

# Modeling Green Energy Consumption and Natural Resources Rents Impacts on Economic Growth in Africa: An Analysis from the Dynamic Panel ARDL Models and the Feasible Generalized Least Squares Estimator

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## Abstract

The concept of green energy is now at the forefront of development discourse, with the United Nations Sustainable Development Goals (SDGs) 7, 11, and 12 all aimed at promoting green energy consumption to combat the three planetary crises: climate change, biodiversity loss, and pollution. Similarly, issues regarding Africa's natural resource curse have caused a stir in the growth and development literature for some time now and there is no sign that it will die out. This study, the first of its kind, simultaneously assesses the impact of green energy consumption and Africa's natural resources rents on economic growth by applying the Feasible Generalized Least Square (FGLS) estimator and the dynamic panel models of the Pooled Mean Group (PMG) and Mean Group (MG) estimators on data from 1990 to 2020 for 24 selected African countries. The results show that green energy consumption has a short-run growth-limiting effect and a long-run growth-enhancing effect in Africa. The study also found evidence of the natural resource curse phenomenon in Africa. The study, therefore, calls for the advancement and usage of green energy for both domestic and industrial production in Africa. The study further calls for a revamp in the global tax policy to curb illicit financial activities and strengthening institutional quality for transparency and accountability in the entire value chain of natural resource management in Africa.

**Keywords:** Green energy, Natural resource rents, Economic growth, SDGs, FGLS, PMG & MG.

## 1. Introduction

Renewable energy usage has increased by a quarter between 2010 and 2019. However, the total share of renewable energy consumption is only 17.7 % of the total final energy consumption. The continuous increase in atmospheric greenhouse gas emissions due to nonrenewable energy consumption has resulted in three planetary crises: climate change, biodiversity loss, and

pollution. Nonrenewable energy consumption has further resulted in about 99 percent of the world's urban population inhaling polluted air (United Nations, 2022). Additionally, Aydoğan & Vardar (2020) contend that the burning of fossil fuels (usually coal and natural gas) stimulates economic growth but it poses serious consequences to our planet and the reduction of its use is vital for the planet's welfare. Consequently, this study argues that the switch from the consumption of non-renewable energy sources to the usage of renewable energy in developing countries may most likely lead to lower growth and development in the short run. However, in the medium-to-the long-term, its impact on growth and development will become positive and more sustainable as greenhouse gas emissions will be lessened. British Petroleum (2022) projected that the share of renewable energy is expected to increase in global sources to between 35% in 2019 to about 65% by 2050.

Besides, Africa is estimated to house the largest amount of the earth's natural resources. For instance, the African continent has an aquaculture sector approximated at USD 24 billion and is home to the second largest tropical forest. Additionally, 64% of Africa's land size as represented is allocated to its 63 international rivers which contain 93% of the total surface water resources. In the mineral sector, the region accounts for roughly 30% of all global minerals reserves while oil reserves and natural gas stand at 8% and 7% of the world's reserves respectively. Yet still, the continent continues to experience high levels of poverty, rising income inequality, low levels of growth, and underdevelopment. This phenomenon is widely referred to as the curse of natural resources (Ari and Auty, 2016). The most common explanation given for this quagmire originates from the Dutch disease in which it is stated that national integration of commodity rents, creates vulnerabilities in the economy such as negative trade shocks and dwindling composition of non-mining commodities tradable in GDP (Sachs and Warner, 1995). In the 2020 African development bank report, minerals alone account for 70% of the total African exports but their contribution to their Gross Domestic Product is only 28%. This indicates poor natural resource management from exploitation, extraction, marketing, and rents. Against this narrative, this study explores the real impact of Africa's natural resource rents on the growth of their economies.

Theoretically, the linkages between the consumption of green energy and economic growth are well exemplified by the environmental Kuznets curve and the Jevons Paradox. The environmental Kuznets curve reveals that the relationship between environmental degradation and GDP per capita takes the shape of an inverted U (Yandle et al., 2004). What this means is that at lower levels of per capita income, there are massive emissions of greenhouse gases into

the atmosphere. These emissions come from the consumption of nonrenewable energy sources which threatens the welfare of plants and animals. However, the theory argued further that beyond a certain level of per capita income, nonrenewable energy discharges will decline as the economy begins to adopt cleaner and sustainable means of production and energy sources. This drop in the use of nonrenewable energy at better levels of per capita income is further supported by the views of the Jevons paradox. This is of the idea that technological improvements will lead to improved efficiency of the resource being used and more and more units of the resource will be used. Similarly, York (2013) contributing to the discussion on the significance of renewable energy usage opined that in many nations, over the last five decades, each quantity of non-fossil fuel energy consumption displaced less than a quarter of fossil fuel energy consumption, and each quantity of non-fossil fuel electricity displace less than one-tenth.

Furthermore, previous empirical studies conducted to examine the nexus between renewable energy and economic growth show mixed and inconclusive results. A few studies found renewable energy contributes positively and significantly to economic growth (see, for example, Kahia et al., 2019; Magazzino et al., 2022; Pao & Fu, 2013). On the other hand, Abbasi et al. (2020) found a negative relationship between renewable energy and economic growth. Likewise, Apergis et al. (2010) found no link between economic growth and renewable energy consumption. In the same vein, the relationship between natural resource rent and economic growth remained mixed and inclusive. For example, empirical studies ( Awosusi et al., 2022; Mehar et al., 2018) reported a positive and statistically significant relationship between natural resource rents and economic growth. On the contrary, Adabor et al. (2020) found a negative relationship between natural resource rents and economic growth.

This study, the first of its kind, contributes to the literature by jointly analyzing the impact of green energy and /or renewable energy consumption and Africa's natural resource rents on the economic growth of African economies. The study also contributes to the existing literature by checking for robustness and accounting for cross-sectional (and temporal) dependence among the residuals through the adoption of the Feasible Generalized Least Square (FGLS) estimator and the Dynamic pane Autoregressive Distributed Lag (ARDL) models of the Pooled Mean Group (PMG) and the Mean Group (MG) estimators. Pesaran & Smithb (1995) posited that in panel data estimation, aggregation can lead to biased estimates especially when the slope coefficients vary across the cross-sectional units. Besides, Hoechle (2007) also postulated that

intentionally ignoring cross-sectional (and temporal) dependence which most likely exists in panel data estimations can lead to spurious regression results.

The rest of the paper is organized as follows: the second section provides a review of the related empirical background in the green energy-vis-à-vis-natural resource rents and economic growth nexus. The third section discusses the methods, variables, and data sources. In addition, the fourth Section discusses the estimation techniques, while the fifth section presents the results. Similarly, section six outlines the discussion of results and the last and final section seven highlights the conclusion and policy directions.

## 2. Literature Review

This section presents the previous empirical discussions on green energy, natural resource rents, and economic growth nexus both within and outside Africa. The reviews are based on three main domains: green energy (renewable energy) consumption and economic growth; nonrenewable energy consumption and economic growth; and finally natural resource rents and economic growth.

### 2.1 Renewable Energy Consumption and Economic Growth

The relationship between renewable energy consumption and economic growth comes with mixed results and submissions. For instance, Pearson (2021) examines the impact of renewable energy consumption on economic growth in Croatia using time series data from 1996 to 2011. The study employed the Autoregressive Distributed Lag (ARDL) model and demonstrated that renewable energy consumption positively impacts economic growth in both the short and long run. In a related study, Qudrat-Ullah and Nevo (2021) using panel data, for thirty-seven African countries, and employing the system Generalized Method of Moments (GMM) found that renewable energy adoption and development will lead to an increase in economic growth in Africa, both in the long and short run. On the contrary, Dogan & Ozturk (2017) examined the impact of the real income (GDP), renewable energy consumption, and non-renewable energy consumption on carbon dioxide (CO<sub>2</sub>) emissions for the United States of America (USA) in the environmental Kuznets curve (EKC) model for the period 1980 to 2014 employing Autoregressive Distributed Lag (ARDL) model. The findings reveal that in the presence of a structural break, CO<sub>2</sub> emissions, real income, quadratic real income, and renewable and non-renewable energy consumption are integrated. Further, results from long-run estimates indicate that increases in renewable energy consumption mitigate environmental

degradation whereas increases in non-renewable energy consumption contribute to CO<sub>2</sub> emissions. In addition, the EKC hypothesis was found not to be valid for the USA.

Moreover, Maji et al (2019) conducted a study using a sample of 15 West African countries and utilizing the panel Dynamic Ordinary Least Squares (DOLS) on data between 1995-2014. The findings show that renewable energy consumption reduces economic growth in West African countries. Similarly, Maji (2015) using the Autoregressive Distributed Lag (ARDL) model on data from 1971 to 2011 in Nigeria reported a significant negative relationship between two indicators of clean energy (alternative nuclear energy and electric power consumption) and economic growth. On the contrary, Riti et al (2022) carried out a similar study in a panel setting in Sub-Saharan Africa by applying the Autoregressive Distributed Lag (ARDL) model to data from 1990 to 2018. The study reveals that there exists a positive and statistically significant relationship between renewable energy consumption and economic growth in the long run. In the same vein, Riti et al (2022) further show that the environmental pillar of sustainability results show that real GDP and real gross fixed capital formation exert positive and significant impacts on emissions of greenhouse gasses (GHG) while renewable energy exerts a negative and significant impact on emissions of GHG.

Last but not least, Apergis and Payne (2012) documented the electricity consumption nexus in Central America within a panel error correction model framework. The findings indicate a long-run equilibrium relationship between real gross domestic product, renewable electricity consumption, non-renewable electricity consumption, real gross fixed capital formation, and the labor force. Additionally, except for renewable electricity consumption, the respective long-run coefficient estimates were found to be positive and statistically significant. Also, the panel error correction model results show a unidirectional causality from renewable electricity consumption to economic growth in the short-run, but bidirectional causality in the long run. The results further indicate bidirectional causality between non-renewable electricity consumption and economic growth in both the short and long run.

## 2.2 Non-Renewable Energy Consumption and Economic Growth

The nexus between non-renewable energy consumption and economic growth comes as mixed and remains inconclusive. For example, Borhan et al ( 2012) investigate the impact of CO<sub>2</sub> on economic growth in 8 ASEAN countries between 1965 and 2010. The study used three equations simultaneous models with the pollution indicator as emissions CO<sub>2</sub>. The findings reveal that the Environmental Kuznets Curve relationship was found. Ivanovski et al (2021)

also examined the link between renewable energy consumption, non-renewable energy consumption, and economic growth by applying the Least Squares Dummy Variable estimation (LSDV) method on data from 1990 to 2015 across a panel comprising OECD and non-OECD countries. The findings show that non-renewable energy consumption exerts a positive and statistically significant impact on economic growth across OECD nations. However, the contribution of renewable energy consumption to economic growth is statistically not significant in these countries for most of the study.

In addition to the above, Brooks (2011) analyses the nexus between economic development and carbon dioxide emissions using global panel data. The findings indicated that there is a diminishing marginal propensity to emit (MPE) carbon dioxide as GDP per capita rises. The study contended that global carbon dioxide emissions growth is not sensitive to average output growth. However, the study found that output and population growth stimulate CO<sub>2</sub> emissions in lower-income nations and the propensity to emit is high (high MPEs).

Similarly, Mikayilov et al (2018) examined the link between economic growth and CO<sub>2</sub> emissions in Azerbaijan. The study employed the cointegration analysis on data over the period 1992–2013. The results from the different cointegration methods were consistent with each other and show that economic growth has a positive and statistically significant impact on CO<sub>2</sub> emissions, in the long run, implying that the Environmental Kuznets curve hypothesis does not hold for Azerbaijan.

In a related study, Sannassee (2015) investigated the nexus between Mauritius's carbon emissions and economic growth by estimating the Environmental Kuznets Curve (EKC) for the period 1975-2009. The results of the study demonstrated that the carbon dioxide emissions trajectory is closely related to the GDP time path. Furthermore, the results show that emissions elasticity to income growth has been increasing over time and failed to prove the existence of a reasonable turning point. Thus, no EKC "U" shape was obtained. Lastly, Chen and Huang (2013) conducted a study to assess the relationship between carbon dioxide (CO<sub>2</sub>) emission per capita and economic growth for N-11 countries between 1981 and 2009. The study adopted the cointegration approach in a heterogeneous panel. Results from the study verified that there is a positive long-run relationship between CO<sub>2</sub> emissions, Electric power consumption, Energy use, and GDP. Likewise, they show that there exists bi-directional causality between CO<sub>2</sub> emission and electric power consumption.

## 2.3 Natural Resource Rents and Economic Growth

The relationship between renewable energy and economic growth in the empirical literature also revealed mixed and inconclusive results. Adabor et al (2020) examined the effect of oil and gas resource rent on the economic growth of Ghana between 2007 and 2019 by using the Autoregressive Distributed Lag (ARDL) time series econometric model. The findings show that oil resource rent had a negative and statistically significant relationship with the economic growth of Ghana. However, gas resource rent was found to have a positive impact on the economic growth of Ghana.

In a similar study, Mohamed (2020) analyzed the link between natural resource rents, human development, and economic growth in Sudan by applying the cointegration and vector error correction modeling (VECM) to data between 1970 and 2015. The results confirm the existence of a long-run equilibrium relationship between natural resource rents, human development, and economic growth in Sudan. Additionally, the results from the VECM show that economic growth is positively affected by natural resource rents and development expenditure. However, it was found to be negatively affected by life expectancy at birth in the short run. Also, natural resource rents, school enrolment, life expectancy, and financial development were observed to be inversely related to economic growth.

Furthermore, Mehar et al (2018) examined the nexus between total natural resources rent and economic growth in Pakistan and India between 1970 to 2017. The study employed cointegration and VECM for the estimations. The study observed that total natural resources rents have a positive and statistically significant effect on Pakistan's and India's GDP per capita. The results from the cointegration analysis depicted that there are 2 co-integrated equations of the relationship between the variables.

Moreover, Ofori and Grechyna (2021) established a link between oil rent fluctuations and remittances received on the economy for a sample of 43 Sub-Saharan African (SSA) countries between 1990 and 2017. They used the Pooled Ordinary Least Squares, the Fixed Effects, the Random Effects, and the Generalized Method of Moments. The study found that forest rent exerts a positive impact on economic growth whilst oil rent and natural gas rent have a negative impact on economic growth. Likewise, a positive marginal and net effect on economic growth from the interaction between remittances and oil rent was observed.

Finally, Elbadawi and Soto (2016) analyzed the impact of oil rents and political governance on economic growth in oil-rich countries. The study uses the cointegration and vector error-

correction mechanisms and found that oil-rich countries with low levels of governance scores are likely to experience the curse, while those with high enough levels may turn resource rents into a driver of growth. The study further indicated that countries with high scores on only one dimension may avoid the curse but are not likely to effectively use resource rents to promote growth.

### 3. Methods, Variables, and Data Sources

This study employs the Dynamic Autoregressive Distributed Lag (ARDL) panel models of the Pooled Mean Group (PMG) and the Mean Group (MG) estimators together with the Feasible Generalized Least Square (FGLS) estimator on data spanning the period 1990-2020 for 24 selected African countries to investigate the impact of green energy (renewable energy) usage and Africa's natural resource rents on economic growth. The dependent variable in this study (InGDP) represents the Gross Domestic Product (growth) log of the various countries. The primary independent variables on the other hand include green energy and Africa's natural resource rents. Renewable energy is used as a proxy measure of green energy and we analyzed its effect on growth together with other non-renewable energy sources such as fossil fuel combustion and carbon dioxide (CO<sub>2</sub>) emissions. Similarly, Africa's natural resource rents are measured along three indicators: mineral rents, forest rents, and total natural resource rents. The control variables used in this study are gross fixed capital formation, inflation, and trade openness. These variables are included to take care of their confounding effects on growth in Africa. Table 1 presents a summary of all the variables and their data sources.

**Table 1:** Variables Description and Data Sources

Variable	Description	Source
InGDP	Log of Gross Domestic Product	
REC	Renewable Energy Consumption (% of final energy consumed)	
CO <sub>2</sub>	Carbon dioxide emissions (metric tons per capita)	
FEC	Fossil Fuel Energy Combustion (% of total energy consumed)	<a href="https://data.worldbank.org/indicator">https://data.worldbank.org/indicator</a> (accessed on September 1, 2022)
FR	Forest Rents (% of GDP)	
MR	Mineral Rents (% of GDP)	
TNR	Total Natural Resource Rents (% of GDP)	

INFL	Inflation, Consumer Prices (annual %)
Trade	Trade (% of GDP)
GFCF	Gross Fixed Capital Formation (% of GDP)

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**Source: Researcher's Construct**

#### 4. Techniques of Estimations

The primary objectives of this study are to investigate the impact of green energy usage and Africa's natural resource rents on economic growth. As such, the current study carefully selects the three estimation techniques based on their relevance to the study's objectives and their peculiar characteristics. The Dynamic Autoregressive Distributed Lag (ARDL) panel models of the Pooled Mean Group (PMG) and the Mean Group (MG) estimators allows us to estimate both the short and long-run impact of the key variables of interest on growth in Africa. In panel data estimation, aggregation can lead to biased estimates especially when the slope coefficients vary across the cross-sectional units (Pesaran & Smithb, 1995). One plausible way to resolve this problem is to use an estimator based on the so-called "Mean Group" method which estimates the short-run coefficients for each country during the period and then calculates the average of the estimated coefficients. This model assumes long-run homogeneity of the slope coefficients across panels. However, the MG method only gives consistent results if the dimension of the panel tends towards infinity.

Another option is to use an estimator based on the so-called "Pooled Mean Group" method. In this case, the long-term coefficients are uniform but the short-term coefficients are allowed to be heterogenous across panels. This method makes it possible to establish a distinction between short-term dynamics and long-term dynamics and takes into account the heterogeneity of the countries. The method also resolves the endogeneity problem in a dynamic specification (Pesaran et al., 1999). Moreover, the validity, consistency, and efficiency of the estimates from the MG and the PMG depend on the following conditions: i) The existence of the long-term relationship between the dependent and the independent variables requires that the coefficient of the error correction term be negative and not lower than -2; ii) The residual resulting from the error correction model is serially uncorrelated and the explanatory variables can be treated as exogenous. This condition can be satisfied by including the lags p and q (p for the dependent variable and q for the independent variable) in the error correction model; and finally, iii) The time dimension (T) should be greater than the panel dimension (N) which makes it possible to avoid the bias in the average of the estimators and solve the problem of heterogeneity.

In the words of (Johansen, 1995; Phillips & Hansen, 1990), the existence of a long-run relationship among the variables is only valid when the variables are integrated in the same order. However, Pesaran et al. (1999) argued that panel ARDL can be used even if the variables are integrated with different orders. Thus, irrespective of whether they are integrated of I (0) or I (1) or a mixture of both. The generic specification of the panel ARDL model is given in model 1.

$$\Delta y_{it} = \theta_i [y_{it-1} - \lambda_i' X_{it}] + \sum_{j=1}^{p-1} \phi_{i,j} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \alpha_{i,j}' \Delta X_{i,t-j} + \varphi_i + \mu_{i,t} \quad (1)$$

Where  $y_{it}$  is the dependent variable for country  $i$  at time  $t$ ,  $X_{it}$  is the vector of independent variables for country  $i$  at time  $t$ .

The operational form of the Dynamic panel ARDL estimations of the MG and the PMG model in equation 1 are reparametrize in models 2 and 3 where equation 2 denotes the causal relationship between green energy including other control variables and growth and equation 3 shows the causal relationship between Africa's natural resource rents including other control variables and growth.

$$\Delta \ln GDP_{it} = \begin{bmatrix} \ln GDP_{it} - \lambda_1 REC_{it} \\ \ln GDP_{it} - \lambda_2 CO2_{it} \\ \ln GDP_{it} - \lambda_3 FEC_{it} \\ \ln GDP_{it} - \lambda_4 GFCF_{it} \\ \ln GDP_{it} - \lambda_5 INFL_{it} \\ \ln GDP_{it} - \lambda_6 Trade_{it} \end{bmatrix} + \sum_{j=1}^{p-1} \phi_{i,j} \Delta \ln GDP_{i,t-j} + \sum_{j=0}^{q-1} \begin{bmatrix} \alpha_{1i} \Delta REC_{i,t-j} \\ \alpha_{2i} \Delta CO2_{i,t-j} \\ \alpha_{3i} \Delta FEC_{i,t-j} \\ \alpha_{4i} \Delta GFCF_{i,t-j} \\ \alpha_{5i} \Delta INFL_{i,t-j} \\ \alpha_{6i} \Delta Trade_{i,t-j} \end{bmatrix} + \varphi_i + \mu_{i,t} \quad (2)$$

Where  $\ln GDP_{it}$  is the log of GDP for each country at time  $t$  and  $REC_{it}$ ,  $CO2_{it}$ ,  $FEC_{it}$ ,  $GFCF_{it}$ ,  $INFL_{it}$ , and  $Trade_{it}$  are the independent variables involving renewable energy consumption, carbon dioxide emissions, fossil fuel energy consumption, gross fixed capital formation, inflation, and trade openness for country  $i$  at time  $t$ . Additionally,  $p$  and  $q$  are the optimal lag lengths for the dependent and the independent variables, respectively.  $\varphi_i$  is the cross-country heterogeneity and  $\mu_{i,t}$  is the panel idiosyncratic error term.

$$\Delta \ln GDP_{it} = \left[ \begin{array}{l} \ln GDP_{it} - \lambda_1 FR_{it} \\ \ln GDP_{it} - \lambda_2 MR_{it} \\ \ln GDP_{it} - \lambda_3 TNR_{it} \\ \ln GDP_{it} - \lambda_4 GFCF_{it} \\ \ln GDP_{it} - \lambda_5 INFL_{it} \\ \ln GDP_{it} - \lambda_6 Trade_{it} \end{array} \right] + \sum_{j=1}^{p-1} \phi_{i,j} \Delta \ln GDP_{i,t-j} + \sum_{j=0}^{q-1} \left[ \begin{array}{l} \alpha_{1i} \Delta FR_{i,t-j} \\ \alpha_{2i} \Delta MR_{i,t-j} \\ \alpha_{3i} \Delta TNR_{i,t-j} \\ \alpha_{4i} \Delta GFCF_{i,t-j} \\ \alpha_{5i} \Delta INFL_{i,t-j} \\ \alpha_{6i} \Delta Trade_{i,t-j} \end{array} \right] + \varphi_i + \mu_{i,t} \quad (3)$$

Where  $\ln GDP_{it}$  is the log of GDP for each country at time  $t$  and  $FR_{it}$ ,  $MR_{it}$ ,  $TNR_{it}$ ,  $GFCF_{it}$ ,  $INFL_{it}$ , and  $Trade_{it}$  are the independent variables involving forest rents, mineral rents, total natural resource rents, gross fixed capital formation, inflation, and trade openness for country  $i$  at time  $t$ . Moreover,  $p$  and  $q$  are the optimal lag lengths for the dependent and the independent variables, respectively.  $\varphi_i$  is the cross-country heterogeneity and  $\mu_{it}$  is the panel idiosyncratic error term.

It is important to state that the Dynamic panel ARDL models as specified in equations 2 and 3 do not account for cross-sectional (and temporal) dependence among the variables across the cross-sectional units. Deliberately ignoring cross-sectional (and temporal) dependence in panel data settings can have dire consequences and may lead to spurious regression results (Hoechle, 2007). Therefore, after checking for cross-sectional dependence, this study further adopts the Feasible Generalized Least Square (FGLS) estimator to counteract the effect of cross-sectional (and temporal) dependence in the residuals and to check for the robustness of the estimates from the PMG and the MG estimations. The FGLS estimator was first developed by Parks (1967) and later popularized by Kmenta (1988). As such, it is often called the Parks or Parks-Kmenta.

The FGLS estimator could be used to estimate panels with heteroskedasticity and contemporaneously correlated error matrix (Beck, 2001; Hoechle, 2007). However, this estimator only produces efficient, consistent and valid estimates when the time dimension ( $T$ ) is larger or greater than the cross-sectional dimension ( $N$ ), and therefore, the estimator is inappropriate to use with medium- and large-scale micro-econometric panels (Beck, 2001; Hoechle, 2007). Besides, the Parks-Kmenta estimator is also criticized for underestimating standard errors since it assumes that the parameters of  $\Sigma$  are known, not estimated (Beck, 2001). Despite these criticisms, the Parks-Kmenta is still relevant in estimating panels with heteroskedasticity and contemporaneously correlated error matrix especially when the time dimension is larger, as in the case of this study ( $T=30>N=24$ ).

The generic form of the econometric specification of the FGLS method is given as:

$$y_{it} = \alpha + \beta x_{it} + \varepsilon_{it}; i=1, \dots, N; t=1, \dots, T. \quad (4)$$

Where  $y_{it}$  is the dependent variable;  $x_{it}$  is a  $k \times 1$  vector of the explanatory variable;  $\beta$  is a  $k \times 1$  vector of coefficients of the explanatory variables;  $\alpha$  is the intercept term; and  $\varepsilon_{it}$  is the idiosyncratic error term.

The FGLS assumes that  $E(\varepsilon_{i,t}, \varepsilon_{j,s}) = \begin{cases} \delta_i^2 & \text{if } i = j \text{ and } s = t \\ \delta_{i,j} & \text{if } i \neq j \text{ and } s = t \\ 0 & \text{otherwise.} \end{cases}$

Thus, with this assumption, the data provides  $T$  sets of residuals to estimate the contemporaneous covariance,  $\Sigma$  [having typical elements  $E(\varepsilon_{i,t}, \varepsilon_{j,s})$ ] along the block diagonal.

The operational form of the FGLS equation specified in model 4 is reparametrize to estimate the causal relationship between green energy including other control variables and growth (see model 5) and also the causal relationship between Africa's natural resource rents including other control variables and growth (see model 6).

$$\ln GDP_{it} = \alpha + \beta_1 REC_{it} + \beta_2 CO2_{it} + \beta_3 FEC_{it} + \beta_4 GFCF_{it} + \beta_5 INF_{it} + \beta_6 Trade_{it} + \varepsilon_{it} \quad (5)$$

$$\ln GDP_{it} = \alpha + \beta_1 FR_{it} + \beta_2 MR_{it} + \beta_3 TNR_{it} + \beta_4 GFCF_{it} + \beta_5 INF_{it} + \beta_6 Trade_{it} + \varepsilon_{it} \quad (6)$$

It should be noted that the results of the FGLS method are only based on short-run analysis and therefore, do not give any long-run implications. This study only adopted the FGLS estimator to account for cross-sectional (and temporal) dependence and to conduct a robustness check on the estimates from the PMG and MG estimators.

## 5. Empirical Results

We begin the empirical results by presenting the Pesaran test for cross-sectional dependence; the Im-Pesaran-Shin and Levin-Lin-Chu tests for unit root of all the variables; the Hausman test and finally display the results of both the FGLS and the Dynamic panel ARDL models of the PMG and the MG respectively based on the decision of the Hausman Test.

### 5.1 Test for Cross-Sectional Dependence

The study carries out the Pesaran test for cross-sectional dependence on models 1, and 2 to ascertain whether cross-sectional dependence exists among the residuals. Table 2 presents the

results of the estimation. The results show that the null hypothesis of the Pesaran test for cross-sectional independence cannot be accepted for both models 1, and 2 respectively, at the 1% significance level. In all, we conclude that models 1, and 2 are cross-sectionally dependent. This necessitates the possible adoption of the FGLS on the models to account for problem cross-sectional (and temporal) dependence and check for robustness.

**Table 2:** Pesaran's Test for Cross-Sectional Dependence

Statistics	Model 1	Model 2
Pesaran's test for cross-sectional independence	51.108	74.721
Prob.	0.0000	0.0000
The average absolute value of the off-diagonal elements	0.671	0.808

Source: Researcher's Calculations through STATA 17

## 5.2 Unit Root Test

Since most economic variables contain a unit root (Darné & Diebolt, 2005), the current study relies on the Im-Pesaran-Shin (IPS) and Levin-Lin-Chu (LLC) first-generation tests of a unit root in heterogeneous panels developed by Pesaran et al. (1997) and Levin et al. (2002), respectively to determine the unit root properties of the panel. Johansen (1995), and Phillips & Hansen (1990) argued that the existence of a long-run relationship among the variables can only happen when the variables are integrated in the same order. However, Pesaran et al. (1999) show that panel ARDL can be used even if the variables are integrated with different orders. Thus, irrespective of whether they are integrated of I (0) or I (1) or a mixture of both. This is one of the essential features of the panel ARDL estimation techniques as it makes the test for unit root useless. Table 3 reports the results of the IPS and the LLC tests for unit root.

The results from Table 3 show that the null hypothesis of the presence of unit root is rejected for all the variables at their first difference forms for both IPS and LLC. The general implication is that all the variables are at most integrated of order one, I (1). Hence, estimating the underlying models with the panel ARDL method(s) will not produce spurious regression results.

**Table 3:** Results of the Im-Pesaran-Shin and Levin-Lin-Chu tests for unit root

Variables	Im-Pesaran-Shin				Levin-Lin-Chu			
	I (0)		I (1)		I(0)		I(1)	
	I.C.	I.C.& Tr	I.C.	I.C. & Tr	I.C.	I.C.& Tr	I.C.	I.C. & Tr
lnGDP	3.9332	0.6470	-12.3716***	-9.7375***	-1.2850*	0.7740	-10.9226***	-9.2694***
REC	1.9826	0.2874	-12.9753***	-10.6332***	-0.5944	-1.4274*	-10.8703***	-8.6415***
CO2	-0.2810	-1.7864**	-14.1361***	-12.0341***	-2.6055***	-3.3949***	-9.6649***	-7.3772***
FEC	1.2544	-2.0342**	-14.6806***	-12.2590***	0.3118	--1.5238*	-10.2407***	-7.6699***
FR	-2.5723***	-3.6038***	-15.9799***	-13.4081***	-2.5826***	-4.4542***	-14.1312***	-11.2605***
MR	-	-	-	-	-64.7133***	-51.8291***	-10.2601***	-4.2127***
TNR	-3.2791***	-2.1095**	-16.5728***	-13.6189***	-2.2721**	-1.0347	-11.7787***	-8.6622***
GFCF	-1.0840	-1.2612	-14.5642***	-12.0503***	-1.9307**	-1.4562*	-12.5214***	-10.3012***
INFL	-6.2105***	-5.8097***	-20.2085***	-18.3233***	-6.1345***	-5.8483***	-17.9277***	-15.0486***
TRADE	-1.0835	-0.9029	-15.1989***	-13.0373***	-1.5731*	-2.4209***	-12.6734***	-10.5770***

Source: Researcher's Calculation through STATA 17

Note: \*, \*\* and \*\*\* denote the absence of unit root at 10%, 5% and 1% significance levels, respectively.

### 5.3 Hausman Test for Selecting an Appropriate Model (s)

Table 4 present the results of the Hausman Test for models 1, and 2 respectively. From the table, the results show that for model 1, the Hausman test favors the PMG model as opposed to the MG model since the probability value of the Chi-square statistic is insignificant even at the 10% level of significance. On the other hand, the Hausman test favours the MG model as opposed to the PMG model for model 2 since the probability value of the Chi-square statistic is significant at the 1% level of significance. Besides, since the Hausman test favours the MG model for model 2, the study further tests to decide between the MG model and the DFE model. However, the Hausman test results still favour the MG model over the DFE model as the probability value of the Chi-square statistic is now insignificant even at the 10% level of significance. Therefore, the study concluded that the PMG model best suits model 1, while the MG model best fits model 2 for the estimation.

**Table 4:** Hausman Test Results

Choosing between models	PMG & MG		MG & DFE
	Model 1	Model 2	Model 2
Test Summary	$\chi^2$ statistic	$\chi^2$ statistic	$\chi^2$ statistic
Cross-section random	-31.51 (1.000)	20.00 (0.0028)	0.04 (1.000)

Source: Researcher's Calculation through STATA 17

## 5.4 Impact of Green Energy on Economic Growth

Table 5: PMG and FGLS Results of Green Energy and Economic Growth

VARIABLES		
	(1) PMG Estimates	(2) FGLS Estimates
<b>Short Run</b>		
ETC	-0.0402*** (0.0139)	
D.REC	-0.0386 (0.0348)	-0.00629* (0.00355)
D.CO2	0.280 (0.324)	0.151*** (0.0501)
D.FEC	-0.0219 (0.0161)	0.00593* (0.00327)
D.GFCF	0.00114 (0.00298)	0.000407 (0.00171)
D.INFL	-0.00443*** (0.00121)	-1.39e-05** (6.30e-06)
D.TRADE	-0.00471*** (0.00142)	-0.00580*** (0.000866)
Constant	0.562*** (0.183)	23.98*** (0.350)
<b>Long Run</b>		
REC	0.121** (0.0580)	
CO2	0.841*** (0.300)	
FEC	-0.0295 (0.0390)	
GFCF	0.101*** (0.0188)	
INFL	-0.000149 (0.000108)	
TRADE	0.0139** (0.00681)	
Observations	720	744
Number of counties		24

Standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Source: Researcher's Calculations through STATA 17

Table 5 present the results of both the PMG and the FGLS estimations establishing the relationship between green energy consumption, and nonrenewable energy consumption, including other control variables and economic growth. The results show that green energy (renewable energy) consumption has a short-run negative impact on the economic growth of African countries, albeit the effect is only significant at the 10% level of significance under the FGLS estimation. On the contrary, carbon dioxide (CO2) emissions exert a short-run positive impact on economic growth in Africa under both estimations, although the effect is only significant under the FGLS. Additionally, fossil fuel energy combustion (FEC) exhibits a short-run mixed effect on the economic growth of African countries. Thus, a positive and statistically significant effect under the FGLS estimation and a negative but statistically insignificant effect

under the PMG estimation technique. Moreover, the estimates from both estimations show that inflation (INFL) and trade openness (Trade) have short-run significant negative effects on the economic growth of African countries, while gross fixed capital formation (GFCF) has a short-run positive but statistically insignificant effect on the economic growth of African countries.

In terms of the long-run dynamics, the findings indicate that both green energy (renewable energy) consumption and carbon dioxide (CO2) emissions have statistically significant positive impacts on economic growth in Africa. On the other hand, fossil fuel energy combustion (FEC) negatively influences economic growth in Africa over the long run, albeit the effect is generally not significant. Furthermore, trade openness (Trade) and gross fixed capital formation (GFCF) have long-run statistically significant positive effects on economic growth in Africa, while the effect of inflation (INFL) is negative, though it is generally insignificant.

### **5.5 Impact of Natural Resource Rents on Economic Growth**

Table 6 reports the estimates of the PMG and the FGLS estimations depicting the nexus between Africa's natural resource rents together with other control variables and economic growth. In the short-run, holding other factors constant, the results show that forest rents (FR) have a statistically significant negative impact on economic growth, while total natural resource rents (TNR) have a statistically significant positive impact on economic growth in Africa under both estimation strategies. On the other hand, mineral rents (MR) appear to have a mixed effect on economic growth in Africa. Thus, a negative and statistically significant effect under the FGLS estimation and a positive but statistically insignificant effect under the PMG estimation. Besides, inflation (INFL) and trade openness (Trade) are found to have a short-run statistically significant negative impact on economic growth in Africa under both estimations. Likewise, gross fixed capital formation (GFCF) has short-run positive effects on economic growth in Africa, even though the effect is generally not statistically significant.

Presenting the results from the long-run perspectives, we found evidence of long-run relationships among the variables as the ETC (-0.1041457) is greater than -2. However, the results indicate that forest rents (FR) and total natural resource rents (TNR) impacts negatively on the economic growth of African countries over the long run, albeit the effects are generally not statistically significant. Also, the effects of mineral rents (MR) on economic growth in Africa are positive, though it is generally not significant. Moving further, trade openness (Trade) and gross fixed capital formation (GFCF) are found to have a long-run positive effect

on economic growth in Africa, while the effect of inflation (INFL) is negative, though these effects are not statistically significant when estimated with Africa's natural resource rents.

Table 6: PMG and FGLS Results of Green Energy and Economic Growth

VARIABLES	(1) MG Estimates	(2) FGLS Estimates
<b>Short-Run</b>		
ETC	-0.1041457*** (0.0302)	
D.FR	-1.161554** (0.4957)	-0.0579*** (0.00481)
D.MR	0.8675665 (1.9153)	-0.0103** (0.00495)
D.TNR	0.7603607* (0.4247)	0.00956*** (0.00191)
D.GFCF	0.0046576 (0.0038)	0.00226 (0.00173)
D.INFL	-0.0032029** (0.00128)	-1.47e-05** (6.08e-06)
D.TRADE	-0.00777763*** (0.00183)	-0.00491*** (0.000875)
Constant	2.407389*** (0.7353)	24.06*** (0.100)
<b>Long-Run</b>		
FR	-1.832447 (4.7523)	
MR	4.990064 (4.3512)	
TNR	-2.382715 (1.7449)	
GFCF	0.1206891 (0.1293)	
INFL	-0.3966344 (0.3969)	
Trade	0.1241572 (0.1236)	
Observations	720	744
Number of countries		24

Standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Source: Researcher's Calculations through STATA 17

## 6. Discussion of Results

The advancement and advocacy for the usage of green energy occupy the heart of growth and development scholarship today. This is mainly because of the three planetary crises faced by the world today: climate change, biodiversity loss, and pollution. Likewise, what is so-called "Africa's resource curse" has also sparked severe controversies in the growth and development literature. This study, the first of its kind, jointly assesses the impacts of green energy and Africa's natural resource rents on economic growth in Africa.

The results acquiescently show that renewable energy consumption has a statistically significant short-run negative and long-run positive impact on economic growth in Africa. The

negative short-run relationship between renewable energy and economic growth in Africa comes as no surprise as shifting to the usage of renewable energy sources for industrial production and other economic activities will take quite a long time for these countries to cover the losses in production. It is not surprising, however, that it positively and statistically significantly impacted economic growth in the long run in Africa. The long-run positive impact of renewable energy consumption on economic growth is more sustainable as the emissions of greenhouse gasses into the atmosphere will be reduced. The reduction in greenhouse gas emissions will go a long way to help combat the current three planetary crises as already mentioned above and their disastrous effects on both plants and animals. The results of this current study corroborate with previous studies (Pearson, 2021; Qudrat-Ullah & Nevo, 2021; Riti et al., 2022) in which renewable energy consumption was found to have a long-run positive impact on economic growth in Croatia, Africa, and Sub-Saharan Africa respectively. However, their short-run results contradict the current study. Likewise, the short-run negative impact of renewable energy on growth in this study is in agreement with the results of the study by Maji (2015) on the effects of renewable on economic growth in West Africa.

Furthermore, carbon dioxide (CO<sub>2</sub>) emissions exert both short and long-run positive and statistically significant impacts on economic growth in Africa. These findings are reasonable in that higher production correlates with higher emissions of greenhouse gasses into the atmosphere as most of the energy sources in Africa come from nonrenewable sources. However, the positive short and long-run impacts of CO<sub>2</sub> emissions on economic growth in Africa are not sustainable as it worsens the three planetary crises already demonstrated in this study. Aydoğan & Vardar (2020) argued that the burning of fossil fuels (usually coal and natural gas) stimulates economic growth but it poses serious consequences to our planet and the reduction of its use is vital for the planet's welfare. Similarly, the findings indicate that fossil fuel energy combustion (FEC) has a short-run significant positive impact and a long-run insignificant negative impact on economic growth in Africa. The results of this study concord with the findings of previous studies (Borhan et al., 2012; Chen & Huang, 2013; Ivanovski et al., 2021; Sannassee, 2015). However, Mikayilov et al. (2018) found no long-run relationship between CO<sub>2</sub> emissions and economic growth in Azerbaijan. The findings of this study further revealed that the Environmental Kuznets Hypothesis does not hold for Africa as higher emissions stimulate growth in Africa over the long run.

In terms of Africa's natural resource rents' impact on growth, we found evidence of the so-called "natural resource curse" in Africa. The findings from Table 6 convincingly show that

forest rents (FR) and mineral rents (MR) have a short-run statistically significant negative impact and long-run statistically insignificant impacts on economic growth in Africa. However, total natural resource rents (TNR) have statistically significant short-run positive growth effects and statistically insignificant negative long-run growth effects in Africa. This could arguably be due to poor natural resource governance in Africa in terms of the entire value chain of natural resources: from exploitation, extraction, marketing, and rents or profits from the sales of natural resources. Due to the poor natural resource governance in Africa, the potential growth and employment elasticities of the luxurious natural resources are lost. Africa's resources are being controlled and governed by foreign companies who extract and repatriate trillions of dollars in tax havens, trade misinvoicing, unfair tax deals, and other illicit financial flows. According to a report by War on Want (2016) about 101 companies listed on the London Stock Exchange (LSE) - most of them British, have mining operations in 37 sub-Saharan African countries. The report indicated that these companies collectively control over \$1 trillion worth of Africa's most valuable resources. In the same vein, Honest Accounts (2017), and War on Want (2016) demonstrated that an approximated amount of \$41 billion is extracted each year out of Africa, mainly in the repatriation of profits by foreign companies, tax dodging, and the costs of adapting to climate change. How can any continent, country, or region be prosperous with such statistics? Africa needs to properly manage and own its resources should the continent want to reap the growth and employment elasticities of its abundant resources. The long-run negative relationship between Africa's natural resource rents and economic growth confirms the findings of the study by Mohamed (2020) in which natural resource rent was found to have a long-run negative impact on economic growth in Sudan.

Apart from green energy and Africa's natural resource vis-a-vis economic growth nexus, the current study also investigates the impact of trade openness (Trade), gross fixed capital formation (GFCF), and inflation (INFL) on economic growth in Africa. The results reasonably show that trade openness and inflation have short-run statistically significant negative impacts on economic growth in Africa. However, the impact of trade openness on growth is positive and statistically significant over the long run, while the effect of inflation is still negative though not statistically significant. The negative short and long-run relationship between inflation and economic growth in Africa indicates that higher inflation rates are detrimental to the growth of the African economies as it distorts the price system and rises the costs of living for the average consumer. This finding is in tandem with studies by (Burdekin et al., 2004; Gylfason & Herbertsson, 2001; López-Villavicencio & Mignon, 2011; Sarel, 1996) in which

inflation is found to hurt economic growth beyond a certain threshold in developing countries. Besides, the findings imply that trade openness initially worsens economic growth in Africa due to significant tax cuts and subsidies, however, it later acts as a stimulant for growth and development in Africa over the long run. This finding provides empirical evidence that the African Continental Free Trade Area (AfCFTA) may be a good step toward revitalizing the growth and employment prospect of the African continent over the long run. These findings corroborate with the results of previous studies (Dollar & Kraay, 2001; Mumuni & Braimah Abille, 2022; World Bank, 2005) in which it is found that trade openness catalyzed long-run economic growth and income inequality reduction. Lastly, the results depict that gross fixed capital formation has a short-run insignificant positive and long-run significant positive impact on economic growth in Africa. The implication is that domestic investment is necessary for the overhaul growth and development of the African continent. The results, therefore, conform with the findings of past empirical studies (Etokakpan et al., 2020; Li et al., 2022; Suwandaru et al., 2021; Zaman et al., 2021).

## 7. Conclusion and Policy Recommendations

This study employs two different estimation techniques (the FGLS and the dynamic panel ARDL models of the PMG and MG) estimators to assess the impact of green energy and Africa's natural resource rents on economic growth in the continent. The findings revealed that green energy initially worsens economic growth in Africa and later acts as a precursor of growth over the long run. On the other hand, carbon dioxide (CO<sub>2</sub>) emissions stimulate economic growth in Africa over the short and long run, while fossil fuel energy combustion stimulates economic growth in the short run and has negative long-run effects on economic growth in Africa. Additionally, the study found evidence of Africa's natural resource curse as the findings reveal that mineral and forest rents have significant short-run negative impacts on economic growth, albeit the effects are generally not significant in the long run. Similarly, total natural resource rents in Africa have statistically significant short-run positive and long-run statistically insignificant negative impacts on economic growth.

Based on these findings, we proposed the following recommendations for a better policy perspective in Africa toward achieving the United Nations Sustainable Development Goals.

First, policymakers and African governments need to develop new modalities for the advancement and usage of renewable energy sources for both industrial and domestic production. This policy measure has the potential to create a greener, cleaner, and more

sustainable growth and development in Africa. The logic here is that the consumption of renewable energy sources will not only significantly reduce the emissions of greenhouse gasses into the atmosphere but will also help in combating the current three planetary crises: climate change, biodiversity loss, and pollution.

Second, this study recommends that African governments need to collaboratively create independent and strong institutions to monitor and effectively manage their abundant and luxurious natural resources. Transparency and Accountability are paramount in the entire value chain of natural resources and to ensure that Africa's natural resources rents are linked to their growth and employment elasticities. Independent and strong institutions across the globe need to also support African governments in imposing tax obligations and royalty rates on the resources extracted by foreign companies.

Third, the global shadow banking system which promotes illicit financial activities and corporate tax evasion via secrecy laws, tax havens, and shell corporations must be destroyed. Thus, there should be a revamp of the global tax rules.

Last but not least, taming inflation, strengthening governments' commitments to the AfCFTA, and encouraging domestic investment and or developing more physical infrastructure are effective ways to promote growth and development in Africa over the long run.

## Declaration Statement

The authors declare no conflict of interest

## Data Availability

Data used for this study can be found online at <https://data.worldbank.org/indicator> (accessed on September 1, 2022).

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