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The dilemmas of relevance: exploring the role of Natural resources and Energy Consumption in managing climate crisis in Africa

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Abstract

The study examines the role of natural resources and energy consumption in managing the climate crisis in Africa, using annual series data from the World Bank from 1980 to 2019. The empirical strategy is based on the second-generation panel techniques that account for cross-sectional dependency in the series. Specifically, the empirical evidence is based on the Westerlund (2017) panel cointegration test, panel augmented mean group, common correlated effects mean group and the vector autoregressive-vector error correction approach. Evidence from the panel analysis confirmed the existence of Carbon Kuznets Curve (CKC) U-shaped nexus in Africa, but the country-level results are mixed. Furthermore, results using the vector autoregressive-vector correction model indicate possible convergence among the variables across the African countries. Natural resource unidirectionally Granger-causes carbon emissions. We suggest the consideration of environmental factors in the utilisation of natural resources. Similarly, energy efficiency is crucial to decouple carbon from energy usage. The study complements the extant literature by assessing the role of natural resources and energy consumption in managing climate crisis in Africa.

Keywords: Carbon Kuznets Curve; carbon emission; Natural resource; climate crisis; energy consumption; Africa

1. Introduction

This study seeks to re-examine the role of natural resources and energy consumption in explaining the Carbon Kuznets Curve hypothesis (CKC) in Africa. This was done with the hope of providing information that can help reduce carbon emissions and promote sustainable development. For more than 300 years, man has found succour and economic potential from the environment, but today the disparity between nature and man is beyond reconciliation. This is obvious from the climate crisis and the suffering that nature has continued to inflict on both man and the economy. For example, earth observers have awakened to the reality of domes of high pressure, which indicates that incidences of high temperatures are likely to increase in different parts of the globe with time. Another example is the rising sea level, and rapid increase in high-tide floods, caused by climate change. While the climate crisis is unlikely to exempt anyone, the immediate priority is to mitigate its impacts, prolong its inevitable consequences on the world's population, and prevent economic misfortunes. However, it would be reckless if policy makers fail to reconsider a pragmatic approach to cut carbon emissions, secure a minimally volatile climate, and prevent economic misfortunes.

Several factors have motivated the choice of Africa as a candidate for this research. Firstly, the African continent is highlighted as the hot spot for climate events. This is evidenced by the extreme temperatures and high trends in rainfall recorded in Africa in recent decades (see Seneviratine et al., 2012; Asongu & Odhiambo, 2019, 2020). Secondly, there is an awakening realisation that numerous restrictions have limited Africa's ability to potentially adapt to reduce carbon emissions. This might have severe consequences for climate policy, highlighting the urgent need for this study. Thirdly, the increase in the level of economic activity, accompanied by an increased in energy consumption, calls for the need to understand the implications of managing climate crises. Lastly, the need to reassess the implications of over-exploiting natural resources in cutting carbon emissions is important for the African continent, given the urgent priority in managing the level of carbon emissions. For example, the excessive exploration of natural resources has been linked to extreme climate change and the African continent appears to be the biggest player (see Asongu et al., 2020; Asongu 2019; Shobande & Enemona, 2021).

Several policy initiatives to cut carbon emissions, introduced at the Rio Earth Summit in June of 1995, have yet to materialise. In particular, the United Nations Framework on Climate Change, endorsed by 150 countries to provide solutions to climate crises, was poorly realised due to poor design, implementation, and monitoring. Ideally, many of the countries that endorsed the climate strategy cannot practice the policy because of the rigidity in its implementation (Shobande, 2021a; Asongu, 2019). In reality, carbon emissions cuts are possible with stringent control and monitoring, but a good understanding of the moderating role of natural resources and energy consumption is critical for reducing carbon emissions (see Asongu & Odhiambo, 2021a, 2021b; Shahbaz et al., 2017; Shobande & Enemona, 2021). It is not only about economic growth, but it is also about an associating mechanism that dictates the level of economic activity. Hence, as the world battles with a renewed provocation of nature, this timely study assesses the role of natural resources and energy consumption in explaining the carbon Kuznets curve for Africa.

The economic intuition that seeks to explain the link between rising economic activities and carbon emissions is settled on the carbon Kuznets curve. The hypothesis is named after Grossman and Krueger (1993), who observed an inverted relationship between economic activities and environmental damage (See Cole et al., 1997; Dasgupta et al., 2002). While the hypothesis has incited a significant number of empirical papers, evidence remains inconclusive. For example, some studies find no meaningful evidence for the CKC hypothesis and argue that it is inappropriate for environmental policy (see Apergis & Payne, 2009; Acaravi & Ozturk, 2010; Wang et al., 2016; Hu et al., 2018). However, evidence on its validity has been confirmed by some prominent studies (Sarkodie et al., 2018; Pincheira & Zuniga, 2020; Shobande & Ogbeifun, 2021; Sen & Abedin, 2021). One important point of contention often cited by critics is that the hypothesis took for granted several factors that are likely to cause a marginal change in carbon emissions. For example, several studies have shown that an increase in the level of economic activity can increase demand for energy consumption and have an impact on carbon emissions. Similarly, the over-exploration of resources has led toa key concern regarding carbon emissions.

This study contributes to the existing literature in several ways. (a) It investigates the role of natural resources in carbon emissions within resource-rich economies in Africa. (b) By controlling for confounders and using the second-generation time series approach, it makes inference and adds new information that can help to mitigate climate risk with the effective and efficient utilisation of resources. Specifically, the empirical evidence is based on the Westerlund (2017) panel cointegration test, panel augmented mean group (AMG), common correlated effects mean group (CCEMG), the vector autoregressive (VAR) approach. This finding confirmed the existence of a CKC, and natural resources and energy consumption were found to be important for mitigating carbon emissions.

The remainder of this paper is organised as follows: section 2 presents a concise literature review; section 3 provides the framework, model, and data descriptions; section 4 discloses the empirical results; and section 5 concludes with policy recommendations.

2. Literature Review

This section presents a variety of theoretical and empirical contributions to the literature on the CKC and the associated mechanisms. It aims to provide a concise analysis of the most modern developments on the subject and to appreciate the strengths of the scholarly contributions, as well as the lacuna in the corresponding literature.

Evidence of the Carbon Kuznets Curve (CKC)

Research seeking to validate the CKC hypothesis is far from being in agreement on whether the hypothesis provides a good fit for formulating the environmental strategy needed to cut carbon emissions and promote environmental quality. Apergis and Payne (2009) observed a causal relationship between carbon emissions, energy consumption, and output for a panel of Central American countries from 1971 to 2004, using the panel vector error correction (VEC) model. The results from their study yielded no valid evidence of the CKC hypothesis. However, they did report a long-run positive relationship between energy consumption and carbon emissions. Acaravci and Ozturk (2010) assessed a panel of 16 European countries, using the autoregressive distributed lag (ARDL), and found no meaningful evidence to validate the CKC hypothesis. Nevertheless, they did observe a unidirectional causality running from economic growth to carbon emissions. Narayan and Narayan (2010) found no CKC hypothesis in 43 developing countries, using a cointegration approach. Furthermore, Wang et al. (2016) found no evidence of the CKC in China from 1990 to 2012. Xu (2018) suggested that policymakers use caution when leveraging on the CKC to implement environmental policies, to avoid policy somersault. In contrast, Kais and Sami (2016) found evidence for the CKC hypothesis in a panel of 58 countries from 1990 to 2012, and Lean and Smyth (2010) confirmed the existence of the CKC hypothesis for a panel of five Asian countries from 1980 to 2006. Moreover, while, Sadik-Zada and Gatto (2020) rejected the CKC hypothesis using a multivariate panel model from 1960 to 2018, Saboori (2018) confirmed the validity of the CKC hypothesis for 17 African countries from 1971 to 2013. Dasgupta et al. (2002) stated that further studies on CKC can help to provide a better understanding of the hypothesis and, in turn, help to cut carbon emissions while flattening the

Kuznets curve. Damir (2019) and Bulut (2021) found evidence of CKC in Turkey. Pang et al. (2019) found evidence of CKC in 30 provinces in China and 105 environmental monitoring cities. Sen and Abedin (2021) found evidence of CKC in China and India from 1972 to 2017, while Shobande and Ogbeifun (2021) found evidence of CKC across countries within the Organisation for Economic Co-operation and Development. Pincheira and Zuniga (2020) conducted empirical studies on the CKC and reported mixed evidence. Chu (2021) consistently found that there is an inverted U-shaped relationship between economic complexity and CO_2 emissions in 118 countries from 2002 to 2014, using a generalised method of moments. Furthermore, using the ARDL, Shahbaz et al. (2014) confirmed the validity of the inverted U-shaped Kuznets curve for the United Arab Emirates from 1975 to 2011.

Evidence on natural resource - carbon Kuznets Curve

Since the seminal Rees (1992) suspected a potential link between the exploration of natural resources and environmental degradation, several studies have sought to theoretically and empirically validate the link. However, the evidence is far from conclusive. Wang et al. (2020) reported that natural resources adversely affected carbon emissions in a panel of G7 countries from 1996 to 2017, using the Westerlund cointegration approach. Dong et al. (2017) suggested that the excessive exploration of natural resources poses an important threat to carbon emissions. Hassan et al. (2019) assessed the link between economic growth, natural resources, and the ecological footprint in Pakistan before reporting that bidirectional causality exists between natural resources and the ecological footprint. Kattumiri (2018) assessed the prospect of sustainable resources for environmental degradation and reported that the effective management of resources can help to reduce carbon emissions. Moreover, Rout (2018), and Srikanth and Nathan (2018) suggested that extreme pollution is correlated with natural resource utilisation.

Evidence on energy - carbon Kuznets Curve

Numerous theoretical and empirical studies, seeking to validate the link between energy consumption and the CKC hypothesis, are not without conflicting findings. Brown et al. (2018) argued that unequal access to energy can lead to pollution. Zhang (2010) observed that production-related activities were associated with increased carbon emissions in China from 1995 to 2005. Furthermore, Akadiri et al. (2019) observed unidirectional causality between energy consumption, income, and carbon emissions in South Africa. Alola et al.

(2019) confirmed the existence of a dynamic relationship between energy and environmental quality. Shahbaz et al. (2017) found an asymmetric relationship between energy consumption, economic growth, and carbon emissions in the Indian economy, using quarterly data from 1960 to 2015. Additionally, Shahbaz et al. (2014) reported that energy consumption reduces carbon emissions in the United Arab Emirates. Using the Clemente-Montanes-Reye's test and the structural break test, Shahbaz et al. (2012) observed a feedback hypothesis between energy consumption, economic growth, and carbon emissions. Sharma et al. (2021) reported that energy has a negative but insignificant impact on carbon emissions in emerging Asian economies and Megazzino et al. (2021) observed that energy (biomass) can reduce carbon emissions in Germany.

The obvious conclusion from the review indicates that further evidence is required to validate the potential of natural resources and energy consumption to explain the carbon Kuznets curve. In particular, understanding the relationship between these variables is important for managing the climate crisis in Africa.

3. Framework and Methodology

This study is framed in the carbon Kuznets curve theoretical underpinning that postulates an inverted-U association between pollutants and economic output, indicating that economic growth initially engenders greater environmental deterioration at low levels of income, but that some factors which may likely have a marginal impact on carbon emissions are not considered (Cole et al., 1997; Shobande & Asongu, 2021). Accordingly, the underlying factors include energy consumption and natural resources rent related problems that can have severe implications on carbon emission were omitted but reconsidered in the present study.

The basic model is:

$$CO_{2it} = f(Y_{it}, Y_{it}^2, X_{it}, v_{it}) \qquad (1)$$

Equation (1) represents the reduced form relationship postulated by the CKC hypothesis to have an inverted U-shape form which implies quadratic terms in levels or log quadratic terms in logs. This is estimated using a panel dataset from Africa. Where index $i\ and\ t$ respectively denoteindividual countries and time; Co_2 is carbon emission per capita; Y signifies income per capita; Y^2 is the quadratic function of income per capita; X reflects thevector of control variables (energy consumption and natural resource), and v_{it} is the error term.

The empirical strategy of this study follows the second-generation panel approach that accounts for cross sectional dependency in the data. Specifically, the study employs the Westerlund (2005) panel cointegration test, panel augmented mean group (AMG) and common correlated effects mean group (CCEMG). We also utilised the panel heterogenous Granger causality test based on the vector autoregressive (VAR) /vector error correction (VEC) that can help to dissect the dynamics of long and short relationships among the variables and provide inference on their convergence to equilibrium.

To capture the short run dynamic, Equation (1) is respecified by making all the variables endogenous and including error term in Equations (2) to (6).

$$CO_{2it} = fCO_{2it-1}, (Y_{it}, Y_{it}^2, EC_{it}, NR_{it}, v_{1it}) \quad (2)$$

$$Y_{it} = f(Y_{it-1}, CO_{2it}, Y_{it}^2, EC_{it}, NR_{it},, v_{2it}) \quad (3)$$

$$Y_{it}^2 = f(Y_{it-1}^2, Y_{it}, CO_{2it}, EC_{it}, NR_{it}, v_{3it}) \quad (4)$$

$$EC_{it} = f(EC_{it-1}, Y_{it}, Y_{it}^2, CO_{2it}, NR_{it},, v_{4it}) \quad (5)$$

$$NR_{it} = f(NR_{it-1}, Y_{it}, Y_{it}^2, EC_{it}, CO_{2it}, v_{5it}) \quad (6)$$

Where EC denotes energy consumption; NR is natural resources; and $v.$ is the error term. All the variables are indexed in natural logarithm. Equations (2) to (6) are further respecified to capture the speed of adjustment known as the long run dynamic of the variables in Equations (7) to (11).

$$CO_{2it} = fCO_{2it-1}, (Y_{it}, Y_{it}^2, EC_{it}, NR_{it}, v_{1it}, ect_{1it-1}) \quad (7)$$

$$Y_{it} = f(Y_{it-1}, CO_{2it}, Y_{it}^2, EC_{it}, NR_{it},, v_{2it}, ect_{2it-1}) \quad (8)$$

$$Y_{it}^2 = f(Y_{it-1}^2, Y_{it}, CO_{2it}, EC_{it}, NR_{it}, v_{3it}, ect_{3it-1}) \quad (9)$$

$$EC_{it} = f(EC_{it-1}, Y_{it}, Y_{it}^2, CO_{2it}, NR_{it}, v_{4it}, ect_{4it-1}) \quad (10)$$

$$NR_{it} = f(NR_{it-1}, Y_{it}, Y_{it}^2, EC_{it}, CO_{2it},, v_{5it}, ect_{5it-1}) \quad (11)$$

The speed of convergence of the variables which determines the long run potential in each model is represented by ect_{t-1}.Beyond the consistency of the underlying equations with the extant literature (Cole et al., 1997; Shobande & Asongu, 2021), the equations are also in accordance with another strand of literature on nexuses between natural resources, human capital, foreign direct investment, renewable energy and carbon emissions (Zafar et al., 2019; Bao & Lu, 2023; Abdulqadir, 2023).

Data

This study focuses on a panel of 16 Sub Saharan African countries selected based on the richness in natural resources and availability of the dataset. The African countries include Angola, Benin, Burkina Faso, Burundi, Cameroon, Chad, Congo, Cote d'Ivoire, Gambia, Ghana, Mali, Mozambique, Togo, Uganda, and Nigeria. The study utilized annual series sourced from the World Bank from 1980 to 2019. The variables' descriptions are as follows. The dependent variable is carbon emission (CO_2 measured in metric tons), and the main independent variable is economic growth measured as per capita income (GDP (constant 2010$). Consistent with the literature (Shahbaz et al, 2017; Shobande, 2021b; Shobande & Asongu, 2021), we control for energy consumption variables (energy consumption and natural resource). Natural resources are measured as the total natural resource rent as percentage of GDP while energy consumption is measured as energy use (kg of oil equivalent) per capita.

4. Results

This section presents and discusses the empirical results of the estimated models. It aims to validate the role of natural resource and energy consumption in managing climate crisis in Africa.

Preliminary Analysis

In time series and panel analyses, it is important check with a preliminary analysis of the series before further analysis in order to understand the prior behaviour of corresponding variables. In this study, an initial check is conducted based on descriptive statistics, cross-sectional dependency test, and the slope of heterogeneity test. Table 2 presents the descriptive statistics of the variables.

Table 1. Descriptive Statistics

Variables	Mean	Std. Dev.	Obs.
$\ln CO_2$	0.33	0.18	640
$\ln Y$	3.96	5.39	640
$(\ln Y)^2$	4.47	1.38	640
$\ln NR$	11.50	9.17	640
$\ln EC$	494.19	188.4	640

Notes. Carbon emission *(CO_2)*,economic growth *(Y)*, quadratic term of economic growth *(Y^2)*, natural resource (*NR*); and energy consumption *(EC)*.

The average (standard deviation) of carbon emission is 0.33 (0.18); economic growth, 3.96 (5.39); the quadratic term of economic growth, 4.47 (1.38); natural resource, 11.50 (9.17) and energy consumption, 494.19 (188.4).

After the descriptive statistics, it is important to conduct cross sectional dependency test (CD) and slope heterogeneity test for several reasons, notably: (a) poor knowledge of CD test may lead to a wrong assumption on the behaviour of the series and generate poor and/or inefficient results (Herwartz & Siedenburg, 2008; Jonsson, 2005). (b) The CD test enables the study to check unobserved common factors that are likely to have spillover effects across the panel. Tables 2-3 report the CD test and slope heterogeneity test.

Table 2. Cross-sectional Dependency test

Variables	CD test	P-value	Mean (ρ)
$\ln CO_2$	4.00***	0.00	0.29
$\ln Y$	4.61***	0.00	0.42
$(\ln Y)^2$	4.72***	0.00	0.42
$\ln NR$	5.79***	0.00	0.27
$\ln EC$	2.87***	0.03	0.31

Notes. Carbon emission *(CO_2)*,economic growth *(Y)*, quadratic term of economic growth *(Y^2)*, natural resource (*NR*); and energy consumption *(EC);* ***, denotes significanceat 1%.

Table 3. Slope heterogeneity test, using (Pesaran & Yamagata, 2008)

Test	Delta	P-value
$\hat{\Delta}$	19.52***	0.00
$\hat{\Delta}$ adj	21.25***	0.00

Notes. ***, denotes significance at 1%.

The results of the CD test and slope coefficient confirmed that there are common unobserved factors among the series. This implies that there are spatial and socioeconomic factors that are common from among these countries. For example, most of these countries share common geographical boundaries (e.g., Sub Saharan Africa), and have natural resource (*see* Shobande &Enemona, 2021).

Given the surprising evidence of cross-sectional dependency identified in the series, the first-generation test is unlikely to be robust (Fan et al., 2015; Gagliandini et al., 2016; Foote etal., 2021; Harvey & Liu, 2021). Thus, the study implements the cross-sectional augmented Dickey Fuller (CADF), and the cross-sectional Im, Pesran and Shin (CIPS) tests. Although, a number of panel unit roots tests account for cross sectional dependency, the proposed approach by Pesaran (2007) is employed owing to two main factors. (a) The CADF and CIPS panel unit roots approach account for cross-sectional dependency average of lagged levels and the first differences of the individual series which appear to be instrumental and robust asymptotically (Shobande & Asongu, 2021). (b)The CADF and CIPS panel unit roots approaches are robust to cross-sectional dependency in size and power properties (see Shobande & Asongu, 2021). Table 4 reports the results of the panel unit root tests conducted based on CADF and CIPS tests.

Table 4: Panel Unit Roots Tests using (Pesaran, 2008)

Variables	CADF			CIPS	
	I(0)	I(1)		I(0)	I(1)
$\ln CO_2$	-1.47	-4.65**		-1.51	-5.61**
$\ln Y$	-1.55	-3.55**		-0.63	4.92**
$(\ln Y)^2$	-1.28	-3.93***		-0.78	5.49**
$\ln NR$	-1.61	-4.12***		-1.55	-5.10**
$\ln EC$	-1.52	-3.36**		-1.36	-5.38**

Notes. Notes. Carbon emission *(CO_2),* economic growth *(Y),* quadratic term of economic growth *(Y^2),* natural resource (*NR*); and energy consumption *(EC);* ***; **, denote significance levels at 1% and 5%, respectively.

The general agreement among the panel unit roots tests is that the series are only stationary after taking their first differences. Thus, based on these results, the Westerlund panel cointegration test was implemented.

Panel cointegration tests

Considering the existence of cross-sectional dependency spotted in the panel of African countries under inquiry, we implement the Westerlund cointegration test proposed by Westerlund (2005). Two motivations call for these considerations. First, the Westerlund approach helps to assess the long run dynamics among the factors. Second, the Westerlund panel cointegration accounts for cross-sectional dependency among the variables using two panel autoregressive (AR) parameters, notably: Panel – specific AR test, and same AR test statistics.

The panel specific AR test can be stated as:

$$VR = \sum_{i=1}^{N}\sum_{t=1}^{T} \widehat{E^2}_{it}\, \hat{R}^{-1}{}_{i}$$

The same AR test can be stated as:

$$VR = \sum_{i=1}^{N}\sum_{t=1}^{T}\widehat{E^2}_{it}\sum_{i=1}^{N}\hat{R}^{-1}{}_i$$

Where $\hat{E}_i = \sum_{j=1}^{t}\hat{e}_{ij}$, $\widehat{R_\iota} = \sum_{j=1}^{t}\widehat{e^2}_{ij}$ and $\hat{e}_{ij}$are residuals from the panel data regression model and VR is the group mean variance ratio statistic. Table 5 reports the results of the Westerlund panel cointegration approach.

Table 5. Results of the panel cointegration test, using (Westerlund, 2005)

Tests	Intercept		Intercept & Trend	
	Statistic	P-value	Statistic	P-value
Variance ratio	-2.1620	0.0013***	-2.9511***	0.0001

Note. ***, denotes significance at 1%.

From the results, the null hypothesis of no cointegration is rejected at 1% level of significance, irrespective of whether a time is included or not. The results suggest the existence of cointegration among the variables, indicating that carbon emissions and other environmental factors are important features for promoting environmental quality across the panel of African countries from 1980 to 2019 estimated.

The main results

Just after the preliminary analyses have been conducted, next we proceed to estimates and discuss our model.

The AMG country level and panel cointegration estimates

Just after confirming the existence of cointegration among the variables, next we implement the augmented mean group (AMG) proposed by Eberhardt and Bond (2009). Two main reasons motivate the use of AMG estimator. First, it is accounts for cross-sectional dependency among the variables. Second, it enables inclusions of common dynamics of parameters that help validate the long run potential of the factors. The AMG is specified as:

AMG – Stage 1

$$\Delta Z_{it} = \alpha_i + \beta_i \Delta X_{it} + c_i f_t + \sum_{t=2}^{T} d_i \, \Delta D_t$$

$+ v_{it}$*AMG – Stage 2*

$$\beta_{iAMG} = N^{-1} \sum_{i=1}^{N} b_i$$

Where Δ denotes the first difference operator; Z_{it} and X_{it} are observable; β_i denotes the coefficients of the country-specific estimates; f_t is the observed common factor with heterogeneous features; d_i is the time dummy; α_i and v_{it} are respectively, the intercept and error term. Table 6 reports the country level and panel analyses of the AMG estimations.

Table 6. Panel and country-specific results of the AMG estimations

Panel	Panel AMG				
	Dependent Variable: CO_2				
	$\ln Y$	$(\ln Y)^2$	$\ln NR$	$\ln EC$	CKC Validity
	0.56** [5.20]	-0.0038** [5.41]	-0.019* [1.96]	0.029 [3.54]	yes
Countries	Individual AMG				
Angola	0.009** [6.72]	-0.0002** [-5.30]	-0.14* [-195]	-0.005** [-3.18]	yes
Benin	0.051** [4.67]	0.00031** [-4.56]	-0.008 [-0.22]	0.0012* [1.98]	yes
Burkina Faso	0.008** [7.01]	-0.003** [-5.91]	-0.004 {-0.38]	0.0002* [3.34]	yes
Burundi	0.005* [1.79]	-0.0001** [-2.3]	-0.0016** [-3.49]	0.0002** [5.63]	yes
Cameroon	0.0014** [3.37	-0.00043** [-3.11]	0.012 [0.95]	0.0007 [0.25]	yes
Chad	-0.002** [-2.81]	0.000014** [3.4]	-0.0005 [-1.44]	-0.0032 [-1.35]	no
Congo	0.0036 [0.63]	-0.00019 [-0.66]	-0.0015* [-2.05]	0.002 [5.24]	no
Cote d'Ivoire	0.028** [2.33]	-0.00008** [-3.11]	0.05* [1.72]	-0.001 [-0.99]	yes
Gambia	-0.034* [-1.89]	0.00006** [3.49]	-0.007 [-0.89]	0.0006* [3.81]	no
Ghana	-0.016** [-2.12]	0.0025* [3.14]	-0.0009 [-0.36]	-0.0001* [-2.37]	yes
Mali	0.016** [2.15]	0.00018** [-2.45]	0.0072 [0.45]	0.0014 [0.61]	no
Mozambique	-0.06** [-5.18]	0.0005** [3.87]	0.003 [2.91]	0.0015 [1.32]	no
Nigeria	0.0049 [0.37]	-0.00014* [-1.79]	0.005* [2.06]	0.0008 [1.07]	no
Togo	0.007 [0.94]	-0.00004 [-0.72]	-0.001 [-0.57]	0.0006 [1.17]	no
Uganda	0.0081* [2.53]	-0.00005* [-2.96]	0.0019*** [4.06]	0.00026** [3.17]	yes
Zimbabwe	0.0037* [-3.25]	-0.000004** [-3.00]	-0.0018* [-1.99]	-0.0053** [-2.77]	yes

Notes. Carbon emission *(CO_2)*,economic growth *(Y)*, quadratic term of economic growth *(Y^2)*, natural resource (*NR*); and energy consumption *(EC)*; ***, **, *; denote 1%, 5%, and 10% significance levels; the value in parentheses represents t-statistics and "yes" in the last columnindicates thatthe CKC hypothesisis valid and "no"implies that the CKC hypothesis isnot valid.

From the AMG results, it is obvious that evidence in support of the CKC hypothesis is relatively mixed for the African countries estimated although, the CKC hypothesis holds in majority of the African countries investigated. Also, panel AMG results suggest that initial economic growth is positively correlated with carbon emissions, while the quadratic terms of economic growth negatively reduce carbon emissions. Similarly, natural resources rent negatively correlate with carbon emissions, while energy consumption positively correlate with carbon emissions.

Robustness tests

To further validate the results of the AMG, we implement the common correlated effect mean group (CCEM), and the results are reported in Table 7.

Table 7. Robustness of the analysis.

Independent Variables	Dependent Variable: $\ln CO_2$	
	AMG	CCEMG
$\ln Y$	0.56*** [5.20]	0.58*** [6.18]
$(\ln Y)^2$	-0.0038** [-5.41]	-0.0041** [-6.25]
$\ln NR$	-0.019* [-1.96]	-0.026** [-2.17]
$\ln EC$	0.029** [3.54]	0.033** [4.01]
Countries	16	16
Obs.	640	640
Wald test	40**	56**
p-value	[0.00]	[0.00]
RMSE	0.038	0.42

Notes. ***, **, *; denote 1%, 5%, and 10% significance levels; the value in parentheses represents the t-statistics

The results obtained from the CCEM are like those of the AMG but differ in magnitude and efficiency of the parameters. A possible explanation is the difference in the Root Mean Square Error (RMSE) terms, which are not too obvious.

Panel Granger Causality: VAR/VEC Approach

As earlier stated, the empirical strategy of the study follows the vector autoregressive (VAR)/ vector error correction (VEC) approach, and the consideration is motivated by two factors. (a) The VAR/VEC granger causality approach helps to uncouple the dynamic relationship among the variables by dissecting the long run and short run relationships. (b) It provides understanding on the speed of convergence of the variables which is important for formulating policy. Table 8. reports the results of the VAR/VEC Granger causality tests.

Table 8. The Panel VAR/VEC Granger causality test

Independent variables	Short run Direction of causality				Long run
	Dependent variable				ECT_{t-1}
	$\ln \Delta CO_{2it}$	$\ln \Delta Y_{it}$ $(\ln\Delta Y_{it})^2$	$\ln \Delta NR_{it}$	$\ln \Delta EC_{it}$	$t-stat/[p-value]$
$\ln \Delta CO_{2it-k}$	-	8.19** [0.00]	2.43 [0.29]	4.56** [0.00]	-0.028*** [0.00]
$\ln \Delta Y_{it-k}$ $(\ln \Delta Y_{it-k})^2$	5.68** [0.00]	-	1.74 [0.41]	9.1** [0.00]	-0.001**** [0.00]
$\ln \Delta NR_{it-k}$	12.9** [0.00]	73.6** [0.00]	-	2.95 [0.22]	-0.03 [0.06]
$\ln \Delta EC_{it-k}$	18.7*** [0.00]	2.73 [0.26]	5.56** [0.036]	-	0.007 [0.33]

Notes. Δ denotes the first different operator, ***, **, *; denote 1%, 5%, and 10% significance level, respectively.

The analysis of the VAR/VEC Granger causality test yields two sets results: First, the speed of adjustment of the variables (i.e., indicating the long run dynamics of the variables) was negative and statistically significant for majority of the variables. Precisely, the coefficients of vector error correction terms and corresponding p-values are -0.028 [0.00]; 0.001 [0.00]; -0.02 [0.00]; 0.007 [0.33]. Second, the short run directions of causality are reported as follows. (a) economic growth and energy consumption bidirectionally Granger-cause carbon emissions; (b) natural resources unidirectionally Granger cause carbon emissions, indicating feedback hypothesis; (c) a bidirectional relationship exists between natural resource and carbon emissions; and (d) energy consumption unidirectional cause natural resources, while economic growth Granger causes energy consumption. The results are consistent with previous studies (Shahbaz et at., 2017; Shobande & Enemona, 2021; Sharma et al., 2021).

Contribution to Theoretical and Empirical Literature

Our analysis makes a significant contribution to the theoretical literature on the role of natural resources and energy consumption in mitigating climate risk. The findings support the resource curse theory, which posits that countries that heavily rely on natural resources tend to have higher carbon emissions due to the dependence on resource extraction and exportation. The study underscores the need for effective governance and management of natural resources to decrease carbon emissions (Wu et al., 2021; Yao et al., 2022; Luo et al., 2022; Anser et al., 2020).

Furthermore, the study supports the green growth theory, which argues that economic growth and environmental sustainability are not mutually exclusive. This theory emphasizes the importance of transitioning to renewable energy sources and implementing sustainable production and consumption practices to reduce carbon emissions while maintaining economic growth (Khan et al., 2023; Hallegatte et al., 2011; Schmalensee et al., 2012; Bowen & Hepbum, 2014; Smulders et al., 2014)).

The circular economy literature also supports our findings, highlighting the need to reduce waste by keeping resources in use for as long as possible and maximizing their value. Additionally, the study provides evidence for the emerging concept of decoupling, which advocates for separating economic growth from resource use and environmental impact (Shobande et al., 2023; Bianchi & Cordella, 2023; Okorie et al., 2023; Jayarathna et al., 2023; Figge & Thorpe, 2023). This can be achieved through strategies such as dematerialization, reducing energy use, and increasing resource efficiency.

Overall, our inquiry into the relationship between effective natural resource usage and mitigating climate change has contributed to the development of a low carbon economy by identifying best practices and strategies for reducing carbon emissions while promoting economic growth and development (Nwani & Adams, 2021; Wang et al., 2020; Balsalobre-Lorente et al., 2021). The study informs policy strategies on natural resource management, renewable energy adoption, and sustainable production and consumption practices, leading to a more effective and efficient transition towards a net-zero economy.

Conclusion and Policy implications

Uncertainty in cutting carbon emissions motivated the need to revisit the mediating role of natural resources and energy consumption in explaining the Carbon Kuznets Curve (CKC) in the management of climate crisis in Africa. The analysis of the paper follows the second-generation panel estimations that account for potential cross-sectional dependency. Specifically, the empirical evidence is based on the Westerlund panel cointegration test, the augmented mean group approach, the vector autoregressive approach, and the panel vector error correction estimator. Our results validate the CKC hypothesis. They also highlight the importance of the effective and efficient management of natural resources, and energy efficiency in mitigating the aftermath of carbon emissions and preventing a climate crisis in Africa. Theresults of this study are consistent with previous findings (Wang et al., 2020; Shahbaz et al., 2012; Saboori et al., 2016; Shobande & Enemona, 2021; Sharma et al.,2021).

Our analysis has significant implications for policymaking aimed at combating climate crisis.

- One of the most effective policy strategies for decoupling emissions from resource utilization is waste reduction, which can be achieved by promoting strategies such as reuse, recycling, and composting. Policymakers can play a key role in this process by implementing policies that promote waste reduction and ensure the sustainable management of waste. These policies can contribute to a reduction in demand for new resources and decrease emissions linked to the production and disposal of waste.
- Policymakers espouse sustainable production practices that entail the application of environmentally friendly technologies and processes, which possess the capability to curtail emissions and enhance resource efficiency. Through the proficient and efficacious implementation of renewable energy sources, such as wind and solar power, substantial reductions in greenhouse gas emissions can be achieved, as they do not discharge hazardous pollutants or greenhouse gases.
- Increasing resource efficiency is another important strategy for decoupling emissions from resource utilization. This can be achieved by using more efficient technologies, better insulation, and energy-efficient lighting. By using resources more efficiently, we can reduce the demand for new resources and reduce emissions associated with resource extraction and processing.
- Raise awareness and educate the public about the benefits of renewable resource is crucial. Policymakers can engage in public outreach and education campaigns to help people understand the importance of transitioning to renewable energy sources and the benefits this can have for the environment and society.

- Fostering international cooperation on renewable natural resources can play a crucial role in reducing the risk of climate change. Policymakers can collaborate with other countries to share knowledge, resources, and best practices for transitioning to renewable natural resources. By working together, countries can leverage their strengths and resources to accelerate the adoption of renewable energy technologies and reduce carbon emissions.

The scope of our investigation concerns the role of natural resources and energy consumption in the mitigation of the climate crisis in Africa. Consequently, this analysis does not purport to examine highly developed economies nor offer country-specific remedies. Subsequent research endeavours could examine the moderating influence of macroeconomic factors in elucidating the connection between natural resources and carbon intensity, which could offer further insight into the present study.

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