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Simultaneous Determination of the Relationship between Economic Growth, Energy Consumption, Trade and the Environment in West Africa

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Abstract

Energy plays important roles in human lives and economic growth. Energy use however, have its environmental impacts. Economic growth may also be achieved through international trade and this can also impact the environment by increasing energy consumption and consequently, pollution. To this end, this study examined the interrelatedness of energy consumption, environmental pollution, international trade and the economic growth in nine of the West African countries from 1990 to 2018 using the method of two stage least squares (2SLS). The study found contrary to expectation, that economic growth and international trade have no significant impact on carbon dioxide emissions in West Africa. Foreign Direct Investment (FDI) and Financial Development (FD) have no significant impact on carbon dioxide emission in West Africa. Trade openness significantly increased emission in the West African countries. Energy consumption, in conformity with economic theory has positively contributed significantly to the rise in carbon emission in West African states. Trade openness significantly increases economic growth. Other results indicate that economic growth bears no significant influence on energy consumption. This is a benefit rather than a problem as de-linking energy consumption from economic growth is a good objective of any government. Urbanization significantly increased energy consumption in West Africa. Lastly, foreign direct investment, significantly contributed positively to trade growth in West Africa. This study recommends a switch to more renewable and clean sources of energy as opposed to the fossil-based energy sources in order to de-link energy demand from emissions in their countries. Governments can also encourage the development and use of energy efficient technology or enact energy conservation policies so as to reduce fossil - fuels use among others.

Keywords: Carbon dioxide emission, Economic growth, Energy consumption, 2SLS, Environment

1.0 INTRODUCTION

Economic growth denotes an increase in the production of goods and services over a period of time. It creates more profits for businessmen, leads to rise in stocks and encourage more investment and consequently more employment. It also increases the purchasing power of the customers which further drives

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economic growth. Based on these, all countries pursue economic growth consistently.

Energy plays important roles in human lives and economic growth. Energy consumption of a country is regarded as a major indicator of economic growth in today's world. Energy is a major input in the production processes. In addition, it is also regarded as a strategic input that creates the basis for international relations and shape of the world politics and economy.

There are two main factors accelerating energy use in the literature and they are population growth and economic growth which tends to increase per capita energy use. Energy use however, have environmental impacts on air, water and land; but its effects varies. The reliability and energy costs are the major determinants of competitiveness and economic growth of small and large enterprises worldwide.

Economic growth can also be boosted through international trade expansion. Trade - induced economic growth can also impact the environment by increasing energy consumption and consequently, pollution and natural resources degradation and depletion. Based on the above, there is a perceived interrelatedness between energy consumption, environment, international trade and economic growth. This study therefore analyzed the interrelatedness of energy use, environment, international trade and economic growth in nine West African countries. These countries are: Benin Republic, Cote D'ívoire, Cameroon, Congo Demographic, Congo Republic, Ghana, Nigeria, Senegal and Togo. The choice of these countries is their similarity and their membership of ECOWAS bloc. The non-availability of data acted as constrain preventing us from including all member ECOWAS countries.

2.0 LITERATURE REVIEW

This section focuses on energy consumption, International trade, environment and economic growth. The first group of literature considered the interrelationship between energy consumption and growth. The second considered energy consumption, growth and the environment. The third group considered energy consumption, growth, environment and international trade while the fourth group considered energy consumption, economic growth, the environment and financial development. In terms of tools of analysis, they are split between causality approach and regression using simultaneous analytical methods.

This review shall cover all the above empirical focuses in order to properly guide our own approach.

Dabachi et. al. (2020) investigated the casual relationships among energy consumption, environmental degradation, energy price, energy intensity and economic growth in OPEC African countries from 1970 to 2018 using the simultaneous equation casualty models. The study found a bi-directional causality between energy consumption and economic growth; energy prices and economic growth; environmental degradation and economic growth. There is a uni- directional casualty running from; economic growth to energy intensity; energy consumption to energy intensity. There is a bi- directional causality between energy prices and energy intensity; environmental degradation and energy intensity and; between environmental degradation and energy prices among others.

Acheampong (2018) examined the dynamic causal relationship between, energy consumption, carbon dioxide emission and economic growth for 116 countries for the period 1990 to 2014 using the panel vector autoregression (PVAR) as well as system generalized method of moments (System- GMM). The study found the existence in support of evidence in support of the environmental Kuznets curve globally and in sub- Saharan African countries. Economic growth does not cause.

Khan, Peng and Li (2019) utilized panel data spanning from 1990 to 2017 to analyze the interrelatedness of financial development, economic growth, energy consumption and carbon emission on one another. The study was carried out on 193 countries using the seemingly unrelated regression, three- stage least squares, dynamic model two- steps generalized methods of moments. The study found economic growth, financial development, energy consumption and carbon emissions affected one another but with wide pollution spread energy consumption decreases financial development. The study also confirmed the existence of environmental kuznet's curve.

Omri et. al. (2015) examined the relationship existing between carbon dioxide emissions, financial development, trade and economic growth for middle east and north Africa (MENA) countries using simultaneous-equation panel data models and spanning from 1990 to 2011. The study found a bi-directional causality between carbon dioxide emission and economic growth. They also found a bi- directional causality between economic growth and trade openness. They validated the feedback hypothesis between trade openness and financial development. There is no causality between carbon dioxide emissions and financial development. They also found unidirectional causality running from financial development to economic growth and; from trade openness to carbon emissions. They established the reality of Environmental kuznet's curve (EKC) related to energy consumption both globally and regionally. Economic growth has no casual impact on carbon emission apart from global and regional levels. However, economic growth has a negative impact on carbon emissions at global as well as at regional levels. Carbon emissions positively cause economic growth. Carbon emission positively causes economic growth in the sub Saharan Africa but negatively causes growth at the global level, MENA, Asia- Pacific and Carribean- Latin America. With the exemption of MENA, and global sample, carbon emission do not cause energy consumption. Lastly, energy consumption positively causes carbon emission in MENA but negatively causes emission in the Sub- Saharan Africa and Carribbean- Latin America.

Saboori and Sulaiman (2013) tested both the Short run and Long run relationship between carbon dioxide emission and economic growth and energy consumption in Malaysia using both aggregated and disaggregated data for the period 1980 to 2009, and using the method of cointegration, Autoregressive Distributed Lag (ARDL) and Granger casuality test and, Vector Error Correction Model (VECM). They found the non- existence of environmental Kuznets when aggregated energy data was used that different energy sources, environmental Kuznets curve was validated. There is a long- run bi- directional casuality between economic growth and carbon emissions among others.

Kasman and Duman, Y. S. (2014) investigated the casual relationship between economic growth, energy consumption, carbon dioxide emissions, trade openness and urbanization in new EU members and candidate countries from 1992 to 2010 using the method of unit roots, co integration and panel causality tests. Their results support the existence of Environmental Kuznets curve. Their results also support the existence of a short unidirectional causality from energy consumption, trade openness and carbon dioxide to carbon emission. There is causality from GDP to energy consumption. There is existence of casualty from GDP to energy consumption and urbanization to trade openness; and from urbanization to trade openness among other findings.

Chuku and Ndifreke (2012) analyzed simultaneously the inter relationship among energy consumption, environmental quality, trade and economic growth in Nigeria from 1970 to 2008 using the method of two- stage least square technique applied on four simultaneous equations. Their results from income equation showed that production in Nigeria is pollution-intensive and environmentally harmful. Their study contradicts the existence of environmental Kuznets curve and prove the existence of U-shaped. The energy equation indicates that there is a direct relationship between energy use and technical progress. Their trade equation and nullifies the existence of pollution- havens hypothesis in Nigeria.

Taghavae, Aloo and Shirazi (2016) employed simultaneous equations systems to analyze the various socio-economic elasticities in the short and long run in Iran utilizing data from 1974 to 2012. The study found per capita carbon dioxide emissions, energy consumption and GDP showed the strongest interactions in terms of relationships and elasticities in the system; in the long run. Trade openness, financial development and labour force as well as urbanization showed the strongest effect in the short run. Generally, in the short run; growth and energy consumption had positive significant impact on carbon dioxide emission but; financial development has negative significant impact on carbon dioxide emission. Trade openness and labour has positive significant positive elasticities on economic growth. In the long run, growth and energy consumption have significant positive impacts on carbon dioxide emission while Islamic revolution reduced carbon emission in Iran. Growth is significantly affected positively by carbon dioxide emission and negatively by energy consumption. Lastly, Urbanization contributed significantly positively to energy consumption in Iran.

Wulansari and Rosadi (2018) analyzed the determinants of economic, social and environmental factors for 33 provinces in Indonesia for the period 2011 to 2014 using the simultaneous panel data analysis. They specified three structural equations and analyzed using the method of error components two-stage least squares (EC2SLS). The study found a negative significant impact of environmental quality on economic growth. Environmental quality also exerted negative significant impacts on human development index and; economic growth significantly reduces environmental quality index in Indonesia.

Honglei, Xiaorong and Quifeng (2011) employed simultaneous equation models of Huang and Laby (2003) to analyze the interactions between foreign trade, FDI, environmental pollution and economic growth in China using the Chinese regional panel data spanning from 1993 to 2007. Their study involve estimation of four structural equations with fourteen variables. They found that increase in employment investment in fixed assets and amount of trade (import and export) causes growth to increase. In addition, the study confirmed the existence of environmental Kuznet's curve in China meaning that environmental pollutions will increase with growth before reaching the turning point. There is a positive correlation between emissions and environmental regulations. The six indicators of emissions are negatively related to the opening of the economy. This means that trade openness is good for the environment or put in another way. Export oriented economy is good for local environment generally.

Various scholars have made contributions in the area of energy consumption, environment, international trade and growth, some have analyzed the relatedness of energy consumption and environment while others the impact of growth on environment. Some have analyzed the interrelatedness of energy, growth and environment using various techniques ranging from causality to least squares. Some have analyzed neglecting the possibility of endogeneity and possible violation of one of the least square's assumptions. The debate is yet inconclusive. This study takes a leap from there using a more innovative technique in making contributions to the discourse of energy consumption, economic growth and environment in Nigeria.

3.0 MATERIALS AND METHODS

The simultaneous model for this study is adapted from Vahid, Alireza and Jalil (2016) and Honglei, Xiaorong and Qiufeng (2011). The functional form of Vahid, Alireza and Jalil simultaneous model is as follows:

CO = f(GDP, E, OP, FD, dr) ....(1)
GDP = f(CO, E, OP, LAB, CAP, dr, dw)...(2)
E = f(CO, GDP FD, U, LAB, CAP, dr)..(3)

Where:
CO is carbon dioxide emission (per capita metric tons)
GDP is the per capital GDP (in constant prices)
E is the energy consumption (per kg of oil equivalent)
OP is trade openness
FD is financial development (domestic credit to private sector as a percentage of GDP)
Dr is the dummy variable capturing Islamic revolution in Iran.
Dw is the dummy variable capturing war periods in Iran.
LAB is the labour force participation (active population as per cent of total population.

CAP is capital (per capita at constant prices
U is urban population as per cent of total population.

This study, adjusted the equations as follows:
For equation one we found the dummy variable capturing Islamic revolution in Iran redundant, and it was removed. Foreign Direct Investment (FDI) has been hypothesized to influence emission and this important variable was omitted in equation one, this we added to equation one. We also removed the two dummy variables capturing war and Islamic revolution and then this study added FDI since it is hypothesized to have a positive impact on growth. For equation three, this study also removes dr, FD and LAB since labour and financial development are not expected to impact on energy consumption. Equation four was adapted fromHonglei, Xiaorong and Qiufeng (2011). The functional form of their trade model is as follows:

T = f (Y, FDI, DT, TN, ER) .... (4)

Where T is foreign trade, Yis total output, FDI is foreign direct investment, DT is geographical positions, TN is tarrif level or trade policy and ER is the exchange rate.
Equation four is adjusted by removing DT since our data is based on aggregated data. Geographical positions can only be relevant for disaggregated data. We added emission because pollution haven hypothesis is based on the hypothesized role of environment in the determination of foreign trade. Based on these adjustments, the functional model for this study are stated thus.

CO2 = f (GDP, E, OPEN, FD, FDI)..(5)
GDPPC = f (CO2, E, TR, OPEN, LAB, GCF, FD)..(6)
E = f (CO2 GDDPC, TR, FDI, URBAN, OPEN, GCF)...................................(7)
TR = f (GDPPC, FDI, E, TAR, EXR) ....(8)

CO2 is the CO2 emissions (metric tons per capita)
FD is the domestic credit to private sector by banks (% of GDP)
E is the energy use (kg of oil equivalent per capita)
FDI is the foreign direct investment, net inflows (% of GDP)
GDPPC is the GDP per capita (constant 2010 US$)
GCF is the gross fixed capital formation (constant 2010 US$) a proxy for capital
LAB is the Labor force participation rate, total (% of total population ages 15-64) (modeled ILO estimate)
OPEN is trade (% of GDP)
URBAN is the urban population (%t of total population)
TR is net trade in goods and services (BoP, current US$
EXR is the exchange rate (LCU per US$, period average)
TAR is tarrif rate, applied, weighted mean, all products (%)

The econometric forms of the structural equations are:

$$CO2_{it} = \beta_0 + \beta_1 GDPPC_{it} + \beta_2 E_{it} + \beta_3 OPEN_{it} + \beta_4 FD_{it} + \beta_5 FDI_{it} + \mu_{1t} \quad ---(9)$$
$$GDPPC_{it} = \alpha_0 + \alpha_1 CO2_{it} + \alpha_2 E_{it} + \alpha_3 TAR_{it} + \alpha_4 OPEN_{it} + \alpha_5 LAB_{it} + \alpha_6 GCF_{it} + \alpha_7 FD_{it} + \alpha_8 TR_{it} + \mu_{2t} \quad (10)$$
$$E_{it} = \varphi_0 + \varphi_1 CO2_{it} + \varphi_2 GDPPC_{it} + \varphi_3 TR_{it} + \varphi_4 FDI_{it} + \varphi_5 URBAN_{it} + \varphi_6 OPEN_{it} + \varphi_7 GCF_{it} + \mu_{3t} ---(11)$$
$$TR_{it} = \pi_0 + \pi_1 GDPPC_{it} + \pi_2 E_{it} + \pi_3 FDI_{it} + \pi_4 TAR_{it} + \pi_5 EXR_{it} + \mu_{4t} \quad ---(12)$$

This study analyzed equations 9, 10, 11 and 12 simultaneously using the method of two-stage least squares (2SLS). Theoretically, it has been confirmed that variables CO2, GDPPC, E and TR are endogenous. In other words, pollution, economic growth, energy consumption and international trade are jointly determined and so are endogenous. The implication of the existence of endogeneity in the explanatory variables of the model is that it causes correlation between those explanatory variables and their respective error terms causing biasedness in our estimates using OLS. Because of this, OLS cannot be applied recursively to each equation as there would be simultaneous equation bias. Another issue is the identification status of our equations.

The study tested for the identification status using the 'order' and 'rank' condition since order condition is a necessary condition while the rank condition is a sufficient condition. The four equations are indeed identified. All the four equations are overidentified. The study tested for panel stationarity of variables and also conducted co-integration of variables of each equation and established co-integration of variables of each equation.

Data for the study were obtained from the World data bank and data ranges from 1990 to 2018. However, we have some missing data which were interpolated or simulated. For instance, carbon dioxide data for each country of the study were having 2014 to 2018 data missing and an autoregressive process of order one was used in generating for each country. Data for tarrif were scantily provided and were all simulated. In a few cases energy consumption data were not up to date just like the carbon dioxide data, these were also generated through an autoregressive process of order one. The nine countries studied are: Benin Republic, Cote D'ívoire, Cameroon, Congo Demographic, Congo Republic, Ghana, Nigeria, Senegal and Togo. The choice of these countries is their similarity and their membership of ECOWAS bloc. The non-availability of data also acted as constraint preventing us from including all member ECOWAS countries, but we believe that the study will not suffer a self - selection bias.

4.0 RESULTS AND DISCUSSION

Stationarity results of variables of the models are presented in table 1. The tests are four in number. Levin, Lin & Chu t*, Im, Pesaran and Shin W-stat, ADF - Fisher Chi-square, PP - Fisher Chi-square. Levin, Lin & Chu t* tested stationarity of the pooled data while other tests are for testing the stationarity of different pooled series.

Table 1: Stationarity results of the variables of the models

	Tests at levels				Tests at first difference				
Variables	Levin, Lin & Chu t*	Im, Pesaran and Shin W-stat	ADF - Fisher Chi-square	PP - Fisher Chi-square	Levin, Lin & Chu t*	Im, Pesaran and Shin W-stat	ADF - Fisher Chi-square	PP - Fisher Chi-square	Order of integration
CO2	-0.00179 (0.4993)	-0.6025 (0.2734)	20.7084 (0.2944)	28.417 (0.0560)	-13.2784 (0.0000)	-11.5148 (0.0000	140.580 (0.0000)	167.802 (0.0000)	I (1)
E	0.54154 (0.7059)	2.28335 (0.9888)	5.87609 (0.9967)	6.45974 (0.9939)	-13.5331 (0.0000)	-11.4252 (0.0000)	137.827 (0.0000)	133.124 (0.0000)	I (1)
EXR	2.38338 (0.9914)	1.01443 (0.8448)	24.3218 (0.1448)	20.4866 (0.3061)	-9.86122 (0.0000)	-8.10829 (0.0000)	109.170 (0.0000)	114.305 (0.0000)	I (1)
FD	-0.75747 (0.2244)	0.22689 (0.5897)	20.1981 (0.3218)	17.2938 (0.5030)	-8.60133 (0.0000)	-9.75590 (0.0000)	117.859 (0.0000)	120.651 (0.0000)	I (1)
FDI	0.14606 (0.5581)	1.26438 (0.8970)	17.8526 (0.4654)	25.5649 (0.1101)	-15.4017 (0.0000)	-16.6126 (0.0000)	197.848 (0.0000)	208.739 (0.0000)	I (1)
GDPPC	4.99296 (1.0000)	5.98377 (1.0000)	2.35422 (1.0000)	14.9814 (0.6632)	-3.72213 (0.0001)	-3.99147 (0.0000)	48.9314 (0.0001)	69.8188 (0.0000)	I (1)
LAB	-1.11955 (0.1315)	0.04053 (0.5162)	17.2818 (0.5038)	5.48022 (0.9979)	4.74945 (0.0004)	-1.94144 (0.0261)	26.5461 (0.0879)	23.5215 (0.1713)	I (1)
OPEN	-0.54174 (0.1055)	-2.55042 (0.0054)	32.1377 (0.0812)	32.2354 (0.0806)	-14.4163 (0.0000)	-13.0767 (0.0000)	161.273 (0.0000)	206.943 (0.0000)	I (1)
TAR	-1.21052 (0.1130)	-1.55989 (0.0594)	25.1676 (0.1204)	39.4717 (0.0025)	-15.1933 (0.0000)	-15.7096 (0.0000)	175.464 (0.0000)	203.640 (0.0000)	I (1)
TR	1.83593 0.1332	-0.56555 0.2859	20.4177 0.3098	19.6183 0.3547	-15.3562 0.0000	-15.2712 0.0000	189.541 0.0000	204.412 0.0000	I (1)
URBAN	-0.73576 0.2309	6.03887 1.0000	19.5189 0.3605	14.9776 0.6635	-2.63474 0.0042	-4.06228 0.0000	269.945 0.0000	20.9456 0.2822	I (1)
GCF	6.33521 (1.0000)	5.97539 (1.0000)	15.8205 (0.6051)	14.0493 (0.7259)	-8.96097 (0.0000)	-9.43838 (0.0000	121.954 (0.0000)	149.530 (0.0000)	I (1)

Results in table one indicates that all variables of the model are stationary at first differences. Meaning that all are integrated of order one. When all variables are integrated of order one, to test for cointegration of each variable, Johansen Fisher Panel Cointegration Test is appropriate and reliable. The cointegration results for each equation are presented in table 2.

Table 2: Johansen Fisher Panel Cointegration Results

	EQUATION 9		**EQUATION 10**		**EQUATION 11**		**EQUATION 12**	
Hypothesized No. of CE(s)	Series: CO2 GDPPC E OPEN FD FDI		Series: GDPPC CO2 E TR LAB GCF FD		Series: E CO2 GDPPC FDI URBAN OPEN GCF		Series: TR GDPPC E FDI EXR	
	Fisher Stat.* (from trace test) Prob.	Fisher Stat.* (from max-eigen test) Prob.	Fisher Stat.* (from trace test) Prob.	Fisher Stat.* (from max-eigen test) Prob.	Fisher Stat.* (from trace test) Prob.	Fisher Stat.* (from max-eigen test) Prob.	Fisher Stat.* (from trace test) Prob.	Fisher Stat.* (from max-eigen test) Prob.
None	204.9 0.0000	123.9 0.0000	397.8 0.0000	328.3 0.0000	453.1 0.0000	310.8 0.0000	139.7 0.0000	118.1 0.0000
At most 1	97.38	59.09	253.6	137.5	301.6	147.6	49.30	42.93

	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0008
At most 2	50.51 0.0001	35.71 0.0077	142.6 0.0000	61.82 0.0000	180.2 0.0000	93.02 0.0000	19.75 0.3469	17.74 0.4732
At most 3	26.31 0.0929	19.24 0.3771	94.41 0.0000	50.03 0.0001	103.0 0.0000	52.68 0.0000	12.23 0.8352	10.39 0.9186
At most 4	18.82 0.4030	15.84 0.6036	57.95 0.0000	30.62 0.0318	64.09 0.0000	37.89 0.0040	21.34 0.2625	21.34 0.2625
At most 5	25.34 0.1158	25.34 0.1158	43.58 0.0007	37.91 0.0040	44.24 0.0005	31.05 0.0284	-	-
At most 6	-	-	31.48 0.0253	31.48 0.0253	45.31 0.0004	45.31 0.0004	-	-
No of cointegrating equations	At most 3		At most 6		At most 6		At most 1	

Table two presents the Johansen Fisher panel cointegration results and examining the results of all equations under two analytical techniques of Fisher Statistics* (trace test) and; Fisher Statistics* (max-eigen test), the null hypothesis of no cointegration was rejected based on the two tests. We therefore conclude that there is cointegration for all equations. There is the need to test for identification of our equations. This precede the estimation of our equations.

Identification

The identification status of equations in a system of simultaneous equation estimation techniques is a pre-condition for estimation. There are two identification status which are: overidentification and exactly identified. This study will subject all the four equations to identification test as follows:

The order Condition

These are the decision criteria for identification:

i. If M < G-1 the equation is underidentified
ii. If M = G-1 the equation is exactly identified
iii. If M > G-1 the equation is overidentified

Where, G is the number of endogenous variables in the system. M is the missing variable (endogenous or exogenous/pre-determined variables) in equation under consideration (Asteriou and Hall, 2007).

In the four equations of this study, the results based on order condition are:

Equation 7: G = 4 and M = 6; therefore 6>4 -1 or 6 > 3 so equation 9 is overidentified.
Equation 8: G = 4 and M = 4; therefore 4>4 - 1 or 4>3 so equation 10 is overidentified.
Equation 9: G = 4 and M = 5; therefore 5>4 -1 or 5 >3 so equation 11 is overidentified.
Equation 10: G = 4 and M = 6; therefore 6 > 4 -1 or 6 > 3 so equation 12 is overidentified

The four equations are identified by order condition (necessary condition), hence, we need to carry out the order condition test which is the sufficient condition.

Rank Condition

Rank Condition for equation 9:

	CO2	GDPPC	E	TR	OPEN	FD	FDI	LAB	GCF	URBAN	TAR	EXR
Equation 1	√	√	√	0	√	√	√	0	0	0	0	0
Equation 2	√	√	√	√	√	√	0	√	√	0	0	0
Equation 3	√	√	√	√	√	0	√	0	√	√	0	0
Equation 4	0	√	√	√	0	0	√	0	0	0	√	√

	TR	LAB	GCF	URBAN	TAR	EXR
Equation 2	√	√	√	0	0	0
Equation 3	√	0	√	√	0	0
Equation 4	√	0	0	0	√	√

There are at least G – 1 = 3 rows and columns with no all-zero elements (in the second table above), so the rank condition is satisfied.

Rank Condition for equation 10:

	CO2	GDPPC	E	TR	OPEN	FD	FDI	LAB	GCF	URBAN	TAR	EXR
Equation 1	√	√	√	0	√	√	√	0	0	0	0	0
Equation 2	√	√	√	√	√	√	0	√	√	0	0	0
Equation 3	√	√	√	√	√	0	√	0	√	√	0	0
Equation 4	0	√	√	√	0	0	√	0	0	0	√	√

	FDI	URBAN	TAR	EXR
Equation 1	√	0	0	0
Equation 3	√	√	0	0
Equation 4	√	0	√	√

There are at least G – 1 = 3 rows and columns with no all-zero elements (in the second table above), so the rank condition is satisfied.

Rank Condition for equation 11:

	CO2	GDPPC	E	TR	OPEN	FD	FDI	LAB	GCF	URBAN	TAR	EXR
Equation 1	√	√	√	0	√	√	√	0	0	0	0	0
Equation 2	√	√	√	√	√	√	0	√	√	0	0	0
Equation 3	√	√	√	√	√	0	√	0	√	√	0	0
Equation 4	0	√	√	√	0	0	√	0	0	0	√	√

	FD	LAB	TAR	EXR
Equation 1	√	0	0	0
Equation 2	√	√	0	0
Equation 4	0	0	√	√

There are at least G – 1 = 3 rows and columns with no all-zero elements (in the second table above), so the rank condition is satisfied.

Rank Condition for equation 12:

	CO2	GDPPC	E	TR	OPEN	FD	FDI	LAB	GCF	URBAN	TAR	EXR
Equation 1	√	√	√	0	√	√	√	0	0	0	0	0
Equation 2	√	√	√	√	√	√	0	√	√	0	0	0
Equation 3	√	√	√	√	√	0	√	0	√	√	0	0
Equation 4	0	√	√	√	0	0	√	0	0	0	√	√

	CO2	OPEN	FD	LAB	GCF	URBAN
Equation 1	√	√	√	0	0	0
Equation 2	√	√	√	√	√	0
Equation 3	√	√	0	0	√	√

There are at least G – 1 = 3 rows and columns with no all-zero elements (in the second table above), so the rank condition is satisfied.

Table 3: 2SLS Results for the equations

	EQUATION 9	EQUATION 10	EQUATION 11	EQUATION 12
	Dependent Variable: CO2	Dependent Variable: GDPPC	Dependent Variable: E	Dependent Variable: TR
	Instrument specification: C OPEN FD FDI TAR LAB GCF URBAN TAR EXR	Instrument specification: C OPEN FD FDI TAR LAB GCF URBAN TAR EXR	Instrument specification: C OPEN FD FDI TAR LAB GCF URBAN TAR EXR	Instrument specification: C OPEN FD FDI TAR LAB GCF URBAN TAR EXR
CO2		4001.182 (6.286007) (0.0000)	245.2628 (3.621746) (0.0004)	
GDPPC	0.000179 (10.38388) (0.0000)		-0.188489 (-10.13608) (0.0000)	-1396529. (-3.178847) (0.0017)
E	0.000187 (3.584264) (0.0004)	-2.563281 (-0.659710) (0.5100)		5082975. (2.531809) (0.0119)
TR		-3.54E-08 (-1.075015) (0.2834)		
OPEN	-0.000764 (-2.759264) (0.0062)	8.466072 (1.880292) (0.0612)	1.606717 (5.458949) (0.0000)	
LAB		6.160638 (0.490602) (0.6241)		
FD	0.008664 (9.41846) (0.0000)	-28.08820 (-1.443088) (0.1502)		
FDI	-4.22E-12 (-0.645695) (0.5191)		-4.76E-10 (-0.086578) (0.9311)	1.215127 (5.533927) (0.0000)
URBAN			7.965787 (11.70533) (0.0000)	
GCF		2.52E-08 (0.716925) (0.4741)	9.96E-09 (17.73503) (0.0000)	
TAR				-30871769 (-0.804388) (0.4219)
EXR				-1191411. (-1.377746) (0.1695)
R-squared	0.540939	0.334326	0.552777	0.196842
Adjusted R-squared	0.533738	0.318540	0.543974	0.184244
Durbin-Watson stat	0.373080	0.343821	0.197211	0.539794
Prob(J-statistic)	0.000002	0.000000	0.000002	0.005952
Instrument rank	9	9	9	9
Included observations:	260	260	260	260

*, **, *** means significant at 1%, 5% and 10% respectively. Numbers in parenthesis under the coefficients are the t-statistics and the probabilities respectively.

Table three above presents the 2SLS results of the four structural equations. A point must be noted about the reported summary statistics of the three equations. They are only asymptotically valid in Eviews estimates. (Eviews User's Guide, 1994-1997, pp. 283). Based on data size of 260, we cannot categorically that our estimates lack the asymptotic characteristics. The summary statistics showed low coefficient of determination, low Durbin Watson statistics, and above all J – statistics that are highly significant is an indication of problem with the estimation of the structural equation. Therefore, we conduct tests for autocorrelation of the Lagrange Multiplier (LM) tests presented in table 4.

Table 4: Autocorrelation results for the equations

Null hypothesis:	Autocorrelation results before correcting for autocorrelation in the equations				Autocorrelation results after correcting for autocorrelation in the equations			
No cross-section dependence (correlation) in residuals	Equation 9	Equation 10	Equation 11	Equation 12	Equation 9	Equation10	Equation 11	Equation 12
Breusch-Pagan LM	82.02902 (0.0000)	130.3258 (0.0000)	184.3830 (0.0000)	366.5169 (0.0000)	30.37244 (0.7329)	32.08332 (0.6554)	29.1184 (0.8909)	49.42288 (0.1102)
Pesaran scaled LM	5.424572 (0.0000)	11.11640 (0.0000)	17.48710 (0.0000)	38.95179 (0.0000)	-0.663214 (0.5072)	-0.46158 (0.6444)	1.72453 (0.3064)	0.57435 (0.3100)
Pesaran CD	3.818731 (0.0001)	1.002249 (0.3162)	2.019605 (0.0434)	17.06288 (0.0000)	0.423452 (0.6720)	0.388110 (0.6979)	0.92637 (0.3543)	0.427060 (0.6006)

The null hypothesis of the tests is based on No cross-section dependence (correlation) in residuals. And three methods of evaluations used are: Breusch-Pagan LM, Pesaran scaled LM and; Pesaran CD. The results for each structural equations in table 3 rejected the no cross-section dependence (correlation) in residuals. This means that there is correlation in cross-section residuals. When the autocorrelation was corrected and we tested for the existence or otherwise of serial correlation in residuals, the results are also depicted in the last four columns to the right in table 4. We cannot reject the null hypothesis in that case indicating that there is no more serial correlation in our residuals and estimates in table 5 is good for interpretation and forecast.

Table 5: 2SLS Results after correcting for autocorrelation

Variables	**Equation 9**	**Equation 10**	**Equation 11**	**Equation 12**
	Dependent Variable: CO2	Dependent Variable: GDPPC	Dependent Variable: E	Dependent Variable: TR
	Instrument specification: C OPEN FD FDI TAR LAB GCF URBAN TAR EXR	Instrument specification: C OPEN FD FDI TAR LAB GCF URBAN TAR EXR	Instrument specification: C OPEN FD FDI TAR LAB GCF URBAN TAR EXR	Instrument specification: C OPEN FD FDI TAR LAB GCF URBAN TAR EXR
CO2		1490.242 (0.880166) (0.3796)	31.53101 (0.366577) (0.7143)	
GDPPC	5.29E-05 (0.528449) (0.5977)		0.039061 (0.568312) (0.5703)	-1109801. (-1.043145) (0.2979)
E	0.000719 (2.035795) (0.0428)	-1.879741 (-0.758630) (0.4488)		4820150. (1.266144) (0.2067)
TR	-3.99E-08 (-0.640330) (0.5226)			
OPEN	0.000700 (1.808379) (0.0718)	24.52012 (2.907468) (0.0040)	-0.036816 (-0.260011) (0.7951)	
LAB		-9.544800 (-1.138053) (0.2562)		
FD	-0.001787 (-1.016037) (0.3106)	-1.656396 (-0.051532) (0.9589)		
FDI	-5.07E-12 (-0.820694) (0.4126)		-6.28E-10 (-0.301713) (0.7631)	0.600671 (2.345910) (0.0198)
URBAN			6.285106 (2.357095) (0.0192)	
GCF		4.00E-08 (1.489784) (0.1376)	-5.40E-10 (-0.906444) (0.3656)	
TAR				-28483316 (-0.876726) (0.3815)
EXR				-1184472. (-0.709887) (0.4784)
AR(1)	0.925662 (27.99757) (0.0000)	0.802277 (14.68903) (0.0000)	0.989957 (116.3379) (0.0000)	0.752271 (17.01404) (0.0000)
R-squared	0.873335	0.781792	0.978425	0.641580
Adjusted R-squared	0.870750	0.775480	0.977892	0.634265
Durbin-Watson stat	2.435799	2.182647	2.060522	1.738721
Prob(J-statistic)	0.144408	0.111773	0.351923	0.346767
Instrument rank	15	9	16	15
Included observations:	251	250	251	251

*, **, *** means significant at 1%, 5% and 10% respectively. Numbers in parenthesis under the coefficients are the t-statistics and the probabilities respectively.

Table above presents the adjusted 2SLS estimates to account for the presence of first-order serial correlation in the TSLS estimates in table 6. The method is known as the non-linear instrumental variables procedure because the model becomes non-linear least squares problem and the model is estimated using instrumental variables.

Equation one relates carbon dioxide emission to a number of explanatory variables. Based on the results, the three tests for the presence of autocorrelation concluded that there is no serial correlation as each of the test statistic is insignificant at the appropriate level of significance. Contrary to expectation, economic growth has no significant impact on carbon dioxide emissions in the in West Africa. In the same vein, trade has no significant impact on emission in West Africa. Foreign Direct Investment (FDI) and Financial Development have no significant impact on carbon dioxide emission in West Africa. Trade Openness significantly increased emission in the West African countries. A unit increased in trade openness other things being constant can bring about 0.0007 metric tonne per capita increase in carbon dioxide emission. This result suggest that trade liberalization generally is detrimental to the environment. This lends credence to the pollution haven hypothesis in West Africa.Energy consumption, in conformity with economic theory is positively contributing significantly to a rise in carbon emission in West African states. A kilogramme of oil equivalent rise in energy consumption can bring about 0.000719 metric tonne rise in carbon dioxide emission per capita. Energy consumption significantly explained carbon emission at five per cent significant level. This result is in consonance with economics and sciences that postulated that emission is the product of energy consumption and carbon dioxide is one of the end products of energy combustion. The above finding agrees with the findings of Shahbaz et. al. (2013) and that of Taghavae, Aloo and Shirazi (2016).

The second equation showed economic growth proxy by real per capita GDP in 2010 prices as related to energy consumption, carbon emission and other explanatory variables. The results indicate that carbon dioxide and gross fixed capital formation directly related to carbon emission but inversely related to energy consumption. However, none of these variables significantly explained economic growth in West Africa. In a similar manner, labour, gross capital formation and financial development do not have significant impact on economic growth in West Africa. However, trade openness significantly increases economic growth. A unit rise in trade openness other things being constant can bring about 24.52012 US dollars increase in real GDP per capita (economic growth). This finding is supportive of the beneficial impact of trade liberalization on economic growth.

The third equation relates energy consumption to economic growth, energy consumption, openness, gross capital formation and foreign direct investment. Results indicate that economic growth bears no significant influence on energy consumption in West African countries. This result may be true as most countries under study are basically agrarian by nature and are at early stage of industrialization, so economic growth may not be seriously linked with energy consumption. Trade openness, gross fixed capital formation and foreign direct investments have no significant impact on energy consumption. Possible reason for this is that trade liberalization can be successful only if certain conditions are met in the local economy. However, countries of West Africa are not so competitive in international trade and in attracting foreign direct investment. In addition, gross fixed capital formation is low in these countries and their impact on energy consumption may be insignificant. Urbanization significantly increased energy consumption in West Africa. A unit rise in the rate of urbanization can bring about 6.285106 kg increase in the energy use (kg of oil equivalent per capita). The reason for this is that urbanization is known for more energy consumption. More energy is required in urban areas for production, extraction, transportation and lighting among others unlike in the rural areas where there is heavy reliance on primary energy. Most of the industrial activities also take place in urban centres. Commercial, economic and social activities of the urban centres require secondary energy than required in the rural areas. This finding is similar to the finding of Taghavae, Aloo and Shirazi (2016).

The fourth equation relates net trade to economic growth, energy consumption, FDI inflows, exchange rate and trade policy (tariff). Results of the 2SLS showed that tariff and exchange rate are negatively related to trade but do not bear significant impact on trade. Economic growth also has negative and insignificant impact on trade while energy consumption has positive insignificant impact on trade. However, foreign direct investment, significantly contributed positively to trade growth in West Africa. A dollar increases in inflow foreign direct investment other things being constant can bring about 0.600671 US dollar increase in net trade in West Africa meaning that FDI is beneficial to trade.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Energy plays important roles in human lives and economic growth. Energy use however, have environmental impacts on air, water and land; but its effects varies. Economic growth can also be boosted through international trade expansion. Trade - induced economic growth can also impact the environment by increasing energy consumption and consequently, pollution and natural resources degradation and depletion. To this end, this study examined the interrelatedness of energy consumption, environmental condition, international trade and the environment in nine of the West African countries from 1990 to 2018 using the method of two stage least squares (2SLS). The study found contrary to expectation, that economic growth and international trade have no significant impact on carbon dioxide emissions in West Africa. Foreign Direct Investment (FDI) and Financial Development (FD) have no significant impact on carbon dioxide emission in West Africa. Trade openness significantly increased emission in the West African countries. This result suggest that trade liberalization generally is detrimental to the environment. This lends credence to the reality of pollution haven hypothesis in West Africa. Energy consumption, in conformity with economic theory is positively contributing significantly to a rise in carbon emission in West African states. Trade openness significantly increases economic growth. This finding is supportive of the beneficial impact of trade liberalization on economic growth in conformity with trade theory. Other results indicate that economic growth bears no significant influence on energy consumption. This is a benefit rather than a problem as de-linking energy consumption from economic growth is a good objective of any government. Urbanization significantly increased energy consumption in West Africa. Lastly, foreign direct investment, significantly contributed positively to trade growth in West Africa.

Based on the foregoing therefore, while the governments of West African countries are liberalizing trade in order to boost their economic growth, they must encourage the development and use of cleaner and renewable energy through sound legislations so as to maximize the growth impact of trade liberalization and minimize the attendant environmental challenges of trade liberalization. In addition, since energy consumption is a major determinant of environmental outcomes, West African governments must encourage a switch to more renewable and clean sources of energy as opposed to the fossil-based energy sources in order to de-link energy demand from emissions in their countries. Governments can also encourage the development and use of energy efficient technology or enact energy conservation policies so as to reduce fossil - fuels use among others. Lastly, since economic growth has no significant impact on emissions, West African governments can pursue the objective of economic growth without necessarily constraining the environment.

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