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Application of a Heterogeneous Panel Non-Linear Autoregressive Distributive Lag (ARDL) on Energy Sources, Economic Growth and Environmental Quality in West African Monetary Zones (WAMZ)

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ABSTRACT

This study explores the asymmetric effect of energy sources and economic growth on the environmental quality (carbon dioxide emission) in WAMZ with a view to testing the efficacy of EKC hypothesis. The study adopts Panel Non-Linear Autoregressive Distributed Lag (PNARDL) Model to a panel of six WAMZ countries with data covering 1990 to 2016. Results indicate that RGDP outcome for zone does not support the EKC hypothesis. Findings showed a long-run asymmetric relationship between renewable energy-carbon emission and between economic growth - CO_2 in WAMZ, while there exists no long-run asymmetric association between non-renewable (fossil fuel)-Carbon dioxide emission in WAMZ. We conclude that negative shock to renewable energy use and shocks to economic growth are factors that improve environmental quality in WAMZ. Since the use of non-renewable energy shows positive but insignificant impact on CO_2, we recommend the use of renewable energy for WAMZ in order to mitigate the damage done by fossil fuel.

1. INTRODUCTION

West African monetary Zones (WAMZ) are among the developing nations and just like other developing nations of the world, they are in need of rapid economic development which is needed for poverty reduction (Chakravarty & Mandal, 2020) as one of the key goal of sustainable development. Energy use has been seen as engine of economic development (Adedoyin, Abubakar, Bekun, & Sarkodie, 2020). Non-renewable energy as one of energy sources (Khan, Peng, & Li, 2019) is a key emitter which accumulates greenhouse gases that deteriorate the environment (United Nations Framework Convention on Climate Change, 1994). WAMZ as such like every other developing countries are face with the twin problem of attaining economic development in order to reduce poverty and at the same time achieve a sustainable environment.

Africa depends mostly on the consumption of fossil-fuel which contributes to about 81% of total energy consumption (Adedoyin et al, 2020). Consumption of Fossil fuel such as, coal, oil, and natural gas, etc. in Africa at large has led to increase in the greenhouse gas emission as well as fast exhaustion of non-renewable resources (coal, oil, and natural gas, firewood, etc). The need for sustainable development points toward management and planning of energy resources. Thus, the energy management recently for Africa is going transformation transition from non-renewable (fossil fuels) to renewable resources and energy-efficient technology to tackle global challenges. Developing nations and of course WAMZ states have seen the necessity of adopting clean technology which uses more of renewable energy such as solar, wind, tidal, waste, etc. rather than non-renewable energy mix (Paramati, Sinha, and Dogan, 2017).

The linkage between environmental quality and energy sources inclusive of economic growth has been a debatable topic without consensus. For instance, the relationship has been examined on the basis of Environmental Kuznets Curve (EKC) hypothesis in which different researchers found different conclusions or versions of the theory. That is, some empirical studies such as Elshimy and El-Aasar (2019), Khan, et al, (2020) and Onuoha et al (2021) have validated the EKC Hypothesis of inverted U-shape association between economic growth and the environmental quality, while Ameyaw, et al, (2020) assert that the association is of 'N-shaped instead of 'U-shaped. Others like Mohamed et al., 2019, could not find support for the EKC hypothesis but instead observed a linear linkage. This controversies of divergent opinions of the nature of the relationship between energy mix, economic growth and environmental quality motivated further inquiry into this subject matter for the WAMZ area, which includes Gambia, Ghana, Guinea, Liberia, Nigeria and Sierra Leone.

Studies like Çıtak, *et al*, (2020) employed time series non-linear ARDL to the USA to verify EKC Hypothesis, Mert and Bölük (2016) employed Panel ARDL to 21 Kyoto nations, and Attiaoui (2017) adopted Panel PMG to 22 African nations etc. This study differs from existing studies and attempts to adopt Panel Non-Linear ARDL that examines both symmetric and asymmetric nature of the linkages between energy sources, economic growth and environmental pollution in the WAMZ nations. By so doing, we believe that a better insight will be revealed for the WAMZ as group of countries with similar economy.

Thus, the aim of this study is to investigate the Environmental Kuznets Curve (EKC) Hypothesis for WAMZ nations using improved method so as to provide explanation for the divergence in conclusions reached by previous studies. The rest of the study is categorized as follows; section 2 gives a review of relevant literature while Section 3 provides the method and procedure adopted in the advancement of this study. Section 4 presents result of the study and its discussion while Section5 concludes the paper with recommendations and policy implications.

2. LITERATURE REVIEW

We adopted the Environmental Kuznets Curve (EKC) Hypothesis in this study. According to Panayotou, 1993, the EKC Hypothesis has inverted "U"-shape, explaining the association between economic growth and environmental degradation. Hence, "at the early stages of development, less attention is given to environmental purity, and the quest for growth usually leads to excessive extraction of resources which together with the unavailability of environmentally friendly technologies result in high pollution of environmental resources". This means that pollution rises with rise in income up to a threshold, beyond which pollution reduces with further rise in income. Ameyaw, et al, (2020) document that in the long-run, such a 'U'-shaped linkage may not hold because surges in income may bring about positive relationship between the pollution and economic growth beyond a specific set limit of income level, thus making the relationship 'N'-shaped.

Less developed nations are faced with the twin burden of achieving and sustaining economic development alongside ensuring environmental cleanness which constitute part of sustainable development goals. But, developing countries in which WAMZ nations belong to, largely depend on the use of non-renewable energy for economic growth, which causes environmental pollution (Onuoha et al, 2021).

Conceptually figure 1 illustrates the environmental quality caused by economic activities from industrial operations due to the exploitation and use of non-renewable and renewable energy sources. The use of these energy sources contribute to economic growth and development, which in turn influences the environment positively or negatively. Also it indicates that income rises due to improved economic activities.

Review of Related Empirical Literature

The linkage between energy sources, economic growth, and environmental pollution on has received empirical attention over the years. In Arab nations, Elshimy and El-Aasar (2019), analyzed the effect of energy sources and livestock on carbon footprint in a FMOLS and DOLS framework and found a support for EKC hypothesis. Also, they observed that while non-renewable energy and livestock increase carbon foot print, renewable energy reduces it. Ameyaw, *et al,* (2020) adopting spatial Durbin panel data technique in the examination of the linkage between CO2 and RGDP in West Africa an N-Shape association rather than inverted U-shape.

Saidi and Rahman (2020) explored the causal effect of economic growth and energy use on CO2 emission in five OPEC nations (Algeria, Nigeria, Indonesia, Saudi Arabia, and Venezuela) from 1990–2014. Employing FMOLS and DOLS, they found a bi-directional causal relationship between GDP and energy consumption for all five OPEC nations while all the countries under investigation except Algeria recorded bi-directional causal relationship between GDP and CO2 emissions. Dabachi, *et al*, (2020) explored the causal links among environmental degradation, energy consumption, energy price, energy intensity, and economic growth using simultaneous-equations models with panel data for OPEC African nations from 1970 to 2018. They found that economic growth and carbon emission, energy consumption and economic growth; and economic growth and energy prices respectively have bi-directional causal relationship for all OPEC African countries. In a similar study, Onuoha et al (2021) employed panel non-linear ARDL to determine the linkages among economic growth, energy sources and environmental quality in ECOWAS sub-region. They found support for EKC hypothesis for the case of low income nations while no evidence of EKC was found in the lower-middle income nations.

In country-specific studies, Khan, et al, (2020) examined the relationship between energy consumption, economic growth, and carbon dioxide emissions in Pakistan for the period 1965 to 2015. Employing ARDL technique, they observed fossil fuel and RGDP add to CO2 in both short run and long run. They did not validate the EKC hypothesis.

Minlah and Zhang (2020) examined the causal relationship between economic growth and carbon dioxide emissions for the existence of the Environmental Kuznets Curve for carbon dioxide emissions in Ghana with data spanning 1960 to 2014. Employing the rolling window Granger causality test and a time-varying approach, their findings indicate that economic growth has a positive effect on carbon dioxide emissions. Similarly, it was also observed that carbon dioxide emissions had a positive effect on GDP. Furthermore, results did not also validate the Environmental Kuznets Curve for carbon dioxide emissions for Ghana, which was observed to be upward sloping.

Zvereva et al, (2018) set out to investigate the interrelationship among CO2 emission, economic growth, disaggregated energy (fossil fuel and renewable) consumption, and population for China. Employing the Autoregressive Distributive Lag Model to data set spanning the period 1971 to 2013, results of the study show that energy consumption (fossil fuel) increases CO2 emissions, both in the short and the long run, but renewable energy consumption reduces CO2 emissions in the long run. Furthermore, economic growth and population increase CO2 emissions in the short run, but a diminishing impact in the long run, which validates the Kuznets curve hypothesis for China.

3. METHODS AND PROCEDURE

3.1 Data Description

Our panel data consist of six nations such as The Gambia, Ghana, Guinea, Liberia Nigeria and Sierra Leone. This paper also employs carbon dioxide emission as the dependent variable to proxy for environmental quality, and energy sources (renewable, non-renewable energy) and economic growth as explanatory variables of interest while urbanization is the control variable. Data for our study covers the period 1990-2016 due to data availability.

3.2 Model Specification

The aim of the study is to investigate the linkage between energy sources (renewable and nonrenewable) and economic growth influence environmental quality (carbon dioxide emission). We adopt urbanization as control variable for the model. Following the works of Elshimy and El-Aasar, 2019; and Onuoha et al, 2021), the functional model is specified thus;

$$CO2 = f\,(REN, FOS, RGDP, URB) \qquad (1)$$

Where: CO2 denote carbon dioxide emission as a proxy for the environmental indicator, REN is renewable energy, FOS is fossil fuel representing non-renewable energy, RGDP is gross domestic product per capita, while URB denotes urbanization.

The regression form and log transformation of equation 1 is;

$$LCo2 = \beta_0 + \beta_1 LREN_{it} + \beta_2 LFOS_{it} + \beta_3 LRGDP_{it} + \beta_4 LURB_{it} + \mu_{it} \qquad (2)$$

Where: L represents the natural log of the variables described in Equations 1. μ_{it} error terms, the subscripts 'i' and 't' represent the country (i = 1. . .6) and time (1990–2016). The coefficients, β1, β2, β3, and β4 represent the long-run elasticity estimates of the dependent variable.

3.2.1. Panel Non-linear ARDL

We adopt the Shin and Greenwood-Nimmo (2014) non-linear autoregressive technique in panel dimension representing a dynamic heterogeneous panel used for large T panels. To justify for why we use this is the fact that (i) our panel data has large T and small N meaning, N<T and N= 6 and T= 27. (ii) the method will enable us estimate both long-run and short-run elasticities which applies to series that are stationary mixed order or at all first difference, and (iii) lastly, it will help us obtain the possibility of an asymmetric effect of positive and negative effect of the independent variables on the dependent variable in both long and short-term periods. Thus, the long-run linkage can linearly modeled as:

$$LCO2_{\ it} = \alpha_{0i} + \alpha_{1i}LCO2_{t-1} + \alpha_{2i}LREN_{t-1} + \alpha_{3i}LFOS_{t-1} + \alpha_{4i}LRGDP_{t-1} + \alpha_{5i}IURB_{t-1} + \varepsilon_{it} \qquad (3)$$

I = 1,2 3……….N;, T = 1, 2, 3,……..T

where : $LCO2_{\ it}$ is the log of Carbon dioxide for each country 'i' over some time 't';
$LREN_t$ represents the log of renewable energy at period 't'; $LFOS_t$ is the log of fossil fuel consumption (non-renewable energy) at period 't'; $LRGDP_t$ denotes the log of RGDP per capita over time t; and $LURB_t$ is the log of urbanization. μ_i is the group-specific effect; 'i' is the unit of countries, and 't' is the number of periods. $\alpha_{1\text{-}5}$ are the long-run coefficients, and ε_{it} is the error term.

Reframing the works of Attiaouil & Boufateh, 2019 who adopted panel linear ARDL and Munir and Riaz, 2020 that employed NARDL on time series data, we incorporate the non-linear panel aspect of the model to establish the long run and short-run asymmetric relationships among the variables. Thus, we specify the PNARDL equation as:

$$LCO2_{\ it} = \delta_{0i} + \delta_{1i}LCO2_{t-1} + \delta_{2i}^{+}LREN_{t-1}^{+} + \delta_{2i}^{-}LREN_{t-1}^{-} + \delta_{3i}^{+}LFOS_{t-1}^{+} + \delta_{3i}^{-}LFOS_{t-1}^{-} + \delta_{4i}^{+}LRGDP_{t-1}^{+} + \delta_{4i}^{-}LRGDP_{t-1}^{-} + \delta_{5i}IURB_{t-1} + \varepsilon_{it} \qquad (4)$$

$where\ \delta_{it}$ denote coefficient vectors for long-run parameters to be estimated and $LREN_{t-1}^{+}$, $LREN_{t-1}^{-}$, $LFOS_{t-1}^{+}, LFOS_{t-1}^{-}$, $LRGDP_{t-1}^{+}$ and $LRGDP_{t-1}^{-}$ indicate the positive and negative partial sum process variation in LREN, LFOS and LRGDP respectively. The values of$LREN_{t-1}^{+}$, $LREN_{t-1}^{-}$, $LFOS_{t-1}^{+}, LFOS_{t-1}^{-}$, $LRGDP_{t-1}^{+}$ and $LRGDP_{t-1}^{-}$can be derived from the following equations;

$$lREN_{it}^{+} = \sum_{j=1}^{t} \Delta REN_{jt}^{+} = \sum_{j=1}^{t} = max(\Delta REN_{jt}, 0) \qquad (4a)$$

$$lREN_{it}^{-} = \sum_{j=1}^{t} \Delta REN_{jt}^{-} = \sum_{j=1}^{t} = min(\Delta REN_{jt}, 0) \qquad (4b)$$

$$lFOS_{it}^{+} = \sum_{j=1}^{t} \Delta FOS_{jt}^{+} = \sum_{j=1}^{t} = max(\Delta FOS_{jt}, 0) \qquad (4c)$$

$$lFOS_{it}^{-} = \sum_{j=1}^{t} \Delta FOS_{jt}^{-} = \sum_{j=1}^{t} = min(\Delta FOS_{jt}, 0) \qquad (4d)$$

$$lRGDP_{t}^{+} = \sum_{j=1}^{t} \Delta RGDP_{jt}^{+} = \sum_{j=1}^{t} = max(\Delta RGDP_{jt}, 0) \qquad (4e)$$

$$lRGDP_{t}^{-} = \sum_{j=1}^{t} \Delta RGDP_{jt}^{-} = \sum_{j=1}^{t} = min(\Delta RGDP_{jt}, 0) \qquad (4f)$$

Substituting Eq. (4) into Eq. (3) to determine the asymmetric PARDL model by differentiating the long-run and short-run asymmetric linkage such as:

$$\begin{aligned} LCO2_{\ it} = {} & \vartheta_{0i} + \vartheta_{1i}LCO2_{t-1} + \vartheta_{2i}^{+}LREN_{t-1}^{+} + \vartheta_{2i}^{-}LREN_{t-1}^{-} + \vartheta_{3i}^{+}LFOS_{t-1}^{+} + \vartheta_{3i}^{-}LFOS_{t-1}^{-} + \vartheta_{4i}^{+}LRGDP_{t-1}^{+} + \vartheta_{4i}^{-}LRGDP_{t-1}^{-} \\ & + \vartheta_{5i}IURB_{t-1} \\ & + \sum_{j=1}^{\rho 1} \gamma_{ij}\Delta lCO2_{i,i-j} \\ & + \sum_{j=0}^{\rho 2} \lambda_{ij}\Delta LREN_{t-j}^{+} + \sum_{j=0}^{\rho 3} \lambda_{ij}\Delta LREN_{t-j}^{-} + \sum_{j=0}^{\rho 4} \lambda_{,ij}\Delta LFOS_{t-j}^{+} + \sum_{j=0}^{\rho 5} \lambda_{ij}\Delta LFOS_{t-j}^{-} + \sum_{j=0}^{\rho 6} \lambda_{,ij}\Delta LRGDP_{j-t}^{+} \\ & + \sum_{j=0}^{\rho 7} \lambda_{,ij}\Delta LRGDP_{j-t}^{-} + \sum_{j=0}^{\rho 8} \lambda_{ij}\Delta lURB_{t-j} + \mu i + \varepsilon t \qquad (5) \end{aligned}$$

Where Δ represent differenced variables, $\rho1$ to $\rho8$ denote respective lag orders, $\vartheta = (\vartheta_{1i}, \vartheta_{2i}^{+}, \vartheta_{2i}^{-}, \vartheta_{3i}^{+}, \vartheta_{3i}^{-}, \vartheta_{4i}^{+}, \vartheta_{4i}^{-},)$ are the coefficients of the long-run positive and negative changes of REN, FOS and RGDP on CO2 emissions, while $\sum_{j=0}^{\rho2} \lambda_{ij} \Delta LREN_{t-j}^{+} + \sum_{j=0}^{\rho3} \lambda_{ij} \Delta LREN_{t-j}^{-}$ and $\sum_{j=0}^{\rho2} \gamma_{,ij} \Delta LREN_{i-j}^{+} + \sum_{j=0}^{\rho3} \gamma_{3,ij} \Delta LREN_{i-j}^{-}$ capture the short-run positive and negative effects of renewable energy on CO2 emissions;

$\sum_{j=0}^{\rho4} \lambda_{,ij} \Delta LFOS_{t-j}^{+}$ + $\sum_{j=0}^{\rho5} \lambda_{ij} \Delta LFOS_{t-j}^{-}$ and $\sum_{j=0}^{\rho4} \gamma_{4,ij} \Delta LFOS_{i-j}^{+} + \sum_{j=0}^{\rho5} \gamma_{5,ij} \Delta FOS_{i-j}^{-}$ express the short-run positive and negative effects of non-renewable energy on environmental quality;

$\sum_{j=0}^{\rho6} \lambda_{6,ij} \Delta LRGDP_{i-j}^{+} + \sum_{j=0}^{\rho7} \gamma_{7,ij} \Delta LRGDP_{i-j}^{-}$ indicate the short-run positive and negative impact of economic growth on CO2. More so, the long term effect of positive and negative changes on the CO2 can be calculated as λ1 = − ϑ2i/ ϑ1i, λ2 = −ϑ3i/ ϑ1i, λ3 = − ϑ4i/ ϑ1i.

Data Descriptive Properties

The data in our model are describe using descriptive statistics (see table 1). The descriptive analysis shows that RGDP has the highest mean value of 6.109704, followed by REN with the value of 4.808663 and URB with mean value of 2.504397. This implies that RGDP, REN and URB matter so much in determining the outcome for Co2 emission.

The correlation analysis in Table 2 is used to show that regressors do not have exact linear representations of each another. Hence, a correlation statistic of 0.80 and above between the explanatory variables shows evidence of a linear linkage between the variables. Our study reveals that variables are not linearly dependent as none of the variables has up to 0.80 value against each other.

Table 1: Descriptive Statistics

Variables	CO2	REN	FOS	RGDP	URB
Mean	-1.185584	4.808663	1.62734	6.109704	2.504397
Std. Dev.	0.8162254	0.9968501	5.794291	1.142952	1.708976
Minimum	-2.41272	3.933529	-3.912023	3.595667	-0.3683348
Maximum	0.000	7.405251	14.8105	7.849285	4.09301
Obs.	162	162	162	162	162

Source: Author's computation using stata 15

Table 2: Correlation Analysis

Variables	lco2	lren	lfos	lrgdp	lurb
lco2	1.0000				
lren	0.6443	1.0000			
lfos	0.8243	0.2562	1.0000		
lrgdp	-0.2697	-0.1282	-0.7479	1.0000	
lurb	-0.4402	-0.6893	-0.3416	0.3491	1.0000

Source: Author's computation using stata 15

3.3.1 Cross-sectional dependence Test

Cross-sectional dependence developed by Pesaran (2004) is an important pre-test for panel data analysis which is employed to decide on the generation of Unit root test to estimate (first or second-generation). So, we employ the Breusch and Pagan (1980) LM test, Pesaran (2004) scaled LM test, Pesaran (2004) CD test, and Baltagi et al. (2012) bias-corrected scaled LM test whose null hypothesis assert that there is no cross-sectional dependence and alternatively there is cross-sectional dependence. However, rejecting H0 means adopting the first-generation unit root tests, otherwise, applying second-generation unit root test (which is the case of this study as can be seen in table 3).

3.3.1 Panel unit root

The study applied a second-generation unit root test as necessitated by the outcome of the cross-sectional dependence test. Thus, CIPS test in heterogeneous (balanced) panels developed by Pesaran (2007) was adopted (see table 4).

4.0. RESULTS AND DISCUSSIONS

4.1. Cross Sectional Dependence and Unit Root Test

Looking at table 3, all the LM tests including Pesaran CD indicate the existence of cross-sectional dependence at a 1% significance level for almost all the variables. So, we estimate a unit root test that allow for cross-sectional dependence such as CIPS. Table 4 is the Pesaran panel unit root test in the presence of cross-sectional dependence (CIPS) shows that all the variables are integrated of order. Hence, the employment of Panel ARDL in a non-linear framework is required.

Table 3: Cross-sectional Dependence Test

Variables	*Breusch-Pagan LM*	*Pesaran scaled LM*	*Bias-corrected scaled LM*	*Pesaran CD*
LCO2	94.77526(0.000)	14.56490(0.000)	14.44952(0.000)	0.095898(0.000)
LREN	143.7197(0.000)	23.5009(0.000)	23.38551(0.000)	0.048065(0.000)
LFOS	77.50694(0.000)	11.41215(0.000)	11.29677(0.000)	1.299449(0.000)
LRGDP	133.2264(0.000)	21.58509(0.000)	21.4697(0.000)	2.654169(0.0080)
LURB	169.8431(0.000)	28.27035(0.000)	28.15496(0.000)	6.145346(0.000)

Source: Author's computation using Eviews 10

Table 4: CIPS Unit root test

	CIPS		
	Level	Ist Diff	Decision
LCO2	-2.294	-4.471	I(1)
LREN	-1.357	-3.839	I(1)
LFOS	-0.841	-4.891	I(1)
LRGDP	-2.053	-3.634	I(1)
LURB	-2.018	-3.597	I(1)
	critical values		
	10%	5%	1%
	-2.21	-2.33	-2.57

Source: Author's computation using Stata 15.

4.3 Panel Non-Linear ARDL results

Table 5 contain the panel Non-linear ARDL estimates of our model. Both mean group and pool mean group were estimated and then run the Hausman test specification which helps us to choose between the two ARDL techniques. Rejecting the H_o of the Hausman test means the application of the PMG otherwise, adopt MG estimator. Hence, the Hausman test results reveals that PMG estimator is the most appropriate estimator for modeling the Energy sources, economic growth and carbon emission linkage for the West African Monetary Zone countries. Below the short-run elasticities estimates in table 5 are the asymmetric tests for both long-run and short-run periods. The asymmetric test as the Wald test has its null hypothesis of no asymmetric relationship while the alternate hypothesis is that there is an asymmetric relationship among the variables.

Table 5: Panel NARDL

	Specification LCO2			
	Mean Group		***Pool Mean Group***	
Variables	***Coefficient***	***Prob***	***Coefficient***	***Prob***
Long Run Elasticities				
Constant	-14.69364	0.168	-0.97916	**0.036**
lren_p	-1.32312	0.33	-1.126538	0.178
lren_n	-3.367215	**0.015**	-9.168208	**0.0000**
lfos_p	-0.0545736	0.163	0.0849037	**0.281**
lfos_n	-0.3391386	0.271	0.0997866	**0.100**
lrgdp_p	-0.7180346	0.218	-1.722958	0.000
lrgdp_n	-0.4207297	0.500	-0.358257	0.006
Lurb	5.470194	0.195	0.3052027	0.175
Shor Run Elasticities				
ECT(-1)	-0.6789552	***0.0000***	-0.348515	***0.021***
lren_p	0.3611168	0.827	-0.041689	0.933
lren_n	0.0535385	0.916	-0.184211	0.738
lfos_p	0.0616521	0.369	0.0486418	0.438
lfos_n	0.1367283	0.289	0.1129013	0.189
lrgdp_p	0.2131512	0.47	0.2911555	0.390
lrgdp_n	-0.0675389	0.782	-0.028969	0.893
Lurb	-5.241481	0.269	-1.072063	0.492
Asymmetric relationship				
Long run Asymetery				
LREN	35.86	0.000		
LFOS	0.03	0.862		
LRGDP	8.58	0.003		
Short Run Asymetery				
LREN	0.05	0.8184		
LFOS	2.09	0.148		
LRGDP	0.49	0.483		
Hausman test		0.1379		

Source: Author's computation

4.4 DISCUSSIONS

Our panel unit root test results using CIPS indicate that all the CIPS statistics are greater than their critical values of 5%, and 1% only at their first differences. This means that the variables are integrated of order one [I(1)]. This test is motivated by the outcome of the cross-sectional dependence test (see table 3).

On the panel non-linear ARDL results using PMG output; findings from the long-run estimates show that a rise in renewable energy brings about a decrease in CO2 emissions insignificantly, while a decrease in renewable energy tends to depress CO2 significantly. These findings are in tandem with the outcome of Citak et al, 2020. The negative effect of renewable energy on carbon dioxide emission is in line with the findings of Attioui, 2017 and contradicts the findings of Zvereva et al, 2020. Also, the insignificant association between positive shock of renewable energy and CO2 is in tandem with the findings of Onuoha et al, 2021.

As for non-renewable energy, positive and negative shocks in fossil fuel consumption add to CO2 emissions insignificantly in WAMZ. More so, the result suggests that both positive and negative components of economic expansion (RGDP) significantly reduce CO2emission in WAMZ nations. Urbanization models has an insignificant positive impact on environmental quality. However, the based on the outcome of the signs of economic growth coefficients, we could not establish or validate the EKC hypothesis which corroborates with the findings of Khan et al (2020): and Minlah and Zhang (2020).

The short-run estimates suggest that Error correction term is negative and significant with error term of 0.349. The sign and significant nature of the ECM meet the theoretical expectation and this further entails the restoration of the long-run equilibrium after an exogenous shock. This further means that errors are corrected at the adjustment speed of about 34.9 percent annually. All the variables exhibit no significant influence on carbon emission in the short run which means there is no short run causal linkages among the variables.

The long-term asymmetric test revealed a Wald test probability values of 0.000, 0.862, and 0.003 for LREN, LFOS, and LRGDP respectively. This means rejection of null hypothesis for LREN and LRGDP but acceptance of Ho for LFOS. This further means that there is a long-run asymmetric relationship between renewable energy-carbon emission and between economic growth - CO2 in WAMZ, while there exists no long-run asymmetric association between non-renewable (fossil fuel use)-Carbon dioxide emission in WAMZ. However, the three variables are seen to exert no short-run asymmetric effect on CO2 (see table 5).

5.0. CONCLUSION AND RECOMMENDATION

Energy consumption irrespective of the source is known as the engine that drives economic development. But economic development has posed a great challenge for developing nations as well as Africa in general and WAMZ in particular. The issue of how to exploit energy sources to address the developmental needs of the WAMZ area has become the central focus of the development agenda of the zone with sustainable development gaining attention recently because of the need to recognize the importance of not destroying the planet as the exploitation of resources go on. The current study sought to investigate the influence of exploitation of different energy sources with economic growth inclusive that comes as a result of environmental pollution (CO2) to validate the Environmental Kuznets Curve Hypothesis for WAMZ.

The study found that the association between environmental quality and economic growth does not validate or find support for inverted U-shape proposed by Panayotou (1993) for WAMZ. Furthermore, the significance of the asymmetric relationship between carbon emission with renewable energy and economic growth in the long run for WAMZ supports our argument that Panel Non-linear ARDL is a superior method of estimation than previous methods used by earlier empirical studies.

We conclude that negative shock to renewable energy use and shocks to economic growth are factors that improve environmental quality in WAMZ. Since the use of non-renewable energy shows positive but insignificant impact on CO2, we recommend the use of renewable energy for WAMZ in order to mitigate the damage done by fossil fuel.

5.1. Policy implications

The study opines that the ECOWAS sub-region is still in dire need of development and so would be exposed to environmental challenges. Strong ecological/environmental policies that accommodate best practices in the exploitation of abundant resources within the sub-region should be pursued as one of the policy options to drive development. Policy on environmental quality should focus on carbon footprint rather than carbon 2 emission to achieve a holistic clean environment safe for humans, plants, animals, and other creatures. The study recommends that policymakers in WAMZ should adopt and promote renewable energy sources than old traditional energy sources such as coal, gas, and oil so as to obtain sustainable environment.

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