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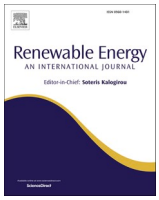
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Navigating the green frontier: The role of employment dynamics and natural capital in renewable energy consumption in Africa

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ABSTRACT

Africa's sustainability aspirations primarily rely on the region's capacity to shift from traditional fuel usage to green energy, a transition critical for attaining sustainable development. Notwithstanding Africa's massive potential for clean energy, the region continues to be regarded as one of the world's most energy-deprived regions. In light of the paradox of enormous resources but poor energy access, comprehending the major drivers of sustainable energy utilization becomes vital for aiding robust decarbonization strategies. This study investigates the impact of sectoral employment, employment status and natural wealth on renewable energy adoption in sub-Saharan Africa between 1991 and 2022. The study also assesses the interaction effect between employment and natural resource rents on renewable energy adoption in Africa. Employing the PCSE approach, the study found that natural resource rents positively influence renewable energy adoption. Employment in the industrial sector and wage employment negatively impact renewable energy consumption. In contrast, employment in agriculture and services and self-employment spur green energy development. The interaction between employment dynamics and natural resources affects clean energy utilization differently. In light of established findings, our study offers several policy suggestions to boost the development and uptake of sustainable energy across the region, aiming to leverage the region's huge clean energy potential while tackling its urgent energy issues.

1. Introduction

Achieving sustainable development across the globe is currently facing serious issues owing to the increasing influence of ecological pollution (Dimnwobi et al., 2021 [1]). As noted by Nwani et al. (2024) [2] and Samour et al. (2024) [3], clean energy is a viable option for lowering greenhouse gas emissions and attenuating climate change. Onuoha et al. (2023a) [4] and Omoju et al. (2024) [5] argued that in an emerging region like Africa, green energy development provides several advantages such as sustainable economic advancement, improving energy security, health, among others. According to Kanzari et al. (2024) [6], Africa represents one of the regions across the world with considerable opportunities for renewable energy owing to the region's several rivers for hydropower, substantial sunshine for solar energy, and substantial wind power assets. However, Onuoha et al. (2023b) [7] and Ezenekwe et al. (2024) [8] observed that these opportunities remain largely unexplored owing to financial barriers, limited technological access, and weak infrastructure. Dimnwobi et al. (2023a) [9] and Dimnwobi et al. (2023b) [10] asserted that the criticality of boosting clean energy in the region's energy mix is essential because the region accounts for the globe's highest population without access to a dependable electricity supply while also facing rising energy demand triggered by the population surge in the region. Accordingly, Dimnwobi et al. (2022a) [11] and Dimnwobi et al. (2022b) [12] emphasized that transiting to green energy provides a huge potential for the region to enhance the quality of life through sustainably satisfying the rising energy demand, promoting sustainable economic growth while also establishing a low-carbon economy to protect the environment.

Natural resources have been touted as being critical in the development of sustainable energy (Okere et al., 2024) [13], with sub-Saharan Africa (SSA) richly gifted with numerous resources like forests, minerals, oil, arable land, natural gas and freshwater (Nchofoung & Ojong, 2023) [14]. The region's resource endowment is further manifested in its resource rents, accounting for roughly 10 % of GDP, considerably surpassing the world's average of 3 % (World Bank, 2023) [15]. These resource endowments are also apparent across diverse sectors: it is a prominent figure in worldwide production of oil, with

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List of abbreviations

AfDB	African Development Bank
AMG	Augmented Mean Group (AMG)
BRICS	Brazil, Russia, India, China, and South Africa
CD	Cross-sectional dependency
CIPS	Cross-sectionally augmented Im, Pesaran and Shin
ILO	International Labour Organization
OECD	Organization for Economic Cooperation and Development
PCSE	Panel-corrected standard errors
SSA	Sub-Saharan Africa
USA:	United States of America

roughly 100 billion barrels of oil pending offshore detection (Nchofoung & Ojong, 2023) [14], while 21 % of the region's land area is covered by forest (Hetemäki et al., 2021) [16]. The region boasts of the globe's major arable landmass. It controls roughly 30 % of mineral reserves globally (AfDB, 2016) [17], which contains essential minerals like aluminum, cobalt, copper, manganese, and iron that are vital for establishing green energy technology (Olaniyi & Odhiambo, 2024) [18]. The criticality of these mineral assets is reinforced by the fact that they are responsible for roughly 70 % of the overall exports from the region (AfDB, 2016) [17]. In light of this significant resource endowment and the consequent resource revenues, it can be theoretically acknowledged that African nations can direct these revenues into funding green energy projects, hence establishing a trajectory for the development of sustainable energy via the optimal deployment of resource wealth.

Employment levels are also critical in promoting the transition to green energy, with the SSA employment-to-population ratio at 63 %, surpassing the world average of 58 % (World Bank, 2023) [15]. The composition of employment in the region exhibits substantial sectoral differences with agriculture being the most significant player, accounting for 52 % of overall employment in 2022, with the service sector and industrial sector contributing 37 % and 11 %, respectively, in the same year in the employment share (World Bank, 2023) [15]. These substantial labour patterns across diverse economic sectors establish an encouraging environment for people to boost their earnings and financial stability, substantially enhancing their capability to fund and embrace clean devices (Karmaker et al., 2023) [19]. SSA employment dynamics marked by sustained increases across diverse sectors create a cornerstone for enhanced ecological awareness and the uptake of green habits. Individuals in the labour market are well placed to engage in and uphold clean energy strategies via their enhanced financial conditions and spending power.

Given the preceding discussions, our contributions to the literature are multi-fold. First, prior studies have extensively assessed how natural resources influence environmental degradation; studies on natural resources and clean energy development are yet to be accorded extensive research attention, and research attention to this nexus in Africa is limited. This study offers empirical perspectives on whether natural capital can spur the region's green energy development. This study is essential in establishing actionable strategies that will assist Africa in leveraging its resource assets to promote clean energy development. Second, the literature on the correlation between employment dynamics and green energy development is still emerging. Few existing studies concentrate on China and European nations, with Africa overlooked. This study expands this emerging field by documenting how Africa's employment dynamics shape green energy adoption. This is critical since the region is facing severe energy deprivation with rising employment levels, and our findings will assist decision-makers in establishing targeted initiatives. Third, our study differs from past studies, which have majorly employed aggregate employment rates by adopting a more disaggregated strategy. Specifically, we used employment across the economy's vital sectors (services, agriculture, and industry) and employment status (self-employment and wage and salaried workers), offering a more comprehensive perspective of employment dynamics. Fourth, to our knowledge, our study is the first to unearth the role of the interaction between employment dynamics and natural capital and its influence on sustainable energy consumption. The utilization of this interaction model assists in revealing whether a concurrent expansion of both natural resources and employment will boost or weaken Africa's clean energy development. Fifth, the analysis of prior studies has either focused on a panel or a single country; our study deviates from this studies by providing both analyses (panel and single-country outcomes). Our adopted strategy is motivated to gain better insights into the distinct conditions in which clean energy adoption is influenced by natural capital, workforce dynamics, and their interactions. The identification of variations existing between African economies can assist in advancing more informed and targeted policy options.

Aside from this section, other parts of this study are ordered as follows: Section 2 offers the synopsis of the theoretical and empirical trends. Section 3 documents the methodology. Section 4 contains the diverse outcomes, while Section 5 provides some suggestions for decision-makers.

2. Literature review

2.1. Theoretical insights

In 1977, John M. Hartwick propounded a theory known as Hartwick's Rule, positing that a country can attain sustainable economic advancement even when utilizing non-sustainable resources once the revenues emanating from these assets are completely rechanneled to capital assets (Hartwick, 1977) [20]. Put differently, exploitation of natural resources leads to a generation of income, which should be employed to establish other types of capital (such as infrastructure, technology, and human capital) to guarantee that the next generations possess the capability to sustain their welfare (Hartwick, 2017) [21]. This theory is contingent on the notion that if these revenues are effectively recommitted, resource exploitation may not engender a reduction in the productive capacity of the economy, hence facilitating intergenerational equity where the next generations can attain equivalent wealth level as the existing ones (Dietz et al., 2007) [22].

In the context of our study, the theory avers that nations endowed with natural assets should invest revenues emanating from these resources in clean energy technologies and infrastructure to guarantee green economic advancement. Increased workforce participation in an economy represents broader economic engagements and output, which further expands the potential of investing in the growth of clean energy via improved fiscal revenue and investments by the private sector. This theory contends that as employment increases and produces more economic yield, some proceeds can be channeled into developing of clean energy to ensure long-term equality. Nevertheless, for green energy development to occur in an economy is contingent on how well these nations align with Hartwick's directives of rechanneling resource rents instead of just utilizing them to meet immediate needs as well as how efficient economy's employment level quickly converts into fruitful investments in facilities that drive clean energy development. This theory also suggests that nations rich in natural resources have increased obligations to fund green energy development to guarantee the next generations' sustainable future while increased employment levels offer the fiscal backbone required for such sustainable enedeavours.

On the other hand, the resource curse theory offers insights into comprehending how substantial natural assets, especially fossil fuels, can ironically impede the transition to sustainable energy. Nations with vast resource deposits usually establish an economic structure that considerably depends on extracting resources, resulting in the

"crowding-out effect" where the traditional energy sector are prioritized ahead of technological innovations and green energy development (Auty, 1993) [23]. This reliance establishes a self-reinforcing cycle where job prospects become concentrated in the extractive industries, hence deepening the economy's dependence on unclean energy options (Sachs & Warner, 1999) [24]. The theory also avers that economies, where most jobs emanate from resource-extractive sectors will be less motivated to transition to clean energy. This occurs because employment in the conventional energy sector dominates the economy, making them resist the transition to sustainable energy in order not to lose their source of livelihoods (Sachs & Warner, 1999) [24]. Relatedly, when a significant segment of the workforce is engaged in the resource-based sectors, social and political pressure to sustain the existing conditions is created, thereby impeding investments in sustainable energy infrastructure. The theory also underlines that resource abundance can result in a condition where high engagement in the labour force does not result in the widespread utilization of clean energy. This arises because the income and spending patterns of those engaged in the labour force are linked to resource-based economic activities, reinforcing reliance on dirty fuels instead of championing the shift to sustainable energy.

2.2. Empirical perspectives

Natural resource abundance has been regarded as a blessing or a curse based on how efficiently an economy manages resource extraction and revenue. There is still no consensus in the literature on whether natural resources are a curse or a blessing for clean energy development. On one hand, some studies argue natural resource stimulates green energy development by offering the needed financial backing to facilitate the transition to clean energy. In line with this argument, Nchofoung and Ojong (2023) [14] affirm that the consumption of clean energy is supported by natural resources in 48 African economies. This also aligns with the discovery of Olaniyi and Odhiambo (2024) [18] in resource-endowed African economies highlighting that clean energy development is spurred by natural resources. Ma et al. (2023) [25] appraise the clean energy consumption effect of natural resources and conclude that natural resources positively drive green energy utilization in OECD nations. Chishti and Dogan (2022) [26] also confirm that natural resources expand clean energy development in 10 leading consumers of renewable energy. Yuan et al. (2023) [27] and Han et al. (2023) [28] establish similar trends in Next-11 nations and 162 economies, respectively demonstrating that natural resources stimulate green energy development. Ullah et al. (2023) [29] study the influence of natural resources on green growth and energy transition in the USA and the author confirmed that energy transition and sustainable growth is promoted by natural resources. The outcome obtained in China by Wang et al. (2023a) [30] is not different, reporting that renewable energy development is supported by natural resources.

Some other studies find that natural resources stymie clean energy development and utilization. These studies document that resource abundance stalls green energy development through political rent-seeking and economic distortion. In this context, Yang et al. (2024) [31] covering Asian economies establish that natural resources hinder the utilization of renewable energy. This aligns with the conclusions of Shinwari et al. (2022) [32] reporting that China's green energy investments is impeded by natural resources. Doğan et al. (2024) [33] also made similar discoveries in OECD nations, highlighting that natural resources stall clean energy transition. A related discovery is also made in the top 15 waste-recycling countries (Shah et al., 2023) [34], finding that natural resource abundance impairs clean energy development. The diminishing effect of natural resources on the green energy transition is further supported in BRICS (Bano et al., 2022) [35] and a global study (Huang et al., 2024) [36].

Other studies reveal different types of natural resource rent can have varying effects on clean energy utilization. This suggests that green energy reacts differently to various resource rents. In this case, Ahmadov and Van der Borg (2019) [37] report that total natural resources encourage green energy production while petroleum rent have the opposite effect in European nations. Liu and Lu (2023) [38] assess the effect of disaggregated resource rent on renewable energy production in BRICS economics and discovers that while forest and oil rents is positively correlated with green energy output, mineral and coal rents impede the production of sustainable energy. This also concurs with the submission of Yu et al. (2023) [39] in a global analysis indicating that while mineral, oil, coal, and natural gas rent shrink sustainability drive by reducing clean energy consumption, forest rent boosts green energy development, particularly at the higher quantiles. In another global study, Wang et al. (2023b) [40] confirm that aside from oil rents which enhance green energy development, mineral and natural gas rents obstruct clean energy development. Likewise, Zhang et al. (2023) [41] document that while forest rents and coal rents reduce green energy transition, oil rents, mineral rents, and natural gas rents stimulate green energy transition in the USA. The preceding highlights that the green energy effect of natural resources is contingent on the type of resource rent involved.

Other studies have arrived at conclusions different from those of the preceding discoveries. For instance, Dingru et al. (2022) [42] highlight that natural resources have an insignificant effect on green energy development. Put differently, this study shows that natural resources cannot influence the utilization of green energy. In China, Zhang et al. (2024) [43] obtain a U-shaped nonlinear connection indicating that lower levels of resource abundance impede clean energy development, while as natural resources expand, its influence on green energy considerably transitions to positive from negative.

The second strand of this section focuses on how employment dynamics could spur clean energy development. It is widely acknowledged that a rise in employment levels can enhance an economy's purchasing power, hence making the utilization and advocating for sustainable practices possible. In this context, Karmaker et al. (2023) [19] find that employment positively drives clean energy utilization in leading remittance beneficiaries. Focusing on China, Zhao and Luo (2017) [44] document that employment dynamics promote green energy development. Relatedly, other studies evaluate the role of unemployment (reduced employment levels) in the uptake of green energy. In this case, Przychodzen and Przychodzen (2020) [45], affirm that increasing unemployment spurs green energy production in emerging economies. On the flip side, Tu et al. (2021) [46] assess the drivers of clean energy development in 27 European nations and report that unemployment undermines the deployment of renewable energy. Long et al. (2024) [47] find that the connection between unemployment and clean energy development in Fiji is insignificant. The literature on the influence of employment on green energy transition has been limited, as scholarly attention has been directed to the role of renewable energy in generating employment. For instance, on one hand, some studies report that green energy development spurs employment generation. This outcome is confirmed in several economies like Portugal (Henriques et al., 2016) [48]; China (Chen, 2018) [49]; Switzerland (Füllemann et al., 2019) [50]; United Kingdom (Arvanitopoulos & Agnolucci, 2020) [51]; South Africa (Khobai et al., 2020) [52]; European economies (Ortega et al., 2020) [53]; Proença & Fortes, 2020 [54]) and China (Liu et al., 2023 [55]). On the other hand, some studies document that employment growth is not encouraged by green energy development. For instance, Çelik (2021) [56] and Saboori et al. (2022) [57] confirm that renewable energy impedes employment growth in the United States of America.

The preceding discussions highlight that no study has assessed the combined influence of employment dynamics and natural resources on clean energy adoption. There is also a lack of studies evaluating the connection between employment dynamics and green energy utilization in African contexts. Moreover, related studies have used aggregated employment data while sectoral employment dynamics, and employment status has been overlooked. Furthermore, the literature neglected how the interaction between employment dynamics and natural capital

influences green energy adoption.

3. Methodology

3.1. Underlining framework

The nexus between natural resources and renewable energy, based on Hartwick's (1977) [20] arguments, is deeply rooted in the principles of intergenerational equity and sustainable development. This theory aims to ensure that future generations can enjoy the same level of consumption as the present generation by reinvesting resource rents into other forms of sustainable enedeavours. As observed by Chang et al. (2015) [58] and Lodhi (2024) [59], this approach balances the depletion of natural resources with the creation of sustainable and equitable resource distribution over time. However, the development of renewable energy faces significant challenges, often attributed to high production costs, which make the use of more affordable fossil fuels an inevitable choice (Labordena et al., 2017) [60]. These high costs associated with transitioning to renewable energy can be more easily managed given the substantial revenues generated from nonrenewable natural resources (Ahmadov & van der Borg, 2019) [37]. Empirically, this suggests a positive relationship between the availability of natural resources and the advancement of renewable energy (Lodhi, 2024) [59].

In line with the above framework and building on previous studies such as Çakmak et al. (2024) [61], the econometric model for study will measure the relationship between natural resource rents and renewable energy, taking into account the impact of employment across various sectors of the economy. Thus, the model specified:

$$\log\,(ren)_{it} = \beta_i + \gamma \log\,(nr)_{it} + \varnothing \log\,(Z)_{it} + \partial log\,(contr)_{it} + \varepsilon_{it} \quad (1)$$

The variables are presented in logarithmic form, indicated by 'log.' The subscripts i and t refer to the ith country in year t, Z is the vector of employment from different sectors of the economy such as Employment in agriculture (% of total employment, modeled ILO estimate) *ase*; Employment in industry (% of total employment, modeled ILO estimate) *ise*; Employment in services (% of total employment, modeled ILO estimate) and employment types; *sse*; Self-employed total, (% of total employment, modeled ILO estimate) *self*; Wage and salaried workers total (% of total employment, modeled ILO estimate) *wsw*. *ren* = Renewable energy consumption of total final energy consumption; *nr* = Total natural resources rents (% of GDP), *contr* = GDP per capita constant 2015 US$ while ε represents the stochastic error term. All the variables are sourced from the World Bank development indicator. *i=1 ….N* represents the number of cross-sections. The functional model is given as thus:

$$\log\,(ren)_{it} = \beta_i + \gamma \log\,(nr)_{it} + \varnothing \log\,(Z)_{it} + \varphi\, log\,(Z^{*}nr)_{it} + \partial log\,(contr)_{it} + \varepsilon_{it} \quad (2)$$

where: φ is the coefficient of the interaction term. This study focusses on the marginal impact of alterations in Z on renewable energy and the influence of natural resource rents on this relationship. The primary focus of this study is (i) impact of sectoral employment and natural resource rents on renewable energy (ii) interacting effect of sectoral employment and natural resource rents through the lens of coefficients $\varnothing$ and φ. We expect the coefficients of Z and *nr* to be positive and complementary, however, if $\varnothing$ is negative (i.e., $\varnothing < 0$) and φ is positive (i.e., $\varnothing > 0$), it indicates that the unconditional Z negatively impacts renewable energy, whereas the conditional effect of Z, mediated by *nr*, alleviates this negative influence. This suggests that the impact of Z is mediated with the enhancement of *nr*. On the a priori expectations, β, γ, $\varnothing$, ∂ and ρ are the parameters to be estimated, and the positive predictor of renewable energy and hence the hypothetical relationship are expressed thus herein:

$$\gamma = \frac{\partial \log\,(ren)}{\log\,(nr)} > 0, \varnothing = \frac{\partial \log\,(ren)}{\log\,(Z)} > 0, \varphi = \frac{\partial ren}{Z^{*}nr} > 0, \partial = \frac{\partial ren}{\log\,(contr)} > 0$$

To address the second objective of this study, we calculate the total effect of Z on renewable energy, given that *nr* is computed as:

$$\frac{\partial \log\,(ren)}{\log\,(Z)} = \varnothing + \varphi\, log\,(nr)_{it} \quad (3)$$

Intuitively, if φ > 0, it implies that *nr* enhances Z's effect on renewable energy. However, if φ < 0, the overall impact of Z on renewable energy will depend on the extent of the negative value, and vice versa.

3.2. Data

The study covers 44 sub-Saharan African countries (See Appendix 1) from 1991 to 2022. Some countries were dropped due to a lack of data. Table 1 and Figs. s.1–2 details the relative association (correlation matrix) and descriptive among the variables.

Prior to the empirical investigation, a series of pre-evaluation statistical procedures were conducted. These included descriptive statistical analysis, correlation analysis, and scatter plots. Additionally, tests for cross-sectional dependency and slope heterogeneity were performed on the variables. Second-generation panel unit-root and panel cointegration methodologies were also employed. Fig. 1, indicates that employment in agriculture and self-employed may negatively predict the renewable energy, while employment in industry, employment in services, wage and salaried workers may positively predict it. However, the chosen panel estimators will validate the accuracy of these preliminary results. Table 1 summarizes the statistical analysis results of the relevant variables. The mean values for *ase, ise, sse gdpc, ren, self nr*, and *wsw* are 54, 11.5, 34.5, 1624, 70.3, 72.7,12.1, and 27.3, respectively. Notably, economic growth (gdpc) has the highest mean value, followed by self-employment (*self*). The standard deviations indicate greater variability in economic growth (gdpc) and renewable energy (ren) Both positive and negative skewness and kurtosis values suggest a significant presence of outliers. The Shapiro-Wilk test values show deviations from normal distributions for all series. This deviation indicates that relying on panel estimators that do not account for temporal fluctuations would lead to misleading results and biased conclusions. Therefore, it is essential to implement relevant time-variant panel methodologies.

The visualizations in Fig. 2A–F further highlight the time-varying characteristics of the specified variables, revealing significant linear relationships between renewable energy, natural resource rents, and employment across various economic sectors. The data points cluster tightly around the ascending and descending trend lines, respectively, reinforcing these positive or negative correlations. Notably, all variables exhibit specific skews and concentrations in their distributions, warranting further empirical investigation and validation.

3.3. Estimation approach

This analysis begins by addressing cross-sectional dependence due to the biased estimates and inferences it can produce (Pesaran, 2004) [62]. To mitigate this econometric issue, the study employs the cross-sectional augmented Im, Pesaran, and Shin (CIPS) test developed by Pesaran (2007) [63], along with various other techniques such as Pesaran's CD-test (2004 [62], 2015 [64]), the CDw test by Juodis and Reese (2022) [65], the CDw + test by Fan et al. (2015) [66], and the CD* test by Pesaran and Xie (2021) [67] for detecting cross-sectional dependency (CD) under the null hypothesis of no CSD, which can be rejected at the 1 %, 5 %, and 10 % significance levels. Second, slope heterogeneity is assessed using the methodology proposed by Pesaran and Yamagata (2008) [68]. For unit-root testing, second-generation methods are employed, including the Pesaran (2007) [63] test and the modified

Table 1
Descriptive statistics.

	ase	ise	sse	gdpc	ren	self	nr	wsw
N	1408	1408	1408	1408	1408	1408	1408	1408
Mean	54	11.5	34.5	1624	70.3	72.7	12.1	27.3
Standard deviation	21.1	6.46	17.1	1870	22.7	19.3	12.4	19.3
Minimum	1.16	2.06	5.31	190	3.68	19.7	4.63E-04	4.36
Maximum	92.5	35	93.4	14223	98.3	95.6	116	80.3
Kurtosis	−0.525	0.678	1.32	9.4	0.27	0.286	11.6	0.286
Std. error kurtosis	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Shapiro-Wilk W	0.968	0.925	0.939	0.666	0.878	0.867	0.758	0.867
Shapiro-Wilk p	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

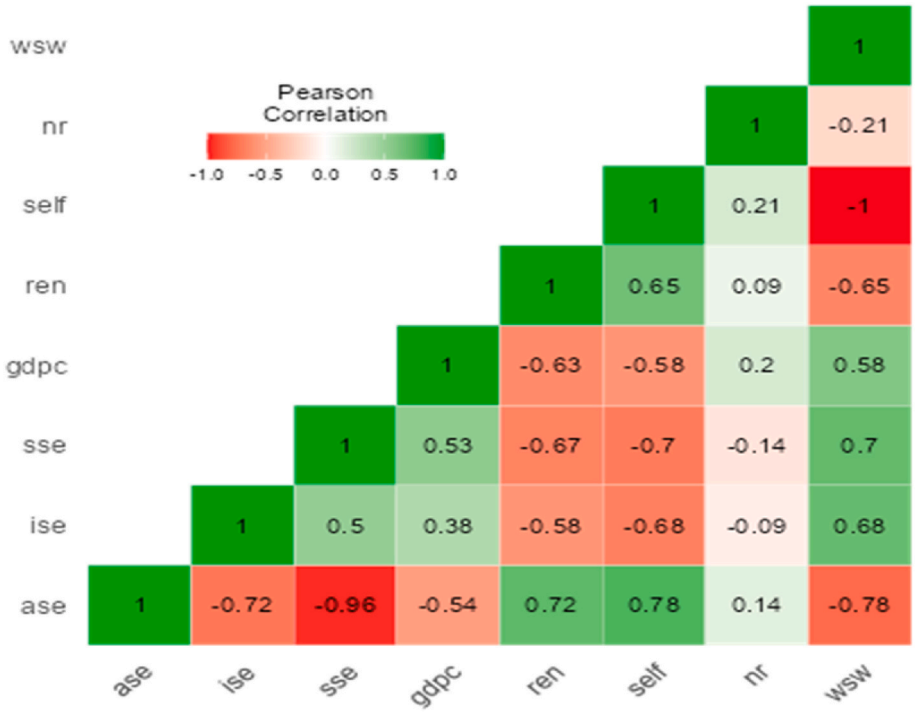


Fig. 1. Correlation heatmap.

CIPS-TR test. Additionally, a third-generation approach is utilized to account for structural shifts in the data, as developed by Karavias and Tzavalis (2016) [69] and Ditzen et al. (2021) [70]. Thereafter, we assess whether a long-run relationship exists among the variables using the method proposed by Westerlund (2007) [71]. Finally, in the presence of cross-sectional dependence, unit root in the data, and cointegration among the variables, the Prais-Winsten regression model with panel-corrected standard errors (PCSE) is an ideal technique due to its ability to address heteroscedasticity and serial correlation in the presence of large N and T (Beck & Katz,1995) [72]. For robustness checks and to ensure the consistency of the results, we also employ the Augmented Mean Group (AMG) technique.

4. Results and discussion

4.1. Preliminary test: CSD, PURT, and cointegration

The results from the preliminary tests are presented in Tables 2 and 3. The array of CD tests rejects the null hypothesis of no cross-sectional dependence at the 1 % significance level, suggesting that any shock in one country may be transmitted to other regions. To examine the stationarity of the variables, slope heterogeneity is confirmed using the Pesaran and Yamagata (2008) [68] test, indicating that the assumption of homogeneous slopes (i.e., that the coefficients are the same across all cross-sections) does not hold. For unit root testing, we employ second-generation methods, including the IPS test (Pesaran, 2007) [63] and the modified CIPS-TR test, along with a third-generation approach by Karavias and Tzavalis (2016) [69] and Ditzen et al. (2021) [70] to account for cross-sectional dependence and structural breaks. Subsequently, the cointegration results, using the method proposed by Westerlund (2007) [71], indicate that a long-run relationship exists among the variables.

4.2. Empirical result

This empirical investigation began with the following tests: the correlation matrix and descriptive statistics, cross-sectional dependency (CD) and slope heterogeneity (SH) tests, stationarity test, and cointegration test. The results confirmed that the PCSE and AMG estimators are suitable for this study. Accordingly, the tests for cross-sectional dependence and slope heterogeneity revealed evidence of cross-sectional dependence, as indicated in Table 2: Panels A and B. This supports the empirical narrative that testing for cross-sectional dependence in dynamic panels, where the number of cross-sectional units (N) is greater than the number of time periods (T), is crucial to avoid inefficient and misleading estimates. Lastly, the stationarity in Table 3 and cointegration tests (Appendix 2) were validated as essential criteria for conducting long-term analysis using the PCSE and AMG estimators.

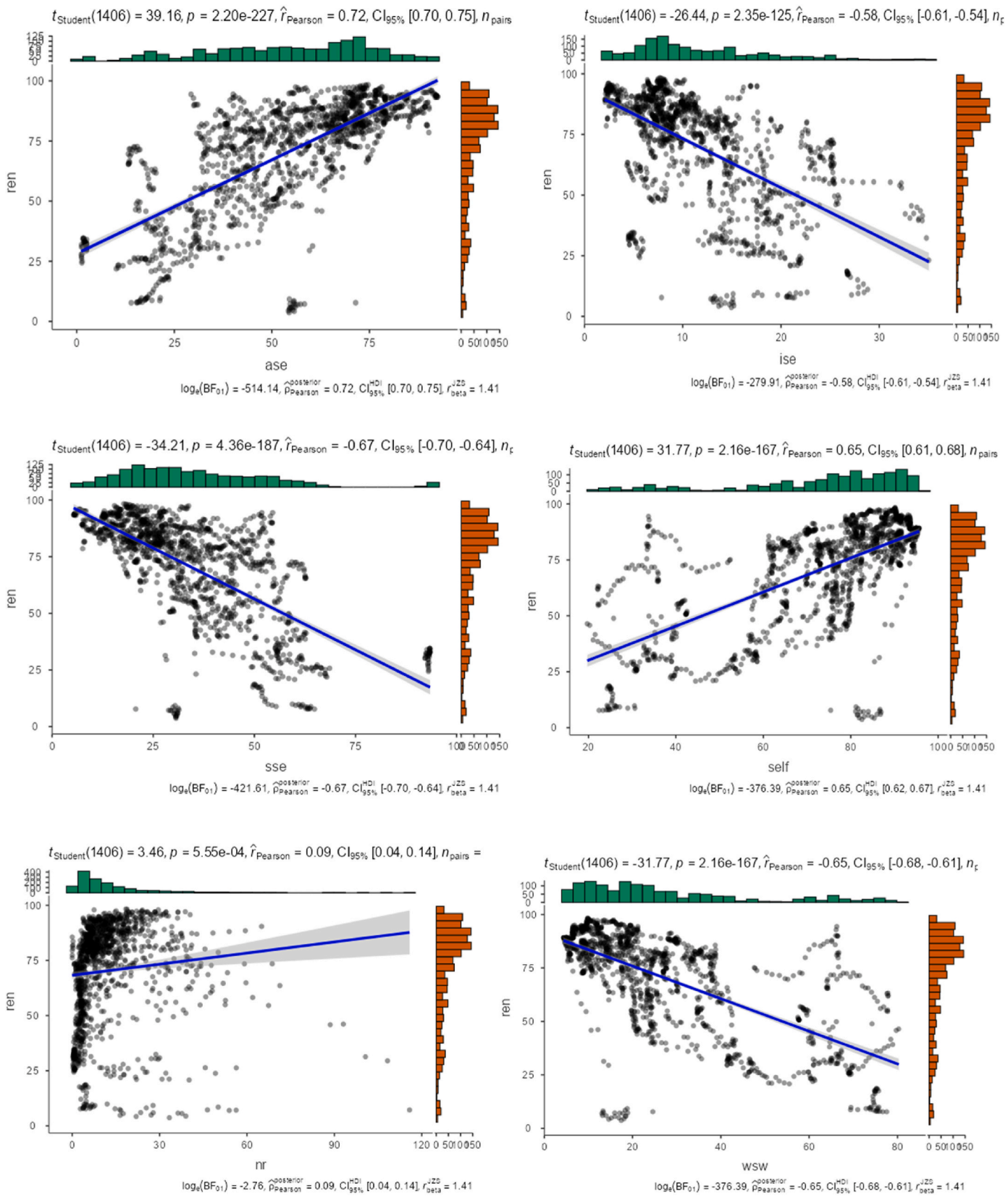


Fig. 2. A–2F: Scatter plot for variables.

Table 2
Cross-sectional dependency (CD) and slope heterogeneity (SH) tests.

Panel A: cross-section independence											
Variable	Pesaran, (2004) [62] CD-test	Pesaran, (2015) [64] CD-test	Juodis, & Reese (2022) [65]. CDw	Fan,et al. (2015) [66] CDw+	Pesaran & Xie,(2021) [67] CD*	Variables	Pesaran, (2004) [62] CD-test	CD	CDw	CDw	CD*
ren	57.949***	57.95***	−2.31***	2861.21***	0.56	Ren	57.949***	57.95***	−1.69***	2861.83***	0.56***
gdpc	55.216***	55.22***	−2.74***	3132.38***	2.82	Gdpc	55.216***	55.22***	−2.04***	3133.07***	2.82***
nrr	27.295***	27.29***	0.17***	1675.64***	3.59	Nrr	27.295***	27.29***	−0.49***	1674.98***	3.59***
self	62.351***	62.35***	−2.3***	3371.02***	2.38	Ase	126.359***	126.36***	−0.42***	4315.26***	0.86***
wsw	61.478***	61.48***	−2.54***	3388.81***	1.76	Ise	28.594***	28.59***	−7.27***	3242.93***	0.3***
						Sse	130.631***	130.63***	−2.07**	4421.35***	4.09***
Panel B: slope heterogeneity											
		p-value						p-value			
Delta	35.739***	0.000				Delta	32.81***	0.000			
adj.	40.434***	0.000					37.885***	0.000			

***p < 0.01, **p < 0.05, *p < 0.1. This information is based on calculations performed by the authors.

Table 3
Stationarity test.

	CD-adjusted (Second-generation) panel unit root tests				Karavias and Tzavalis (2016) [69]		Ditzen et al. (2021) [70]		
Series	CIPS (level)	ΔCIPS	TCIPS (level)	ΔTCIPS	MIN Z-STAT	BREAK POINT	COFF.	T-STAT	BREAK DATE
ren	−2.086	−2.284**	−2.008	−3.228***	−12.7134***	1997	F(1/0)	3.98***	1994
gdpc	−2.086	−3.299**	−1.612	−2.715***	−16.4189***	1997	F(2/1)	4.79***	2003
self	−1.692	−3.144**	−2.604	2.748***	−1.1048***	n/a	F(3/2)	5.02***	2021
wsw	−1.923*	−2.947**	−2.436**	−2.747***	−8.0051***	1997	F(4/3)	2.78	n/a
ase	−1.301	−5.571**	−1.989	−2.628***	−21.1129***	1997	F(5/4)	2.22	n/a
ise	−2.328*	−3.228**	−1.732	−2.395***	−6.5300*	1997			
sse	−1.733	−3.144**	−1.943**	−3.134***	−22.6264***	1997			
nrr	−1.523	−3.596**	−2.106	−2.785***	−13.9546***	1997			

***p < 0.01, **p < 0.05, *p < 0.1. Information is based on calculations performed by the authors.

The empirical results of this study, presented in Table 4, follow the framework outlined in Equation (1). It provides baseline estimation results, incorporating natural resource rents and various employment variables as regressors. Columns (1) to (5) detail these baseline estimations, while Columns (6) to (10) introduce interaction effects between natural resource rents and employment variables. This modeling approach effectively assesses the consistency of the results.

The findings in Columns (1) to (10) reveal that economic growth negatively and significantly impacts renewable energy consumption in Africa. This aligns with recent empirical studies, which indicate that economic growth in Africa hinders renewable energy consumption in the long run. The negative impact of economic growth on renewable energy consumption in Africa can be attributed to the inefficiency of current renewable energy sources, the prioritization of non-renewable energy for immediate economic benefits, and the lack of sufficient policy and investment support for renewable energy development (Maji et al., 2019) [73]. Conversely, natural resource rents positively influence the adoption of renewable energy in Africa. This relationship remains robust across various models and specifications, indicating that resource rents can drive green energy initiatives (Nchofoung & Ojong, 2023) [14]. This suggests that when managed effectively, it can provide the necessary financial resources, technological advancements, and strategic investments to promote the adoption of renewable energy in Africa (Liu & Lu, 2023) [38].

In columns (2) and (6), employment in the industrial sector and wages and salaries are negatively related to renewable energy adoption in Africa. The industrial sector in Africa remains heavily reliant on fossil fuels due to their cost and availability, despite the potential of renewable energy. This dependence on traditional energy sources can hinder the adoption of renewable energy. Additionally, wages and salaries negatively impact renewable energy adoption through income inequality. For example, unfair income distribution from wages and salaries can influence renewable energy consumption through various channels at different times (Beldi & Ghazouani, 2024) [74]. This suggests that economic disparities, potentially related to wage structures, might impact negatively on renewable energy adoption. Further, employment in the agriculture sector has been shown to foster the utilization of green energy. Specifically, employment in agriculture supports the transition to renewable energy. Finally, the estimation reveals that employment in the service sector and self-employment is positively associated with a

Table 4
PCSE estimated result.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
gdpc	−0.338***	−0.383***	−0.407***	−0.344***	−0.391***	−0.328***	−0.376***	−0.427***	−0.350***	−0.380***
	(0.027)	(0.026)	(0.033)	(0.031)	(0.031)	(0.036)	(0.026)	(0.032)	(0.030)	(0.029)
nr	0.00733	0.0357***	0.0383***	0.0213*	0.0342***	0.0517	0.135***	0.339***	0.674***	0.328***
	(0.011)	(0.012)	(0.011)	(0.012)	(0.011)	(0.071)	(0.038)	(0.122)	(0.206)	(0.082)
ase	0.149***					0.149***				
	(0.022)					(0.022)				
ise		−0.0458**					0.0311**			
		(0.021)					(0.035)			
sse			0.0114**					0.0019**		
			(0.034)					(0.034)		
self				0.223***					0.470***	
				(0.073)					(0.080)	
wsw					−0.0196**					−0.251***
					(0.029)					(0.046)
ase*nr						0.0354**				
						(0.044)				
ise*nr							−0.0957***			
							(0.036)			
sse*nr								−0.174**		
								(0.068)		
self*nr									−0.362***	
									(0.113)	
wsw*nr										0.242***
										(0.055)
Net effect						0.118	−0.053	−0.151	0.153	−0.039
Threshold Value of Employment							0.325		1.298	0.001
Constant	2.575***	2.981***	2.987***	2.420***	2.987***	2.541***	2.875***	3.078***	2.004***	3.307***
	(0.114)	(0.072)	(0.065)	(0.213)	(0.072)	(0.145)	(0.085)	(0.064)	(0.200)	(0.102)
Observations	1408	1408	1408	1408	1408	1408	1408	1408	1408	1408
R-squared	0.489	0.473	0.471	0.482	0.471	0.49	0.475	0.474	0.491	0.486

***p < 0.01, **p < 0.05, *p < 0.1.

statistically significant increase in renewable energy, with significance at the 1 % level. This is likely due to the sector's decentralized nature, economic diversification efforts, and the creation of numerous job opportunities across various regions and industries (Proença & Fortes, 2020) [54]. However, this finding contrasts with literature indicating that the share of services in the economy has a negative and significant impact on renewable energy consumption in OECD countries (Camara, 2024) [75].

At this point, our results have shown that natural resource rents and sectoral employment have a multifaceted impact on renewable energy in Africa. For instance, natural resource rents positively impact renewable energy adoption, while employment dynamics have mixed associations with renewable energy consumption. Hence, the pertinent question is: can the interaction of natural resource rents and sectoral employment alter the landscape of renewable energy adoption in Africa? To answer this question, we must consider the overall impact of utilizing natural resource rents to facilitate the transition to renewable energy via workforce dynamics. Specifically, the interaction of natural resource rents positively influences agriculture and wages and salaries in relation to renewable energy. However, it negatively impacts the service sector, self-service, industrial service sector, leading to a mixed net effect. To illustrate, in Columns (6), we computed the net effect of employment dynamics using Eq. (4) as follows:

$$\frac{\partial \log\ (ren)_{it}}{\partial (Z)_{it}} = 0.149 + 0.0354\text{nr} \tag{4}$$

Therefore, the net effect of employment in agriculture on renewable energy adoption is 0.118 at an average level of natural resource rents. Agriculture and self-service exhibit positive net effects, while the industrial, service, and wages and salaries show negative effects. Additionally, the threshold level of natural resource rents is computed, revealing that the interaction effects have mixed effect. Specifically, the association between natural resource rents and employment in specific economic sectors for instance, industrial sector, self-service, wages and salaries influences renewable energy investments, highlighting the importance of efficient extraction and management of natural resources. Our findings suggest that increasing employment levels across different sectors can effectively drive the demand for green energy when managed strategically within resource-rich economies. This underscores the need for thoughtful management of natural resources to maximize their positive impact on renewable energy adoption (Wang et al., 2023a) [30].

4.3. Further discussion on empirical results: case of country-specific

In this section, we incorporate total employment and its interaction with natural resource rents to provide country-specific estimations within a framework that accounts for cross-sectional dependence. To achieve this, we use the Augmented Mean Group (AMG) estimator. While focusing on the interaction effect, the results, presented in Table 5, are divided into two sections: Panel A displays the model without the interaction term, whereas Panel B incorporates the interaction term. The interactive impact of employment and natural resource rents on renewable energy consumption shows regional variations. For instance, in West Africa, the effect is generally negative and statistically insignificant, except for Nigeria, where the influence is positive but still insignificant. This suggests that while the region has committed to increasing renewable energy usage in line with international agreements like the Kyoto Protocol, the adoption pace remains slow due to infrastructural and policy challenges. To enhance renewable energy investments, there is a need for stronger legal frameworks and the reduction of bureaucratic bottlenecks. Similarly, the interactive impact of employment and natural resource rents on renewable energy consumption is found to be asymmetrically negative in central and eastern African countries. This indicates that in these regions, the combination of employment and natural resource rents tends to reduce renewable energy consumption. This trend can be attributed to significant energy access issues, with many rural areas lacking reliable electricity and relying heavily on traditional biomass for their energy needs (Cabello-Vargas et al., 2021) [76]. Results from Southern African countries reveal a mixed effect. South Africa, Namibia, Lesotho, and Botswana exhibit a positive and significant impact on renewable energy consumption. In contrast, Eswatini, despite having a clear roadmap for transitioning to renewable energy, struggles due to a lack of coherent policies and technical skills. This indicates that Southern Africa has significant potential for renewable energy sources, including hydro, solar, wind, biomass, and geothermal. However, the region faces challenges in electricity access, particularly in Eswatini, where significant proportion of the population had access to electricity (Justo et al., 2022) [77].

5. Conclusion and policy suggestions

5.1. Conclusion

This study investigated the impact of employment from different sectors of the economy, employment types and natural wealth on renewable energy adoption in sub-Saharan Africa. Additionally, the study also assesses the interaction effect between employment and natural resource rents on renewable energy adoption in sub-Saharan Africa. The study used the PCSE and AMG estimators and a panel of 44 sub-Saharan African economies from 1991 to 2022. Our study documents the following: (i) Natural resource rents positively influence renewable energy adoption (ii) Employment in the industrial sector and wage employment negatively impact renewable energy consumption. In contrast, employment in agriculture, services and self-employment spurs green energy development (iii) The interaction between natural wealth and employment dynamics reveals a positive influence on agricultural employment and wages and salaries while negatively influencing industrial, service and self-employment (iv) In the country-specific assessments, the interaction of natural resource rents and employment dynamics has a mixed regional effect, with positive effects in some economies and adverse or insignificant effects in others.

5.2. Policy suggestions

Our study documents the enhancing influence of natural wealth on clean energy adoption; hence, we suggest that decision-makers should tactically rechannel revenues from resource extraction into green energy projects. This may involve the creation of national investment funds designated particularly for green energy initiatives and establishing clear guidelines for directing resource rents into sustainable projects. Relatedly, decision-makers can also adopt strategies that will incentivize firms engaged in the extraction of natural resources to incorporate clean energy solutions in their activities.

Our study reports that sectoral employment has a differing influence on clean energy adoption. While agricultural and service employment enhances renewable energy development, industrial employment obstructs the utilization of clean energy. We suggest that the decision-makers in these economies should launch grants and subsidies for farmers to embrace green energy facilities like wind energy for farm activities, solar-driven irrigation networks, and biomass processing facilities. Additionally, the agricultural extension workers should be empowered to offer specialized training on green energy utilization in farming. To enhance the positive influence of service employment on clean energy uptake, decision-makers can introduce sustainable design standards, provide tax breaks for enterprises that shift to clean energy options, and establish certification programs that acknowledge and compensate service businesses adopting sustainable energy. Additionally, financial institutions should be encouraged to offer low borrowing rates for companies in the service sector that invest in clean energy facilities. Tackling the negative influence of employment in the industrial

Table 5
Country Specific result.

	Country	gdpc	empr	nrr	_cons	gdpc	empr	nrr	empr*nrr	_cons
1	Angola	−0.577***	2.933**	−0.006	−1.554	−0.587***	−7.628	−13.085	7.234	17.571
		(0.000)	(0.008)	(0.883)	(0.438)	(0.000)	(0.571)	(0.431)	(0.432)	(0.472)
2	Benin	−2.979***	−2.361	−0.091	15.044***	−2.576	−4.985***	−13.200***	−7.142	18.641***
		(0.000)	(0.230)	(0.207)	(0.000)	(0.000)	(0.000)	(0.000)	(0.654)	(0.000)
3	Botswana	−1.360***	−0.947	0.009	8.181***	−1.381***	−0.760	1.267	0.744**	7.940***
		(0.000)	(0.004)	(0.638)	(0.000)	(0.000)	(0.115)	(0.592)	(0.005)	(0.000)
4	Burkina Faso	−0.722***	−0.979	−0.040***	5.708***	−0.685	−1.354**	−0.897	−0.461	6.305***
		(0.001)	(0.070)	(0.072)	(0.000)	(0.002)	(0.057)	(0.394)	(0.416)	(0.000)
5	Burundi	0.328***	−0.587**	0.078***	2.159***	0.397***	−2.345	−2.223	−1.210	5.329**
		(0.000)	(0.002)	(0.000)	(0.000)	(0.000)	(0.139)	(0.281)	(0.264)	(0.062)
6	Cabo Verde	−0.254***	1.092	−0.137	0.566	−0.261	3.513	3.438	−2.084	−3.561
		(0.000)	(0.023)	(0.000)	(0.505)	(0.000)	(0.429)	(0.598)	(0.584)	(0.639)
7	Cameroon	−0.171***	0.470	−0.047	1.605	−0.188**	−0.297	−1.816	0.944	3.093**
		(0.000)	(0.000)	(0.002)	(0.000)	(0.000)	(0.642)	(0.213)	(0.225)	(0.014)
8	Central African Republic	−0.041	1.821	−0.038**	−1.209	−0.016	−16.373	−32.602	−17.876	31.871
		(0.167)	(0.004)	(0.031)	(0.288)	(0.724)	(0.533)	(0.488)	(0.489)	(0.505)
9	Chad	−0.122***	0.931***	0.031**	0.517	−0.122***	0.885***	−0.040	−0.039	0.602
		(0.000)	(0.000)	(0.001)	(0.009)	(0.000)	(0.074)	(0.957)	(0.925)	(0.512)
10	Comoros	−2.144***	2.226	0.008	4.853	−2.121	−2.110	−30.068**	18.671	11.756
		(0.000)	(0.183)	(0.921)	(0.010)	(0.000)	(0.474)	(0.079)	(0.079)	(0.007)
11	Congo, Dem. Rep.	−0.029**	0.069*	−0.002	1.939	−0.029	−0.048	−0.161	−0.087	2.154
		(0.003)	(0.059)	(0.708)	(0.000)	(0.004)	(0.882)	(0.713)	(0.716)	(0.000)
12	Congo, Rep.	−0.808**	2.873	−0.114*	−0.288	−0.810	2.443	−0.619	−0.291	0.461
		(0.004)	(0.170)	(0.066)	(0.920)	(0.005)	(0.903)	(0.979)	(0.983)	(0.989)
13	Cote d'Ivoire	−0.510***	0.564	0.077**	2.450	−0.516	2.060	4.610	−2.534	−0.206
		(0.000)	(0.578)	(0.025)	(0.120)	(0.000)	(0.576)	(0.667)	(0.673)	(0.975)
14	Djibouti	0.188**	0.526	0.047	0.116	0.190	0.743	−0.823	0.628	−0.193
		(0.007)	(0.058)	(0.240)	(0.817)	(0.007)	(0.306)	(0.759)	(0.746)	(0.858)
15	Equatorial Guinea	−0.864***	2.703	0.795***	−1.540	−0.762	−46.121	−65.564	−38.618	82.001
		(0.000)	(0.542)	(0.000)	(0.841)	(0.000)	(0.106)	(0.087)	(0.183)	(0.093)
16	Eritrea	−1.237***	3.576***	−0.131***	−1.165	−1.224	5.037	3.200	−1.785	−3.927
		(0.000)	(0.000)	(0.000)	(0.462)	(0.000)	(0.140)	(0.670)	(0.658)	(0.542)
17	Eswatini	0.160**	−1.007**	0.024	2.857	0.213***	−8.153	−18.846	11.915	13.986
		(0.021)	(0.018)	(0.699)	(0.001)	(0.000)	(0.000)	(0.000)	(0.231)	(0.000)
18	Ethiopia	−0.056***	−0.007	0.002	2.127***	−0.062**	0.971	1.397	−0.740	0.298
		(0.000)	(0.941)	(0.706)	(0.000)	(0.000)	(0.142)	(0.134)	(0.135)	(0.809)
19	Gabon	−0.849***	0.344	−0.077	4.748***	−0.888***	−1.349	−2.179	−1.316	7.600
		(0.000)	(0.400)	(0.007)	(0.000)	(0.000)	(0.523)	(0.398)	(0.414)	(0.030)
20	Gambia, The	0.431**	−2.263	0.009	4.453***	0.395**	−1.945	1.270	−0.725	4.002
		(0.014)	(0.000)	(0.615)	(0.000)	(0.030)	(0.000)	(0.420)	(0.423)	(0.000)
21	Ghana	−0.777***	0.858	0.038	2.566**	−0.775***	−0.380	−2.336	−1.290	4.836
		(0.000)	(0.017)	(0.285)	(0.001)	(0.000)	(0.855)	(0.551)	(0.544)	(0.206)
22	Guinea	−0.222**	0.550**	0.026**	1.537**	−0.251**	1.045	0.901	−0.511	0.775
		(0.007)	(0.001)	(0.037)	(0.004)	(0.003)	(0.010)	(0.166)	(0.178)	(0.316)
23	Guinea-Bissau	−0.065***	1.167	−0.014	0.114	−0.075	0.133	−1.580	0.901	1.939
		(0.000)	(0.000)	(0.039)	(0.714)	(0.002)	(0.939)	(0.543)	(0.547)	(0.524)
24	Kenya	−0.402***	0.109	−0.002	2.940	−0.449	−1.636	−9.671	−5.229	6.312
		(0.000)	(0.694)	(0.885)	(0.000)	(0.000)	(0.019)	(0.007)	(0.207)	(0.000)
25	Lesotho	0.950***	4.614	−0.241	−9.081	0.709	−0.391	−12.856	7.230**	0.378
		(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.844)	(0.005)	(0.006)	(0.924)
26	Liberia	−0.015	−1.036	−0.026	3.976	−0.007	−4.807	−5.540	−2.938	11.027
		(0.514)	(0.018)	(0.067)	(0.000)	(0.809)	(0.471)	(0.569)	(0.571)	(0.377)
27	Madagascar	0.040	−0.550	0.011	2.869	0.037	1.909	5.995	−3.123	−1.835
		(0.678)	(0.010)	(0.479)	(0.000)	(0.694)	(0.267)	(0.149)	(0.149)	(0.578)
28	Malawi	0.065	0.524	0.051	0.711	0.004	1.750	2.919	−1.559	−1.375
		(0.321)	(0.001)	(0.000)	(0.114)	(0.926)	(0.000)	(0.000)	(0.210)	(0.002)
29	Mali	−0.251***	2.626	−0.032	−2.193	−0.247	3.368	1.284	−0.717	−3.570
		(0.000)	(0.000)	(0.035)	(0.000)	(0.000)	(0.020)	(0.612)	(0.603)	(0.183)
30	Mozambique	0.002	2.036	−0.054	−1.867	−0.007	−1.558	−5.989	3.118	4.996
		(0.965)	(0.000)	(0.000)	(0.065)	(0.831)	(0.230)	(0.003)	(0.003)	(0.046)
31	Namibia	−0.695***	1.095	0.077	2.179	−0.542	1.296	8.772	5.295**	1.323
		(0.000)	(0.020)	(0.019)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)
32	Niger	−0.593	−0.527	−0.114	4.592	−0.599	−1.880	−3.017	−1.542	7.154
		(0.003)	(0.397)	(0.001)	(0.006)	(0.003)	(0.454)	(0.563)	(0.578)	(0.145)
33	Nigeria	−0.048***	0.727	0.004	0.802	−0.045	−0.163	−1.710	0.974	2.359
		(0.018)	(0.021)	(0.759)	(0.150)	(0.031)	(0.914)	(0.546)	(0.545)	(0.370)
34	Rwanda	0.041	0.603	0.065	0.732	0.027	2.528	5.565	−3.181	−2.558
		(0.173)	(0.125)	(0.034)	(0.314)	(0.444)	(0.356)	(0.472)	(0.477)	(0.585)
35	Sao Tome and Principe	−1.048***	−1.068**	−0.145***	6.724	−1.029	2.169	11.158	−6.795	1.285
		(0.000)	(0.012)	(0.000)	(0.000)	(0.000)	(0.550)	(0.375)	(0.369)	(0.833)
36	Senegal	−1.172***	−0.107	0.075	5.374	−1.050	4.199	14.156	−8.454	−2.176
		(0.000)	(0.686)	(0.179)	(0.000)	(0.000)	(0.000)	(0.000)	(0.232)	(0.295)
37	Sierra Leone	−0.161***	0.764	0.054	0.956	−0.167	−0.966	−2.931	−1.686	4.031
		(0.001)	(0.000)	(0.012)	(0.004)	(0.000)	(0.103)	(0.004)	(0.003)	(0.000)

(*continued on next page*)

Table 5 (*continued*)

	Country	gdpc	empr	nrr	_cons	gdpc	empr	nrr	empr*nrr	_cons
38	South Africa	−2.369***	−0.122	0.068	10.053	−2.355	0.090	0.528	0.277**	9.649
		(0.000)	(0.596)	(0.038)	(0.000)	(0.000)	(0.928)	(0.802)	(0.027)	(0.000)
38	Sudan	−0.273***	2.997***	0.007	−2.119	−0.266	3.055	0.138	−0.080	−2.234
		(0.020)	(0.000)	(0.321)	(0.002)	(0.059)	(0.000)	(0.929)	(0.933)	(0.145)
40	Tanzania	−0.132***	0.381***	−0.004	1.602***	−0.132	0.740	0.992	−0.519	0.914
		(0.000)	(0.000)	(0.357)	(0.000)	(0.000)	(0.079)	(0.386)	(0.384)	(0.260)
41	Togo	−0.135	1.050	−0.079	0.510	−0.017	10.392	17.848	−10.229	−16.195
		(0.318)	(0.494)	(0.031)	(0.857)	(0.911)	(0.070)	(0.093)	(0.192)	(0.115)
42	Uganda	−0.067***	−0.268	−0.005	2.658***	−0.072	−2.794	−4.339	−2.369	7.293
		(0.000)	(0.184)	(0.435)	(0.000)	(0.000)	(0.046)	(0.068)	(0.168)	(0.004)
43	Zambia	−0.168	−0.041	0.039**	2.470***	−0.178	1.752	3.056	−1.754	−0.578
		(0.000)	(0.818)	(0.007)	(0.000)	(0.000)	(0.000)	(0.000)	(0.400)	(0.262)
44	Zimbabwe	−0.438***	−1.140**	−0.117***	5.393***	−0.424	2.250	7.673	−4.342	−0.732
		(0.000)	(0.054)	(0.000)	(0.000)	(0.000)	(0.557)	(0.378)	(0.371)	(0.916)

***p < 0.01, **p < 0.05, *p < 0.1.

sector on clean energy, we suggest that decision-makers in these nations should consider creating compulsory green energy caps for industrial plants, enforce carbon pricing frameworks, and offer assistance for industries transitioning from traditional to clean energy options.

The study revealed that self-employment spurs the utilization of green energy. We suggest decision-makers establish financial support mechanisms and stimulus packages for self-employed individuals. This may involve providing grants, tax rebates, and subsidized loans for installing renewable energy devices. The policymakers should also organize periodic capacity-building programs to assist self-employed individuals to gain more insights and utilize green energy solutions in their operations.

5.3. Limitations and future research directions

This research is not without some limitations. First, the study concentrates solely on Africa. It may not correctly capture the prevailing circumstances and dynamics in other notable regions across the globe, highlighting the essentiality of future research endeavours to extend to different regional contexts for wider applicability. Moreover, while this research assessed sectoral workforce dynamics and employment types, other demographic employment issues like gendered and youth employment warrant research attention by scholars. Besides, this study employed aggregated resource rents; however, it has been documented in the literature that different types of natural resource rent can have diverse influences on development outcomes, and as such, future research should adopt both aggregated and disaggregated natural resources analysis.

CRediT authorship contribution statement

Kingsley I. Okere: Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Stephen Kelechi Dimnwobi:** Writing – review & editing, Writing – original draft, Visualization. **Ismail O. Fasanya:** Supervision, Software, Resources, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1. selected countries

Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo Dem. Rep, Congo, Rep., Cote d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe.

Appendix 2
Cointegration Test

Statistic	value	Robust P-value	Value	Robust P-value
Gt	−2.848 ***	0.0100	−3.1120***	0.000
Ga	−11.212***	0.0300	−12.023***	0.000
Pt	−15.628***	0.3400	−15.376***	0.500
Pa	−9.064***	0.3500	−10.588***	0.140

***p < 0.01, **p < 0.05, *p < 0.1: (Pt and Pa statistics) and the cross-sectional units (Gt and Ga statistics).

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