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Transitory And Permanent Features Of Shocks In Renewable Energy Consumption In Africa: Evidence From Seemingly Unrelated Regression (Sur-Adf)

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Abstract:
This research work examines the stability and stationary features of the renewable energy consumption in the selected ten (10) African countries between the period of 1991 and 2023. The study aims at finding out whether the shocks coming from the renewable energy consumption management policies would make the modern energy to revert quickly to equilibrium (transitory) or move it farther away from equilibrium (permanent). Using a more sophisticated estimation technique – Seemingly Unrelated Regression (SUR-ADF), findings from the study reveals that the renewable energy consumption in the major oil producing countries in Africa has a stationary process and therefore giving it the potential to revert back to equilibrium by itself without major policy formulation. Whereas, non-stationary features were identified for non-oil producing countries, thereby making the renewable energy consumption management policies to be effective for the countries.

Keywords: *Renewable Energy, Seemingly Unrelated Regression, Transitory, Permanent, Policy shocks.*

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I. Introduction

Energy consumption acts as an essential groundwork of socio-economic development of any nation. Access to low-cost, dependable and adequate energy is a facilitating component of livelihoods, provision of education and modern health services; and agricultural and industrial productivity. As a result of a significant growth rate of population in Africa, both energy demand and consumption have equally been on the increase. International Energy Association (IEA, 2023) projected the Africa's population living in the rural areas to be 40% by 2050 and this will definitely drive an increase in the consumption and demand level of energy use. Hence, there is a need for modern energy provision in order to level up with the booming population growth rate. Likewise, economic growth equally serves as a catalyst for energy infrastructure particularly in Africa. International Energy Association (IEA, 2022) has termed most of the African economies to be among the fastest-growing economies in the world. In this regard, in a bid to meet up with the booming population growth rate and fast-growing economy in Africa, there must be a robust push for investment in renewable energy.

Renewable energy is a form of energy which is obtained from natural resources that are regenerative on the time scale of humanity. It includes sunlight (solar), tides, wind, rain, geothermal, heat and waves. These energy sources are readily produced, regenerated rapidly through non-man made process. The existence of these energy sources are not controlled by their consumption rate and this won't make them depleted on the long-run. For instance, sunlight or wind will continue to shine and blow after the consumption of energy produced by them. The conventional energy supply such as fossil fuels has caused great damages on the environment as well as the dweller of it, in the area of energy-related greenhouse gas emission and global climate change. In this regard, a significant transformation of the energy sector from the conventional-based system of energy production and consumption to renewable energy sources is quite pertinent. A swap from the fossil-based system of energy to renewable energy sources and also the need to control the environmental effects of conventional energy consumption actually require the designing of renewable energy policies. Hence, the study that would enhance appropriate policy formulation is truly needed. One of the best ways to get a better design of policy formulation for the renewable energy consumption is to understand clearly its stationary feature.

A deep understanding of the equilibrium position of the renewable energy consumption is very necessary because of the following reasons, first, if the renewable energy consumption has no unit root, that is, stationary, any shock coming from the formulation of policies will have short-term impact on the renewable energy consumption; and it will revert back to its original equilibrium value after a short period of time. But, if the renewable energy consumption has unit root, that is, non-stationary, any policy designed to manage the renewable energy consumption will have permanent effects on it and thus make the policy an effective one. Another very important reason which is the second one is that, if the renewable energy consumption is stationary, all the past data used in the estimation of the renewable energy consumption value can actually be reused to make an effective

decision on its present and current situation. The third reason being the fact the renewable energy consumption has a strong connectedness with the other macroeconomic fundamentals (Hsu et al, 2008). As a result of this, any stationary component inherent in the renewable energy can be transferred into other macroeconomic variables, thereby affecting the alternative stabilization policies used by government on all these macroeconomic variables.

Several empirical studies have been put up to either investigate the relationship between energy consumption and some macroeconomic parameters or examine the sole behaviour of the energy consumption on its own. Many of these previous researchers actually centred on the developed countries (Sadorsky, 2019; Apergis and Payne, 2018; Marques and Fuinhas, 2020; Akar, 2018). The small number of studies that worked on African countries were either centred on the fossil-based system of energy without regards to renewable energy consumption (Kivyiro and Arminen, 2021; Awodumi and Adewuyi, 2020; Adom et al, 2019; Adom and Amuakwa-Mensah, 2021) or were focused on the studies that examined the stability and stationary of the renewable energy consumption with the adoption of univariate stationary test (Ouedraogo, 2019; Aissa et al, 2020; Attiaoui et al, 2021; Ackah and Kizys, 2020; Ergun et al, 2019). Most of these past empirical studies have their findings contradictory and inconclusive due to the univariate stationary test they used such as the conventional ADF and PP tests which are incapable at times to reject the null hypothesis of a unit root because of their less exponential tendency.

This research work is therefore exceptional and original because, it examines the behaviour of the renewable energy consumption in terms of the stability and stationary of selected ten (10) African countries. Two countries represent each of the five (5) major regions in Africa. Nigeria and Ghana represent West Africa, South Africa and Botswana represent South Africa. Kenya and Tanzania represent East Africa, Egypt and Algeria represent North Africa while Angola and Cameroon represent central Africa. These countries were chosen because they have a very large GDP base in their respective regions and any findings with respect to these countries can be used as a full generalization for the entire African countries. Moreover, this research work also corrects the setbacks of the previous studies who focused on the fossil-based energy and equally adopted a univariate stationary test to investigate the behaviour of the renewable energy consumption. These are actually achievable in this current study by adopting the Seemingly Unrelated Regression (SUR-ADF) method which is capable of taking into consideration the contemporaneous cross-correlations of the error term (Breuer et al, 2002). This study also centres on the behaviour and stability of modern energy, that is, renewable energy consumption.

The remaining sections of this research work are structured as follows: section 2 presents the review of empirical literatures, section 3 explains the data set and research method. Section 4 reports the results and discussion of findings, while section 5 present the conclusion and policy recommendations.

II. Literature Review

Sadorsky (2019) used an error correction model and seemingly unrelated regression to investigate the drivers of renewable energy in G7 countries from 1980 to 2010. Findings from his results revealed that per capita GDP, per capita CO_2 emission and oil prices are the key determinants of renewable energy consumption per capita. Apergis and Payne (2018) incorporated the granger causality test to assess the dynamic relationship among the renewable energy, per capita GDP, per capita CO_2 emission and oil prices for 25 OECD countries from 1980 to 2013. Reports from the results of their study showed that per capita GDP, per capital CO_2 emission and oil prices have a positive and statistically significant impact on per capita renewable energy consumption in both short and long run. Findings from the study further revealed that a bi-directional causality exists between the variables in both the short and long run

Ouedraogo (2019) examined the relationship among the renewable energy consumption, economic growth and development in ECOWAS countries from 1980 to 2014. By adopting the FMOLS estimation techniques, findings from his study confirmed a significant positive impact of economic growth on renewable energy consumption in the short run in ECOWAS. The findings further showed that a rise in real GDP increases the renewable energy consumption in the short run while the renewable energy consumption on the other way round impacts positively on the GDP per capita growth in the long-run.

Ergun et al (2019) used the random effects generalized least squares to investigate the effects of Human Development Index, per capita GDP, Foreign Direct Investment and democracy on the share of renewable energy in total energy consumption for a panel of 21 African countries from 1990 to 2015. Findings from their study confirmed that countries with higher GDP per capita and higher HDI have a lower share of renewable energy in total energy consumption. In addition, an increase in foreign direct investment enhances higher renewable energy consumption. Also, democracy which is represented by the political rights and civil liberties ratings do not have a direct link with the renewable energy consumption.

Yue et al (2019) examined the relationship between different financial development indicators and energy consumption for a panel of transition economies. Findings from their study revealed that financial development has a neutral effect on energy consumption and financial intermediates have a considerable but positive impacts on energy consumption.

Adom and Amuakwa-Mensah (2021) examined the relationship between foreign direct investment and energy productivity by considering the role of industrialization, income and trade openness. Using a baseline regression approach, findings from the study revealed that foreign direct investment and industrialization reduces energy productivity but income and trade openness promote energy productivity.

III. Data And Methodological Framework

The data for this research work is on the annual time series of renewable energy spanning from 1991 to 2023. The data on the renewable energy consumption which is the percentage share in the total final energy consumption was sourced from the World Development Indicators (WDI) of World Bank. Data on the renewable energy consumption were collected for the selected ten (10) African countries. Two countries represent each of the five (5) major regions in Africa. Nigeria and Ghana represent West Africa, South Africa and Botswana represent South Africa. Kenya and Tanzania represent East Africa, Egypt and Algeria represent North Africa while Angola and Cameroon represent central Africa. These countries were chosen because they have a very large GDP base in their respective regions and any findings with respect to these countries can be used as a full generalization for the entire African countries.

The stability and stationary of the renewable energy consumption was investigated in this research work by applying seemingly Unrelated Regression ADF (SUR-ADF). The strong economic bonds among the selected African countries actually require the adoption of SUR-ADF, because it takes care of the contemporaneous cross-correlations of the error term (Breuer et al, 2002). The SUR-ADF test is an extended version of the univariate unit root test. The traditional version of an individual ADF test is presented as follows:

$$\Delta Y_t = \alpha + \theta y_{t-1} + \sum_{j=i}^{\rho} \delta_j \Delta y_{t-j} + \varepsilon_t \dots\dots\dots\dots\dots\dots\dots 1$$

Where $\alpha, \theta \; and \; \delta_j$ represent the coefficients, ρ depicts the order of lag for the autoregressive process and ε_t represents the error term. For any time series procedure, the autoregressive coefficient, θ represents the renewable energy dynamics. Stability and stationary is lacking if θ is set, to zero or the null hypothesis of a unit root in the renewable energy consumption cannot be rejected. In this kind of situation, the value of the renewable energy consumption will find it difficult to return to its original equilibrium, thus, any shock to it will be permanent. In another way round, if the autoregressive coefficient, θ, is non-zero or the null hypothesis of a unit root can be rejected, this implies that the value of the renewable energy consumption will revert to equilibrium easily and any shock to it through policy implementation will be temporary.

The SUR-ADF applies seemingly unrelated regressions (SUR) in order to present the original ADF as follows:

$$\Delta Y_{1,t} = \alpha_1 + (\theta_1 - 1) y_{1,\ t-1} + \sum_{i=1}^{\rho} \delta_i \Delta y_{1,t-i} + \mu_{1,t} \dots\dots\dots\dots\dots\dots\dots 2$$

$$\Delta Y_{2,t} = \alpha_2 + (\theta_2 - 1) y_{2,\ t-1} + \sum_{i=1}^{\rho} \delta_i \Delta y_{2,t-i} + \mu_{2,t} \dots\dots\dots\dots\dots\dots\dots 3$$

$$\Delta Y_{v,t} = \alpha_v + (\theta_v - 1) y_{v,\ t-1} + \sum_{i=1}^{\rho} \delta_i \Delta y_{n,t-i} + \mu_v \dots\dots\dots\dots\dots\dots\dots 4$$

θ captures the autoregressive coefficient for series i. Any lagged augmentation in the series is capable enough to take care of any issue coming from the serial correlation (Breuer et al, 2002). In this regard, the significance of each $\theta_i - 1$ can be estimated, hence, the unit root hypothesis of each cross-sectional unit can be investigated. In addition, the critical values for both the conventional ADF tests and the SUR-ADF tests are estimated through the application of Monte Carlo simulations with 10,000 replications.

IV. Results And Discussions

Table 1: The Results of Augmented Dickey Fuller (ADF) Unit Root Test

Countries	No Intercept and Trend	Intercept Only	Intercept & Trend
Nigeria	-1.7241	2.8421	2.4903
Ghana	0.3443	-0.3414	0.3245
South Africa	1.3293	-1.7205	-1.4214
Botswana	-0.4358	0.3624	-0.8194
Kenya	-1.3872	-2.3142	1.3254
Tanzania	-1.4395	0.4981	0.1802
Egypt	1.0425	-4.5342**	2.0241
Algeria	-1.4325	-2.1124	-1.3594
Angola	-4.8242**	0.3214	0.4109
Cameroon	2.3572	1.0518	1.3232

Source: Author's Computation via E-view Software

The traditional ADF unit root test in the table 1 above was depicted under the three major regressions (No intercept and trend, intercept only, intercept and trend). The results revealed that the null hypothesis of unit root test in the renewable energy consumption were rejected only at 5% significance level for Egypt (under intercept only) and Angola (under no intercept and trend). But the ADF test was unable to reject the null hypothesis for the remaining eight countries. This is an indication that only the Egypt and Angola are stationary and would be able to revert quickly to their mean values while the remaining eight countries (Nigeria, Ghana, South Africa, Botswana, Kenya, Tanzania, Algeria, and Cameroon) are non-stationary and would keep farther away from equilibrium. As a result of the fact that the traditional ADF could not account for the contemporaneous cross-correlations of the selected countries in this study, the estimation technique would therefore be tagged incapable to give a comprehensive and conclusive findings on the renewable energy consumption for the selected African countries, hence, there is need for a more robust test to bridge the gap.

Table 2: Seemingly Unrelated Regression ADF with Critical Values

Countries	SUR-ADF Statistics	Critical Values		
		1%	5%	10%
Nigeria	-4.4238**	-5.2108	-4.1024	-3.4031
Ghana	-3.9571*	-5.4038	-4.2432	-3.8107
South Africa	-2.0314	-5.0021	-4.1097	-3.7138
Botswana	-1.2084	-5.1197	-4.2631	-3.5302
Kenya	-2.1239	-5.3214	-4.4208	-3.3241
Tanzania	-1.3472	-5.7301	-4.1273	-3.1139
Egypt	-4.8342**	-5.4984	-4.4131	-3.4243
Algeria	-4.7148**	-5.1737	-4.5094	-3.4243
Angola	-4.6031**	-5.2035	-4.3183	-3.6517
Cameroon	-2.4301	-5.8491	-4.1024	-3.1873

Source: Author's Computation via OXGauss Codes in OXEdit Software
Note: (*) (**) represent 10% and 5% level of significance respectively
Critical Values for the SUR-ADF were calculated based on Carlo Simulations with 10,000 replications.

In a bid to capture the contemporaneous cross-correlations of the selected African countries in this study, table 2 above presented the results of SUR-ADF test. The test showed a more improved results in such a way that the null hypothesis of unit root were now being rejected for more countries when compared with the conventional ADF test results. Findings from the SUR-ADF results revealed that the null hypothesis of unit root test in the renewable energy consumption were rejected for Nigeria, Ghana, Egypt, Algeria and Angola, while the null hypothesis of unit root test in the renewable energy consumption were accepted for South Africa, Botswana, Kenya, Tanzania and Cameroon. This is a strong implication that under the SUR-ADF results, renewable energy consumption could now be best described as a stationary process in Nigeria, Ghana, Egypt, Algeria and Angola and they have the potential of converting quickly to their mean value. Meanwhile, the renewable energy consumption was revealed non-stationary in South Africa, Botswana, Kenya, Tanzania and Cameroon, and they would not be able to revert quickly back to equilibrium.

Findings from the SUR-ADF results further unveiled that the stability and stationary features of the renewable energy consumption are traced to the major oil producing countries among the selected ten African countries in this study (except for Cameroon and South Africa who were not included in the results). Whereas, the non-stationary process was attached to non-oil producing countries among the selected ten African countries. The implication of these findings is that any shock from the policies aimed at managing the renewable energy consumption in the African oil producing countries would be temporary and in this regard, the renewable energy consumption, by nature, has the potential of reverting to equilibrium by itself without major policy formulation. But the indication of the findings in the African non-oil producing countries is that any policy formulation to manage the renewable energy consumption would have permanent and effective outcome on it.

V. Conclusion And Policy Recommendations

This study investigated the stability and stationary of the renewable energy consumption in the selected ten (10) African countries between the period of 1991 and 2023. The research work intended to uncover whether the policy shocks to renewable energy consumption would make it transitory or permanent. In a bid to achieve this, a more powerful estimation techniques – Seemingly Unrelated Regression (SUR-ADF) was employed. From the findings, the study therefore concluded that the stability and stationary process were found in the major oil producing countries among the selected ten African countries; while the non-stationary features were traced to non-oil producing countries among the selected ten African countries during the period under review.

The policy implication of these findings is that the policy analysts and government in the African non-oil producing countries should intensify on investing in rich and robust policies that would provide lasting and effective impacts. Whereas, the policy experts and government in the African oil producing countries should invest less in formulating rigorous policies in the management of renewable energy, as this would just have temporary effects; but instead, they can take into a greater cognizance, the management of past data on the renewable energy consumption, as this would provide better demand predictions and decision making on the renewable energy.

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