et al. (2011) stressed the necessity of climate change assessment in terms of environmental and the issue of energy. It is important to note that acceptable cost implication by the citizenry and technology development have potentials to lower the intensities of emissions.

Clearly, relationship exist between energy consumption and environmental stress, but very little empirical evidence that examined interactive effect of energy consumption and ICT development on environment quality particularly in the less developed countries.

Though, there exist related studies on the subject matter. The first set of studies focused on economic growth and environmental quality and economic growth connections by testing how valid the hypothesis on Environmental kuznet Curve (EKC) and confirmed existence of the EKC between economic growth and environmental pollution (Niu & Li, 2014; Akpan & Chukwu, 2011; Al-Mulali et al., 2015; Jebli et al., 2016; Onafowora & Owoye, 2014; Shahbaz et al., 2013 among others).

Another set of studies examined the relationships between carbon emission, energy consumption and growth (Alam et al, 2011; Alam et al, 2015; Acaravci & Ozturk,

2010; Ozturk & Uddin, 2012; Shahbaz et al, 2013; Zhai, & Song, 2013; Zhang et al 2013). The last set is related to ICT development, environmental quality economic growth (Wang & Han, 2016; Lee and Brahmasrene, 2014; Sohag et al., 2015). However, little or no study to the best of researchers knowledge have analyze the relationships between ICT development, energy consumption and environment quality, hence the study.

The rest of the paper is organized as follows: Section 2 presents a review of related literature on the linkage between energy consumption, information technology, environmental quality indicator and control variable. In Section 3, we present data and research method. Section 4 presents the empirical results and discussion. Concluding remarks are presented in Section 5.

2. Empirical Literature

Studies that revolved around energy consumption, ICT development, CO2 emission and the growth of the economies, though many of these studies were somehow in terms of the data used. Ozturk and Uddin's in (2012) showed positive connection between energy consumption and GDP growth, hence, granger causality was observed among carbon emission, energy consumption, and GDP growth between 1971-2007. Whereas, Azomahou and Phu (2001) showed that the process of the impact of GDP growth on greenhouse gas emission especially during later stages of the development was found to be negative.

The results of the analysis done by Lin et al in (2016) in Nigeria showed that industrial value-added has an inverse and indirect link CO_2 emissions, though the result was significant. Also, Co2 emission and energy intensity showed positive, weak and significant relationship with CO_2 emission. The results of the Kaya Identity framework provided no evidence that industrialization lead to increase in carbon emissions in Nigeria. However, economic growth and population were found to influence CO_2 emission significantly.

Investigating carbon emission, energy intensity, economic growth and globalization in Turkey in 1970-2010, Shahbaz et al (2013) showed that economic growth can be boosted at the cost of environment. The results also validated the presence of EKC. A long run relationship was also found among information communication technology (ICT), carbon emission (Co_2) and economic growth (Lee and Brehmasrene, 2014). In this panel data of nine South East Asia, ICT showed significant positive effect on economic growth and carbon emission showed inverse bidirectional relationship between economic growth and carbon emissions.

In addition, a positive relationship was observed in Zhang et al (2013) between energy consumption and carbon emission China Also, there is a unidirectional

positive relationship running from pollutant emission to economic development and a unidirectional negative relationship between pollutant emission and energy consumption.

Between 1985 and 2012, Ali *et al* (2016) showed that technological innovation (TI) had a negative but insignificant relationship with environmental pollution in Malaysia during the period under study. It was also shown that higher economic growth improves the environmental quality in the long-run and is in line with the environmental Kuznets curve (EKC) hypothesis. In the same vein, financial sector development lessen the CO_2 emissions and improved the quality of the environment. It was discovered that the impact of energy consumption in the short-run was environmentally friendly.

Technology Innovation has been discovered to decrease the rate at which energy is being consumed and ultimately reducing CO_2 emissions as a result of its effeiciency, whereas, the strength of energy consumption was confirmed to be boosted by growth and trade openness (Sohag et al., 2015). In addition, Parry (2003) found that optimal pollution control welfare gains were greater than the welfare gains from the technological innovation.

In summary, the above analyses implied that there exist little or no studies that have spanned through the variables employed in this paper within the 5 selected countries. Thus, the paper contributed the existing studies in the areas of ICTs, environmental quality and energy consumption. The need to examine these variables is of utmost essential, given the increased debate on how the dominant variable is affecting environment which has been having devastating effects to human race.

3. Data and Methods

The information about energy consumption was taken from U.S. Energy Information Administration (EIA, 2017) and other variables were sourced from World Development Indicators of World Bank over the period of 1990–2017 for Nigeria, Benin, Ghana, Togo, Ivory Coast and Senegal. The variables involved emissions from carbon dioxide from the consumption of energy in million metric tons, Petroleum products consumption, GDP per capital, fixed telephone subscription (FXT), mobile telephone subscriptions (MT), energy consumption, per capita income and money supply (m_2). These variables were selected so as to examine the long-run relationship between carbon emission and its regressors for the selected 6 ECOWAS. The literature on the environment showed that information technology can be applied to determine the impact on different dependent variables including energy consumption, carbon emission and economic growth (Cheze et al, 2013; Greaker & Pade, 2009). The introduction of technology as an endogenous factor open the ways for better economic growth and efficient consumption. We derived

carbon emission function from the endogenous growth model presented by Romer and the production function can be written as

$$y = f(K, L, A) \quad (1)$$

Where y is income, A= Technology development K= capital Stock L=available labour stock

Since it is obvious that environmental quality is affected by economic growth, then:

$$Co_2 = f(y) \quad (2)$$

Since information technology (IT) is part of technology development

Thus, we can say that co_2= (K, L, IT) (3)

Furthermore, energy consumption (EC) as a capital can be divided into polluting capital (k_p) and non polluting capital (k_{np}) as shown below

$$k = k_p + k_{np} \quad (4)$$

Also, fossil fuel subsidy (f_c) contributes to damaging the environment through its effect on marginal investment in new capacity (Holton, 2012)

$$CO_2 = f(IT, f_c, L, EC) \quad (5)$$

Where EC is the energy consumption in kilotons of oil equivalent (Azam et al, 2015; Saboor and Suleiman, 2015) IT is measured of fixed telephone subscriptions (FXT) and mobile telephone subscriptions (MT) (Akanbi et al, 2012) and L can be replaced by GDP since labour activities can be considered as economic activities(Ali et al, 2016). Thus,

$$CO_2 = f(FXT, MT, f_c, EC, GDP) \quad (6)$$

The GDP can be squared to test for kuznet hypothesis, the model can be specified as

$$CO_2 = f(FXT, MT, f_c, EC, GDP, GDP^2) \quad (7)$$

Also from literature, IT development has link with financial deepening which is measured with m_2 (Charfeddine, and Khediri, 2015; Shahbaz et al, 2013; Ejumedia and Ejumedia 2015). Therefore,

$$CO_2 = f(FXT, MT, f_c, EC, GDP, GDP^2, m_2) \quad (8)$$

$$log(Co_2)_{it} = \beta_0 + \beta_1 LOG(FXT)_{it} + +\beta_2 LOG(MT)_{it} + \beta_3 LOG(f_c)_{it} + \beta_4 LOG(EC)_{it} + \beta_5 LOG(GDP)_{it} + \beta_6 LOG(GDP)^2_{it} + \beta_7 LOG(m_2)_{it} + \epsilon_i \quad (9)$$

where '*i*' represents cross section identifiers, that is, country 1 to country 5, '*t*' represents time period from 1990 to 2015, 'Log' represents natural logarithm, and ε represents error term.

Equation (9) shows the empirical relationship between environmental quality, energy consumption, information technology development and other variables. This equation was tested by number of panel econometric techniques for robust results. The study first carried out unit root tests using Im *et al*. (2003) for confirming the stationary series of the candidate variables. The study further used Levin *et al*. 2002) panel unit root test for only those variables that does not confirmed their stationary properties by Im *et al*., 2003). We assumed a common values foe all the β_{i}, thereby formulating the null hypothesis as:

$$H_0;\ \beta_0 = 0$$

$$H_i;\ \beta_0 < 0$$

Thus, an estimator of β is absorbing the heteroscadasticity across the time series that make up the panel. While, the approach of (IPS) is determined by the ADF regressions; however, the H_0 and H_1 are considerable different from the LLC approach, that is, the implication that all the series are stationary is determined by rejecting the null hypothesis:

$H_0;\ \beta_0 = \beta_2 =, \ldots = \beta_{\mathrm{N}} = 0$: Some but not necessarily all β_{i}

This paper utilized panel Cointegration by Pedroni (1999) panel co-integration for substantiating the long-run nexus among the variables under consideration. Pedroni's tests allow the four panel statistics 'within' dimension including panel *v*-statistic, panel rho-statistic, panel ADF-statistic, and panel PP-statistics, while there were four weighted panel regression statistics also available in 'within dimension'. In addition, there were three group statistics available for substantiating the relationships including group rho-statistic, group ADF-statistic and group PP-statistic. In almost all cases, panel *v*-statistics substantially showed positive and greater magnitude, while remaining panel and group statistics showed negative sign. However, for long-run cointegration relationship between the variables, the respective probability values may also have had a considerable impact on confirmation of co-integration relationship between the variables.

The study employed dynamic panel approach – Generalized Method of Moments (GMM) that handle the problem of endogeneity problem in the given data set. Equation(10) showed the GMM model specification.

$$log(C_{o2})_{it} = \beta_0 + \theta_{\mathrm{it}} + \beta_1 \mathrm{LOG(FXT)_{it}} + \beta_1 \mathrm{LOG(MT)_{it}} + \beta_2 \mathrm{LOG}(f_c)_{\mathrm{it}} + \beta_3 \mathrm{LOG(EC)_{it}} + \beta_4\, LOG(GDPc)_{it} + \beta_5\, LOG(GDPc)^2{}_{it} + \beta_6 \mathrm{LOG}(m_2)_{\mathrm{it}} + \epsilon_{\mathrm{i}} \quad (10)$$

where θ represents list of instrumental variables including the first lagged value of the explanatory variables.

4. Results and Discussion

This section presented the order of estimations, that is, correlation matrix, panel unit root test, panel co-integration, dynamic panel modeling, and robust least square regression. Table 1 showed the correlation matrix between the variables in which carbon dioxide emissions had positive correlation with the energy consumption, as the correlation coefficient value of $r = 0.539$, $P < 0.000$ depicted the significant association among the variables. There was weak negative association between fixed line telephone subscriptions and carbon emission, that is, $r = -0.137$, $P < 0.000$, while there was very weak positive association between mobile telephone subscriptions and environmental quality in selected countries as $r = 0.054$, $P < 0.000$.

Table 1. Correlation Matrix

	CO2	**EC**	**Fc**	**MT**	**FXT**	**M2**
CO2	1					
EC	0.539***	1				
Fc	0.633***	0.712***	1			
MT	0.054	0.004	0.012	1		
FXT	-0.137	0.178	0.001	0.628***	1	
M2	-0.471	0.211***	0391	0.519	0.442	1

**** Significant at 1 percent level*

The result further confirmed the conventional hypothesis, that is, GDP per capita increases carbon dioxide emissions in the selected countries, as the value of correlation coefficient indicates the positive and high correlation between them, that is, $r = 0.651$, $P < 0.000$. In addition, the results endorsed the fact that financial development reduces carbon dioxide emissions, that is, the coefficient value indicates $r = -0.471$, $P < 0.000$. Finally, fossil fuel subsidy does more harm to the environment, as correlation coefficient value indicates positive association between fossil fuel subsidy and carbon emission (0.633, $P < 0.000$)

Table 2. Results of Panel Unit Root Test

Variables	Level		First Difference	
	Constant	Constant+ Trend	Constant	Constant +Trend
Co_2	4.012	-1.032	-6.214	-2.153***
EC	5.071	-3.218**	-3.015	-1.031***
GDP	3.631	-1.371**	-3.221	-2.121***
MT	1.461	-2.107**	-1.311	-0.759***
FXT	3.239	-1.031**	-3.175	-2.132***
M2	4.017	-2.031	-5.218	-3.713***
Fc	3.631	4.021	2.641	5.217
Levin, Lin and Chu (LLC) panel unit root test				
Fc	-2.314	-4.371**	-1.714	-0.319

Note: ** (5 percent level of significance) ***(10 percent level)

Table 2 results showed that the data series of money supply and carbon dioxide emissions are more volatile in nature, as both of the variables are non-stationary at level; however, the data became stationary at first difference. The remaining variables, that is, energy consumption, fixed line telephone, mobile telephone subscription and GDP were stationary at level when adjusted the time trend in the series. However, without adjusted trend in the data series, both the variables were differenced and stationary. Finally, the data set of fuel subsidy is not captured any stationary series till second differenced in IPS (Im, Pesaran and Shin) approach. The LLC panel unit root test confirmed that population data is stationary at level, although, it does not become significant at first difference. The results confirmed the mixture of order of integration among the variables, therefore, it would be cautious to use robust least square regression that are less sensitive to outliers

Table 3. Pedroni- Residual co-integration Result

	Statistic	**P**	**Weighted Stat.**	**P**
Panel v-Statistic	0.381619	0.2139	−1.162839	0.2915
Panel rho-Statistic	2.852751	0.9784	2.979391	0.1899
Panel PP-Statistic	2.979391	0.1899	−3.103340	0.0010
Panel ADF-Statistic	2.763213	0.9931	−2.060473	0.0197
Alternative hypothesis: individual AR coefs. (between-dimension)	**Statistic**		**P**	
Group ADF-Statistics	−1.631132		0.0580	
Group rho-Statistic	2.121515		1.0000	
Group PP-Statistic	-6.9287		0.0000	

Pedroni residual co-integration result for evaluating null hypothesis of no co-integration against the alternative hypothesis of co-integration relationship between the variables was shown in Table 3. It showed that both the weighted panel PP-statistic and weighted panel ADF-statistic significant at 1% and 5% level, respectively. Similarly, group PP-statistic and group ADF-statistic also tend to showing significance at 1% and 10% levels. The results rejected the null hypothesis of no co-integration and accepted the alternative hypothesis of co-integration among the variables. The results established the long-run association between carbon emission and explanatory variables in the panel of selected countries. We employed dynamic heterogeneous technique, generalized method of moments (GMM) to adjust the problem of endogeneity in the given model. This was shown in table 4.

Table 4. Regression Analysis using Generalized Method of Moments (GMM)

Variables	coefficient	SE	t- statistics	p-value
C	−0.816184	3.740940	−0.218176	0.8275
LOG (EC)	0.828618	0.235484	3.518795	0.0005
LOG(FXT)	-0.215999	0.155783	-1.386537	0.0082
LOG(GDP)	0.313812	0.244223	1.284943	0.2002
$LOG(GDP)^2$	0.265458	0.414985	0.639681	0.0031
Log(MT)	-0.389132	0.126110	-3.085655	0.1071
LOG(MS)	0.611611	0.162902	3.754472	0.0002
LOG(fc)	0.218910	0.113181	1.934158	0.0021
R-Squared	0.633560	Mean dependent var		1.731545
Adjusted R-Squared	0.581682	SD dependent var		2.261818
SE of regression	1.559039	Sum-squared resid		22.5796
Durbin–Watson stat	0.281840	*J*-statistic		1.81E-42

The results of GMM in table 4 showed that energy consumption and fuel subsidies have positive and significance impact on carbon emission. Variables like money supply showed negative and significant impact on carbon emission. In a similar vein, the results indicated that financial sector development will lessen the CO_2 emissions, thus, improving the quality of the environment in selected countries. The other statistics including adjusted R-squared show that about 58.21% variation in environmental quality is explained by the model, while the value of *J*-statistic shows that the problem of endogeneity has been adjusted and the results are free from errors.

The result further depicts that along with the increase fixed line subscription, there will be improvement in environmental quality, as if there is one percent increase in fixed line subscription, carbon emission reduce by 0.21 percent. However, the magnitude is far less than the magnitude of mobile telephone subscription that reduces emission by 0.38 percent though not significant. The empirical results also revealed that mobile telephone is having a negative but insignificant relationship with environmental pollution in selected countries during the period under study. The result showed that environmental damage continues to increase as economies of these selected countries grow, there is no inverted U-shape relationship found between economic growth and environmental pollution. In a similar vein, the results indicated that financial sector development will lessen the CO_2 emissions, thus, improving the quality of the environment in selected countries. The other statistics including adjusted R-squared showed that about 58.21% variation in environmental quality is explained by the model, while the value of *J*-statistic shows that the problem of endogeneity has been adjusted and the results are free from errors.

5. Conclusions

This paper examined the dynamic linkages between energy consumption, ICT development and environmental quality in selected ECOWAS countries using dynamic heterogeneous panel econometric technique- Generalized method of moment (GMM). This paper confirmed the conventional hypothesis, that, GDP per capita increases carbon dioxide emissions in the selected countries. The results implied that environmental quality indicator is affected by the combustion of fossil fuels energy due to the high abundance and cheap source of energy in the selected countries. Therefore, for a carbon free energy, it is substantially required that petroleum pricing policy established to address the problem of high emissions in selected countries. The results also showed there is no inverted U-shape relationship found between economic growth and environmental pollution. The implication is that environmental damage continues to increase as economies of these countries continue to grow. The results obviously would facilitate the policy planners to formulate the policies related with the carbon free economy thereby enhancing sustainable development in ECOWAS countries.

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