Economic Research-Ekonomska Istraživanja

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rero20

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To cite this article: Lingli Qing, Riazullah Shinwari, Xiang Ma, Yaode Wang & Abd Alwahed Dagestani (2023) Revisiting resources, cleaner energy and sustainable economic performance: the role of cleaner electricity from BRICS economies, Economic Research-Ekonomska Istraživanja, 36:3, 2186908, DOI: 10.1080/1331677X.2023.2186908

To link to this article: https://doi.org/10.1080/1331677X.2023.2186908

Published online: 15 May 2023.

ECONOMIC RESEARCH-EKONOMSKA ISTRAŽIVANJA
2023, VOL. 36, NO. 3, 2186908
https://doi.org/10.1080/1331677X.2023.2186908

Revisiting resources, cleaner energy and sustainable economic performance: the role of cleaner electricity from BRICS economies

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ABSTRACT

Since the last three decades, the natural resources and energy sector has been regarded as a substantial determinant of economic growth and prosperity. However, the literature is still contradictory and scant for BRICS economies and needs more empirical evidence for appropriate policies. This study aims to analyze the influence of natural resources and cleaner energy on economic performance in the presence of consumption expenditure. Using second-generation diagnostic, unit root, and cointegration tests, the results verify the long-run equilibrium association between the variables during 1990-2021. Due to non-linear data dispersion, the study uses the method of moment quantile regression. It concludes that both natural resources and cleaner energy have an asymmetric influence on the economic growth of these nations. The region's significant factors of economic growth are electricity production from renewable sources and oil rents. Renewable electricity output and mineral rents adversely affect economic growth and performance. Besides, consumption expenditure is also negatively and significantly affecting economic growth. Based on the empirical outcomes, this study also suggested policies that could benefit the BRICS economic growth and performance.

ARTICLE HISTORY
Received 15 September 2022
Accepted 24 February 2023

KEYWORDS
Natural resources; economic performance; cleaner energy; renewable electricity; oil rent; mineral rent; BRICS

JEL CODES
O44; Q32; E23; Q39; F43

1. Introduction

Sustainable economic performance is categorized by economic growth. Key factors such as environmental, social, or economic sustainability significantly contribute to this phenomenon. It considers the long-run effects of economic activities on the environment and societies for encouraging growth besides forming an efficient economy and investment opportunities (Basiago, 1998; C. Wang et al., 2020; Younis & Chaudhary, 2017).

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In recent decades escalating concerns about the environment have raised the awareness of sustainability and clean energy for promoting sustainable economic growth (Ielasi et al., 2018). Since traditional energy adversely impacts the environment, therefore, the use of renewable energy sources for creating clean energy is uplifted. It limits emissions and promotes sustainable economic growth, which is imperative for cumulative sustainable economic performance. Thus, renewable energy sources for production are now the focus of every modern economy. Besides, Global Environmental experts anticipated that the use of renewable energy might reach almost 50% of the overall energy utilization by reaching 2040 due to its increasing demand (Simionescu et al., 2019; Xu et al., 2020). For this purpose, the study focuses on using clean energy and economic performance to evaluate sustainable policy strategies.

Renewable electricity production is beneficial in governing climate change and endorses energy security, besides giving enormous economic and social benefits (Dorfleitner & Grebler, 2022; Hmaittane et al., 2019; Sokulski et al., 2022). Figure 1 presents the electricity production sources from renewable sources in BRICS economies. From the graphical analysis, it can be observed that the promotion of renewable energy has been significantly encouraged in the recent few years. Brazil has played an important part in generating electricity from renewable sources to attain economic development among the BRICS economies. Then comes the economies of India and China, respectively, for renewable production. However, the South African nation has made minor progress in this regard, while the Russian Federation has not even focused its industry on renewable electricity production. In Contrast, Figure 2 represents the utilization of oil rents in BRICS countries. Over the years, Russia has significantly

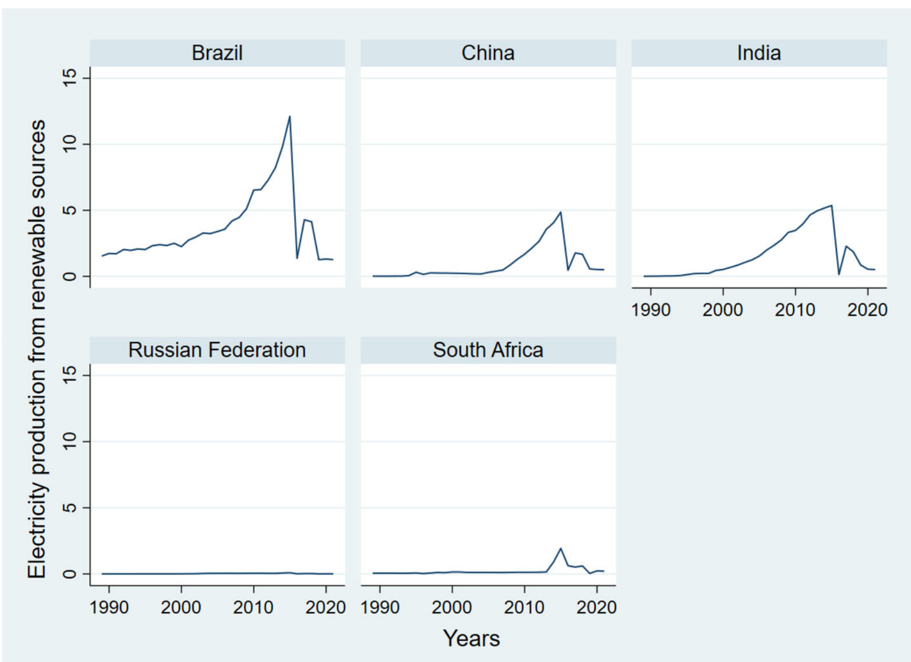

Figure 1. Electricity production from renewable sources in BRICS.
Source: Authors estimation based on (WDI, 2021).

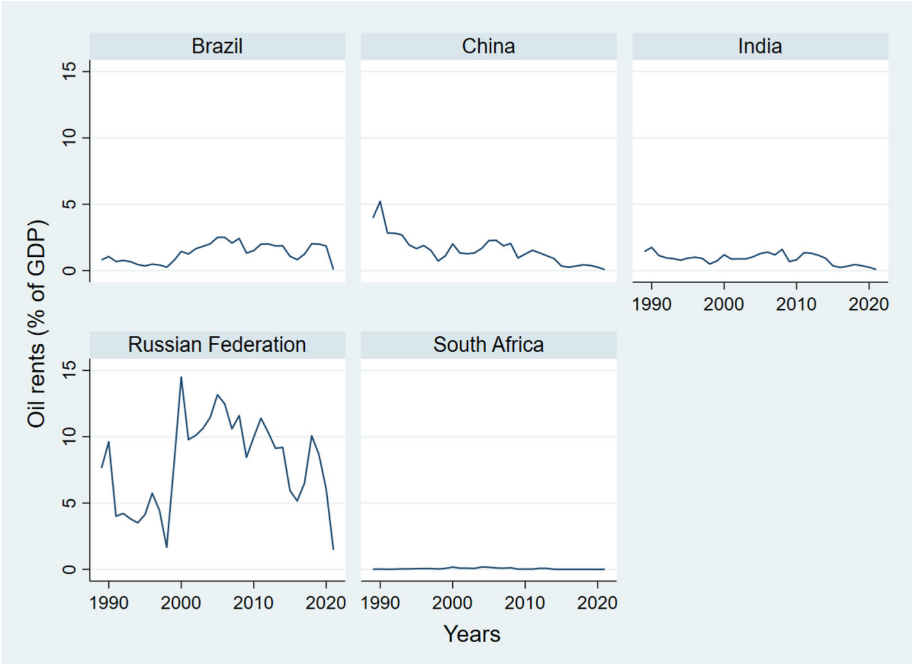

Figure 2. Oil rents in BRICS nations.
Source: Authors estimation based on (WDI, 2021).

engrossed its economic activities based on oil rents for economic progression. China, Brazil, and India respectively come after that. At the same time, the economy of South Africa has no significant involvement in oil rents in terms of contributing toward economic development. This signifies the existence of diverse economic structures in different economies. Therefore, the study explores the determinants of economic growth in BRICS for a more comprehensive understanding of the factors that drive these economies' economic growth. Based on these statements and research requirements, the study aims to accomplish the succeeding objectives. First, the study revisits the influence of resource rents on economic growth in BRICS. Second, the study examines the effect of renewable electricity production and output on economic growth in BRICS. The study employs the following variables for achieving sustainable economic performance; Oil Rents (ORNT), Mineral Rents (MRNT), Electricity production from renewable sources except for hydroelectricity (ELREC), Renewable Electricity output (REO), Final consumption expenditure (FCEX), and economic growth (GDP) using Quantile regressions for assessing reliable estimates in BRICS economies.

BRICS countries have their own unique economic and political situation. Therefore, the impact of different factors varies from one country to another country. However, simultaneously identifying common patterns and trends for sustainable development in BRICS nations helps researchers and policy enthusiasts make informed decisions for a nuanced understanding of complex phenomena like sustainable economic performance. This motivated the authors to explore the determinants of sustainable performance in the BRICS because sustainability is in demand for research areas and mitigating the harmful effects of economic development without compromising resources is the foremost priority of the contemporary world. Hence, the study is significant in evaluating BRICS's sustainable economic growth factors. Nevertheless, the study backs the literature in the following ways. First, the prior studies examined the resource growth nexus in different economies (Hu et al., 2022; Su et al., 2022; Umar et al., 2022; Xie et al., 2022). However, the study is unique in assessing the impact of final consumption expenditure alongside the resource rents for evaluating economic performance. Correspondingly, evaluating sustainable performance is crucial for ensuring basic needs without compromising the resources for future generations. In today's world, it is one of the pressing concerns in the field of research. In addition, the literature on final consumption expenditure is limited, considering sustainable growth, and a few examined the impact of FCEX on carbon emissions (Azam et al., 2023). Thus, the present study significantly contributes to the available literature by inspecting the relationship between resource rents and FCEX on GDP. Second, according to the available knowledge of authors, the study contributes to the pragmatic literature by measuring the influence of renewable electricity production and output separately on economic performance for the first time in BRICS economies. As previous literature has evaluated the impact, but the evidence is scarce on economic growth or is mostly based on a sustainable environment (Murshed et al., 2022; Yang et al., 2022; Yuan et al., 2022). Hence, the present research contributes to the empirical literature by investigating Renewable electricity output and Renewable electricity production on the GDP of the economy. Third, the study significantly contributes to the empirical literature by examining resource revenues, clean energy, and economic growth nexus in BRICS economies with an updated data period from 1989 to 2021 using updated and reliable econometric analysis.

The manuscript has five sections which are organized as follows. After the introductory Section 1, Section 2 elaborates on the empirical literature covering all study variables. Section 3 deals with the data and methodology part. Section 4 is about the results, their interpretations, and economic discussions. Section 5 is on the conclusion and policy implications.

2. Literature review

This section documented the empirical literature on the association between economic growth, natural resource rents, final consumption expenses and renewable energy production and out-put.

2.1. Nexus between resource rents and economic growth

Efficient allocation of resource rents is fruitful in promoting sustainable development. However, in the prevailing literature, the impact of resource rents is heterogeneous. In Nigeria, (Okoye et al., 2022) determined the oil rent and growth nexus between 1990 and 2019. The study identifies that oil rents substantially promote economic development by intensifying the country's economic activities during the selected period. On the opposite, in the Saudi economy between the period 1970 to the year 2017, (Sweidan & Elbargathi, 2022) empirical investigation depicted that the effect of oil rents is usually positive in both periods (long and short run). Nonetheless, oil rents showed an overall mixed influence on economic growth. In a copula-based examination of oil rents and the economic growth nexus, the study demonstrated a positive effect of rents on manufacturing output (Alfaki & El Anshasy, 2022). In Malaysia, using NARDL analysis, (Badeeb et al., 2021) examined the relationship between ORNT and GDP from an oil curse perspective. The variable nexus depicted that oil rents have an asymmetric influence on all economic sectors. However, the manufacturing sectors validate the presence of the oil curse phenomenon, indicating that oil rents have a detrimental economic impact. In another research, (Fuinhas et al., 2019) examined the energy and growth relationship from an oil rents perspective. The study established that oil production and prices are fruitful components of economic development, whereas oil rents are the significant reasons behind the resource curse phenomenon. They signify that oil rents are negatively associated with the country's GDP. However, in contrast, (Aimer, 2018) observed the nexus in OPEC economies for the period between 1997 to the year 2015. The outcomes demonstrated that a percentage increase in oil rents causes a 0.46% rise in economic growth during the selected time frame. Similarly, (Balsalobre-Lorente et al., 2023) determined the resource and growth relationship and found that resource rents are significant in promoting economic development. (Zhang & Zhang, 2023) observed the resource rents and economic growth nexus using MMQR and BSQR techniques in China. The study reveals that oil rents have an inverse but insignificant effect on economic growth, signifying the presence of the resource curse hypothesis from 1990 to 2020, demonstrating that oil rents are unpleasantly associated with the economy's GDP. In the case of resource-ample economies, (Y. Wang, 2023) determined the resource growth relationship from 1990 to 2020. The outcomes established that oil rents significantly deteriorate economic growth due to having a negative impact of oil rents on the GDP of the country.

The following empirical studies determined the rent growth nexus for the mineral rents and growth relationship. (Namahoro et al., 2023) observed the African economies from the period between 1980 and 2018. The results showed that resource rents are negatively related to the economic growth of the sample economies. In global data analysis, (Fu & Liu, 2023) inspected the mineral rents and growth association from the year 1990 to 2020. The outcomes depicted that mineral rents are significant components in improving economic growth, causing a significant increase in sustainable development. In African economies between 1990 and 2020, (Mumuni & Mwimba, 2023) estimated the resource growth relationship. The consequences of the nexus determined that mineral rents have an asymmetric influence on growth. In the Short run, rents lower growth, while the rent effect significantly increases growth in the long run. (Ampofo et al., 2020) examined the resource growth relationship in mineral-rich economies. The results depicted that mineral rents unfavorably affect the economy causing lower economic growth in some economies. However, in some economies, resource rents significantly increase economic growth by positively affecting the GDP. In developing Asian economies, (Huang et al., 2020) determined the nexus from 1996 to 2016 using Pool PNG regression techniques. The outcomes from the analysis showed that mineral rents are contributing factors in economic growth. From 1987 to 2017, (Inuwa et al., 2022) determined the resource growth nexus in Nigeria. The findings demonstrated that mineral rents are positively and significantly related to economic growth. Similar results were observed in emerging Asian countries (Baz et al., 2022). (Xie et al., 2022) also analyzed the nexus with significant results on global data.

2.2. Final consumption expenses and economic growth

The increase in inflation has a significant positive effect on final consumption expenditures, which has a meaningful impact on economic development (Obinna, 2020). The nexus between Final Consumption expenses and Economic Growth has been scarce recently. However, the following will clarify their association. (Almasifard, 2013) signified the share of final consumption expenses on economic growth. The analysis depicted a significant effect on the Gross Domestic Product. (Arapova, 2018) explored the substantial determinants of final consumption expenses in panel economies. The results demonstrated that several economic and social factors significantly influence the consumer's final expenses. (Hajamini & Falahi, 2014) examined the nexus between FCEX and economic growth. The outcomes demonstrated that FCEX has an asymmetric impact on economic growth in diverse income levels of economies. Further, after the governance threshold level, the positive effect of FCEX converts to a negative one on economic growth. Likewise, (Agalega & Acheampong, 2013) analyzed the FCEX and GDP nexus in Ghana. The empirical analysis demonstrated heterogeneous associations between the study factors. In India, (Mishra, 2011) scrutinized the consumption growth nexus. The findings described that consumption and growth are associated with each other. (Dey & Tareque, 2018) analyzed the nexus in Bangladesh using ARDL analysis. The outcomes depicted that FCEX substantially influences GDP and positively influences the economic growth of Bangladesh. A previous study of Bangladesh's economy by (Test, 2011) scrutinized the nexus and found that economic growth substantially influences FCEX and validates the Keynesian consumption functions. (Hong & Lim Choon Seng, 2019) examined the nexus and observed a significant correlation among the variables in Malaysia.

2.3. Renewable electricity production and output impact on GDP

Renewable electricity production has a significant influence on economic growth. (Ohler & Fetters, 2014) inspected the ELREC and GDP nexus in OECD countries between the period from 1990 to the year 2018. The findings depicted that in the long run, ELREC positively affects GDP, while in the short run, it negatively relates to the GDP of the economy. Similarly, (J. Wang et al., 2022) examined the electricity production and GDP relationship and found a significant association in Pakistan. (simi Simionescu et al., 2019) analyzed the ELREC and GDP association in EU economies. The results demonstrated that economic growth has a crucial and meaningful impact on ELREC in EU economies, but no causal effect was observed. (York & McGee, 2017) examined the impact of electricity production impact on economic growth for CO2 emissions. The results showed a significant but suppressing impact of electricity production on emissions. (Rashed et al., 2022) analyzed the ELREC and GDP relationship. The study determined a one-way directional causal effect from

ELREC to GDP. Similar significant outcomes were determined in another novel research on the nexus (Minh & Van, 2023). (Asratie, 2022) analyzed the determinants of ELREC in East African economies and found GDP as one of the significant determinants of ELREC. (Amri, 2017) observed the unidirectional link between renewable electricity and GDP. (Ameyaw et al., 2021) scrutinized the causal impact of electricity production on economic growth in China. In global data, (Laureti et al., 2022) analyzed the positive impact of RELO on GDP with a 0.83% growth rate.

2.4. Summary and gap

The empirical literature depicts that determinants of economic growth are still an imperative issue of concern for researchers for attaining sustainable development. Among the contributors to economic growth, natural resource rents, final consumption spending, and renewable energy consumption are some significant drivers of growth. They have enhanced or deteriorating influence on growth (Baz et al., 2022; Hong & Lim Choon Seng, 2019; Li et al., 2023; Minh & Van, 2023; Mirza et al., 2023; Qin et al., 2023; J. Wang et al., 2022; Y. Wang, 2023; Xie et al., 2022). However, due to ambiguous outcomes and scarcity of empirical literature, the present study investigates the GDP determinants. The study is unique in assessing the impact of final consumption expenditure alongside the resource rents and renewable electricity production and output simultaneously for evaluating economic performance in BRICS. Correspondingly, evaluating sustainable performance is crucial for ensuring basic needs without compromising the resources for future generations. In today's world, it is one of the imperative concerns in the field of research. Likewise, the literature on final consumption expenditure is insufficient considering sustainable growth, while a few scrutinized the impact of FCEX on carbon emissions. For instance, the recent study by (Azam et al., 2023). Thus, the present study significantly contributes to the available literature by inspecting the relationship between resource rents, renewables, and FCEX on GDP, whose findings might be resourceful for policy enthusiasts.

3. Data and methods

3.1. Variables and model

Following the study's objectives and literature, this study considers natural resources and renewable energy to examine their influence on the economic growth of emerging economies. Specifically, this study uses the gross domestic product (GDP: constant 2015 US$) as a primary explained variable. At the same time, natural resources are depicted via oil rents (ORNT: % of GDP) and mineral rents (MRNT: % of GDP), while renewable energy instruments are considered to be electricity production renewable sources (ELREC: % of total energy excluding hydroelectric) and renewable electricity output (REO: % of total electricity output). Concerning natural resources, oil and mineral rents play a crucial role in the economic as well as industrial expansion of the country, which are also evident in the latest studies of (Badeeb et al., 2021; Fu & Liu, 2023). Nonetheless, there are several renewable energy sources, and governments are still investing in these energy projects. Therefore, it is critical to analyze if these sources are helpful for sustainable economic performance, particularly in the case of emerging economies. as a result, this study considered ELREC and REO for the comprehensive examination of the issue. Further, this study added final consumption expenditure (FCEX: % of GDP) as the control variable. Following the empirical model of (Fuinhas et al., 2019), the model is constructed as follows:

$$GDP_{it} = \theta_1 + \delta_1 ELECREC_{it} + \delta_2 REO_{it} + \delta_3 ORENT_{it} + \delta_4 MRENT_{it} + \delta_5 FCEX_{it} + \varepsilon_{it} \quad (1)$$

In the above model, θ indicates the intercept, while $\delta's$ report the slope of each explanatory variable. Further, i and t are given in the subscript for cross-sections (BRICS economies: including Brazil, Russia, India, China, and South Africa) and time period (1990-2021), respectively. Moreover, the random error of the model is depicted via vector ε. Data for all these variables are extracted from the World Bank (2022).

3.2. Estimation strategy

Before estimating the data empirically, descriptive statistics are employed to summarize the data in this study. This section assesses each variable's mean, median, highest, and smallest values. In addition, we compute the standard deviation, which displays the discrepancy between observations and the mean value, as well as the instability of a variable. In addition, we use two criteria, skewness and Kurtosis, to determine the data's regularity. In contrast, a thorough examination of data normalcy is also performed to analyze the data distribution. Regarding this, we used (Jarque & Bera, 1987) normalcy test, which is commonly characterized as follows, withstanding the normality as a null hypothesis:

$$JB = \frac{N}{6}\left(S^2 + \frac{(K-3)^2}{4}\right) \quad (2)$$

This research explores the panel features of the data, such as slope coefficient heterogeneity (SCH) and panel cross-section dependence, in accordance with the elements of data normalcy (PCD). Between 1760 and 1840, globalization and international trade flourished, causing some countries to specialize in certain services and goods while other economies did the same. Consequently, some economies depend on the assistance of other governments and countries to achieve their goals in the domains of technology, finance, the economy, the environment, and others. Due to this dependence, governments and politicians may implement actions that cause one country to resemble other states or countries, highlighting the essential issue of slope homogeneity in an econometric model. If the slope homogeneity problem arises, the study of panel data may be inefficient and murky (Breitung, 2005; Wei et al., 2022). The problem is handled utilizing the SCH technique developed by (Pesaran & Yamagata, 2008). This assessment is appropriate since it presents both the

SCH and the adjusted SCH as follows:

$$\hat{\Delta}_{SCH} = \sqrt{N(2k)^{-1}}(N^{-1}\acute{S}-K) \tag{3}$$

$$\hat{\Delta}_{ASCH} = \sqrt{N}\sqrt{\frac{T+1}{2K.(T-K-1)}}(N^{-1}\acute{S} - 2K) \tag{4}$$

the slope coefficient's homogeneity as per Eq (4). The hypothesis also implies that slope coefficients are homogeneous up to the statistical significance threshold.

As was earlier discussed, globalization and cross-border trade enhance a nation's proficiency in products and/or services that are gaining significance on a global stage. These countries depend increasingly on economies with a specialized focus. Ignoring this panel problem, PCD might lead to contradictory results from the empirical investigation (Campello et al., 2019). We employ the (Pesaran, 2004) CD test to examine if the chosen economies show cross-sectional dependence. The formula for cross-sectional dependence is as follows:

$$\text{CD}_{Test} = \frac{\sqrt{2T}}{[N(N-1)]^{1/2}}\sum_{i=1}^{N-1}\sum_{k=1+i}^{N} T_{ik} \tag{5}$$

The test's null hypothesis asserts that there is no dependency between the cross-sections of the panel.

The stationarity analysis for each given variable follows the diagnostic results. Since identifying the unit root is essential for comprehending long-term forecasts, this study used the (Pesaran, 2007) CIPS unit root test, an extended form of the (Pesaran, 2006) test. As a null hypothesis, this test presupposes the existence of the unit root. In contrast, the null hypothesis may be discarded if the statistical results exceed the critical values by 1%, 5%, or 10% levels. It is conceivable that the variable does not exhibit stationarity at the level. Thus, this test may be performed on the first difference. In addition, the CIPS test successfully addresses both cross-section dependence and slope heterogeneity issues of panel data.

(Westerlund, 2007) established the error correction model (ECM) to analyze the long-run cointegration of indicators in panel nations. By merging group mean and panel statistics, this test tackles the existence of cross-sectional dependency and slope heterogeneity with precision. Formulations such as $G_\tau = \frac{1}{N}\sum_{i=1}^{N}\frac{\hat{\alpha}_i}{S.E\hat{\alpha}_i}$, and $G_a = \frac{1}{N}\sum_{i=1}^{N}\frac{T\hat{\alpha}_i}{\hat{\alpha}_i(1)}$, respectively, are popular methods for evaluating the group mean statistics. However, for estimating the panel's forecasts, the statistical formulations are $P_\tau = \frac{\hat{\alpha}}{S.E(\hat{\alpha})}$, and $P_a = T.\hat{\alpha}$.

(Koenker & Bassett Jr, 1978) created panel quantile regression; it produces dependent mean and conditional variance depending on predictors' values. Quantile regression offers consistent results if the data set seems to have an atypical data distribution. We employed the novel method of moments quantile regression (MMQR) methodology developed by (Machado & Silva, 2019) to account for the uneven distribution of the data, which is the extended version of panel quantile regression. This innovative method examines quantile values' variability and distributional characteristics (Sarkodie & Strezov, 2019). Eq. (6) presents a straightforward equation for predicting the conditional quantile location-scale $Q_y(\tau|R)$ variant:

$$Y_{it} = \theta_i + \vartheta R_{it} + \left(\delta_i + \rho \acute{Z}_{it}\right)\mu_{it}, \tag{6}$$

In accordance with the preceding formula, there exists the probability $p\left(\delta_i + \rho.\acute{Z}_{it} > 0\right) = 1$. As for the calculated coefficients, they are θ, ϑ, δ, and ρ. The subscript i indicates the fixed effect represented by θ_i and δ_i for $i = 1, 2, 3, \ldots, n$. Whereas Z captures the defining difference of component $\mathbb{l}$, the k-vector of R's standard elements:

$$Z_{\mathbb{l}} = Z_{\mathbb{l}}(R), \ \mathbb{l} = 1, \ 2, \ \ldots, \ k \tag{7}$$

Where R_{it} is orthogonal to i and t (time) but uniformly and independently scattered for every fixed i and t. (Machado & Silva, 2019) . This contributes to the suppression of external behavior and the component's stability. As a consequence, Eq. (1) may appear as follows:

$$Q_y(\tau|R_{it}) = (\theta_i + \delta_i q(\tau)) + \vartheta R_{it} + \rho \acute{Z}_{it} q(\tau) \tag{8}$$

Where *ELREC*, *REO*, *ORENT*, *FCEX*, *and MRENT* are all represented by the vector R_{it}, which is the vector of explanatory variables in the preceding equation. In this empirical study, each of these variables is considered in their natural logarithmic form. The right-hand side of the above equation describes the location of the regressors and the quantile distribution of the explained variable (Y_{it}, which in this research represents *GDP*) is reliant on R_{it} and the placements of these components. The scalar coefficient likewise expresses the quantiles' fixed effect for i $-\theta_i(\tau) \equiv \theta_i + \delta_i \ q(\tau)$. Noticeably, the individual impact has little effect on the intercept. As the constituents are not time-dependent, the effects will likely vary. Lastly, the symbol $q(\tau)$ represents the $\tau - th$ sample quantiles, which are regarded as the 25th, 50th, 75th, and 90th in this study. In this investigation, the following quantile formula was used:

$$\min_q \sum\nolimits_i \sum\nolimits_t \gamma_\tau\left(R_{it} - \left(\delta_i + \rho \acute{Z}_{it}\right)q\right) \tag{9}$$

The checking procedure is demonstrated by $\gamma_\tau(A) = (\tau - 1)AI\{A \leq 0\} + TAI\{A > 0\}$.

The current research applies the Bootstrap quantile regression (BSQR) as a robust estimator to confirm or justify the empirical model of the study. The BSQR is another non-parametric method that addresses the problem of data asymmetry.

4. Results and discussions

This section is organized as follows. First, the interpretation of the outcomes from research estimations is held then their economic discussions are documented at the end of this section 4.

In Table 1, the descriptive stats are presented for all variables. The average and median values are not identical, demonstrating that the data is unbalanced. The range of the variables is displayed with the values of maximum and minimum values. The data spread from the mean position is depicted with standard deviation values. Except for the Future Consumption Expenditure (FCEX) variable, which is negatively skewed with the value of −0.600713, all variables are positively skewed. The kurtosis values depict that the information used for the research is not normally distributed. While the Jarque Bera analysis and the probability distribution further demonstrate that data is non-normal and irregularly distributed.

4.1. Diagnostic tests

For the diagnostic analysis, Slope heterogeneity and Cross-sectional tests are applied, and outcomes are presented in Tables 2 and 3 below, respectively. The slope heterogeneity demonstrates that variables have or do not have significant differences. At the

Table 1. Descriptive stats.

	ORNT	MRNT	ELREC	FCEX	GDP	REO
Mean	2.363739	0.783134	1.284625	71.93080	2.04E + 12	24.10392
Median	1.152040	0.654208	0.230734	72.85549	1.19E + 12	16.56825
Maximum	14.49236	2.525932	12.11841	85.12763	1.58E + 13	95.40534
Minimum	0.000816	0.069013	0.002207	48.91336	1.79E + 11	0.071288
Std. Dev.	3.288116	0.595206	2.000280	10.00221	2.95E + 12	29.47871
Skewness	1.914972	1.204739	2.398197	−0.600713	2.978638	1.582281
Kurtosis	5.638255	3.740965	10.08919	2.311488	11.55852	3.987072
Jarque-Bera	148.6984	43.68797	503.6760	13.18264	747.5700	75.54773
Probability	0.000000	0.000000	0.000000	0.001372	0.000000	0.000000

Source: Authors estimation.

Table 2. Slope heterogeneity.

Model-1	
Slope heterogeneity test	Statistics
$\tilde{\Delta}$	7.809***
$\tilde{\Delta}_{Adjusted}$	8.798***

Note: Significance level is denoted by. *** for 1%, ** for 5%, and * for 10%.
Source: Authors estimation.

Table 3. Cross-section dependence.

Cross-section dependence	
GDP	ELREC
16.263***	12.84***
REO	ORNT
13.482***	10.639***
FCEX	MRNT
3.152***	12.091***

Note: Significance level is denoted by. *** for 1%,.** for 5%, and * for 10%.
Source: Authors estimation.

Table 4. Unit root.

Pesaran CIPS unit root test		
Variables	I(0)	I(1)
GDP		
REO	−4.121***	–
ELREC	−2.284	−5.699***
ORNT	−2.297	−5.121***
FCEX	−3.988***	–
MRNT	−2.989**	–

Note: I(0) represents leveled data, while I(1) indicates the first differenced data. The significance level is denoted by *** for 1%, ** for 5%, and * for 10%.
Source: Authors estimation.

same time, the Cross-sectional dependence depicts whether the variables used have a significant correlation among their errors. Either the error term of one variable is correlated to another error of another variable or not. These tests become necessary when the underlying factors, such as economic, social, or financial factors of one country, affect the other in a panel data analysis. Therefore, different models are used to overcome heterogeneity and dependence issues. The slope test depicted significant results and rejected the null hypothesis of homogeneity among the variables. The statistics are significant at a 1% significance level with 7.809 and 8.798 values. The test verifies the existence of heterogeneity among the variables.

Then the cross-sectional dependence analysis is applied to all variables. The test results demonstrate that all variables ORNT, MRNT, ELREC, FCEX, GDP, and REO are statistically significant. They reject the null hypothesis of no interdependence among the study variables at a 1% level of significance with values as 10.639, 12.091, 12.84, 3.152, 16.263, and 13.482, respectively. This justifies that all variables are cross-sectionally correlated with each other in the panel data of BRICS economies. Therefore, after applying diagnostic checks on the information under consideration, the authors applied the unit root analysis that is used to evaluate the stationarity of the data. Table 4 demonstrates the unit root results from Pesaran's test (CIPS) for all variables. The table shows that the variables REO, FCEX, and MRNT are non-stationary at levels of −4.121, −3.988, and −2.989, respectively. They signify the presence of unit root at the level I(0) with significant values at a 1% level of significance. Then at the first difference, ELREC and ORNT are significant, with a 1% significance level with −5.69 and −5.121 statistics, respectively. The test findings depict that some variables have shown the existence of unit roots at a level while the remaining few variables demonstrated the existence of unit roots at the first difference. This leads to assessing the presence of long-run correlation among the study variables.

4.2. Regression analysis and robustness

The study uses (Westerlund, 2007) cointegration tests to evaluate long-run relationships among the variables. The test results are demonstrated in Table 5. The Z-values and test Statistics (Gτ, Ga, Pτ, and Pa) of data are presented in the table. All four statistics have shown significant outcomes at a 1% significance level. The test outcomes verify the presence of a long-run association between the study variables. Oil rents, Mineral rents, Electricity production from renewable resources, Final consumption expense, and Renewable electricity are all significantly associated with economic growth in BRICS

Table 5. Cointegration results (Westerlund-2007).

Statistics	Value	Z-value
G_τ	−3.903***	−3.746
G_a	−17.480**	−1.676
P_τ	−7.518***	−2.709
P_a	−14.154**	−1.721

Note: Significance level is denoted by *** for 1%, ** for 5%, and * for 10%.
Source: Authors estimation.

Table 6. Estimates of quantile regression–MMQR.

			Quantiles			
Variable	Location	Scale	Q0.25	Q0.50	Q0.75	Q0.90
ELREC	0.263***	0.052**	0.212***	0.268***	0.311***	0.344***
	[0.026]	[0.020]	[0.037]	[0.025]	[0.026]	[0.031]
REO	−0.087	−0.130***	0.040	−0.101*	−0.210***	−0.294***
	[0.061]	[0.047]	[0.084]	[0.059]	[0.060]	[0.072]
ORENT	0.183***	0.079**	0.105	0.191***	0.258***	0.309***
	[0.047]	[0.036]	[0.067]	[0.046]	[0.047]	[0.057]
FCEX	−4.460***	0.224	−4.681***	−4.438***	−4.249***	−4.103***
	[0.332]	[0.254]	[0.484]	[0.323]	[0.325]	[0.409]
MRNT	−0.260***	−0.110**	−0.152**	−0.271***	−0.364***	−0.436***
	[0.065]	[0.050]	[0.091]	[0.063]	[0.064]	[0.078]
Constant	20.519***	−0.130	20.647***	20.506***	20.396***	20.312***
	[0.589]	[0.451]	[0.863]	[0.573]	[0.577]	[0.729]

Note: *GDP* is the dependent variable. The significance level is denoted by *** for 1%, ** for 5%, and * for 10%.
Source: Authors estimation.

economies during the given period. This signifies examining the Quantile analysis and the results from MM Quantile regressions which are elaborated in Table 6 of the study below. Due to the existence of irregular distribution of the data and having significant heterogeneity and co-dependence, the study employs Quantile Regressions. The analysis outcomes show that all explanatory variables are significantly associated with the dependent variable, i.e. economic growth (GDP). Renewable electricity production is positively related to economic growth in BRICS. The EREC and GDP showed positive and significant outcomes in all quantiles. They are indicating that increasing electricity production increases economic growth. Renewable electricity output in BRICS has shown negative results in most quantiles signifying that electricity output tends to lower the growth levels in BRICS. REO is positively associated with GDP, but after the first quantile, it becomes negative and highly significant. Depicting that at first, electricity output increases growth, but after a certain time, it lowers the growth rate in the economy. Then the oil rents have shown a positive association with economic growth, whereas the mineral rents are statistically negative and significantly related to economic growth (GDP) in all four quantiles (Q0.25, Q0.50, Q0.75, and Q0.90). These associations demonstrate that oil rents significantly increase economic growth while mineral rents lower the growth levels in the country. Both results signify that resource rents have a mixed effect on economic growth due to their different types. Lastly, the role of final consumption expenditure is negatively associated with economic growth, indicating that increasing consumption expenses tend to limit growth in the country.

The graphical presentation of the quantiles of all variables from MMQR is presented in Figure 3. The figure illustrates the estimated quantiles of ELREC, REO, ORNT, FCEX, and MRNT that Table 6 has shown. They were moving toward the Robustness analysis

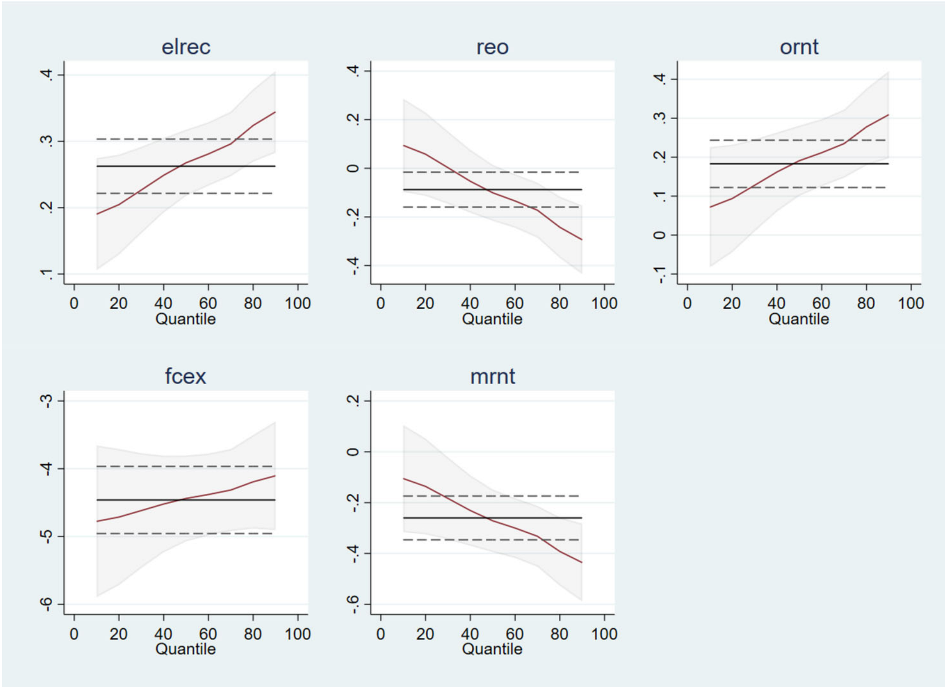

Figure 3. Quantiles from MMQR.
Source: Authors estimation.

Table 7. Robustness–BSQR.

Variable	Quantiles			
	Q0.25	Q0.50	Q0.75	Q0.90
ELREC	0.166***	0.286***	0.315***	0.325***
REO	0.132*	−0.118	−0.223***	−0.240***
ORENT	0.073	0.224***	0.264***	0.273***
FCEX	−4.286***	−4.163***	−3.936***	−3.960***
MRNT	−0.061	−0.223**	−0.303***	−0.416***
Constant	19.814***	20.043***	19.842***	19.972***

Note: *GDP* is the dependent variable. The significance level is denoted by *** for 1%, ** for 5%, and * for 10%.
Source: Authors estimation.

presented in Table 7. Lastly, the study employs Bootstrap Quantile regressions as a robustness check test to examine the reliability of the regression findings. The robustness test results have shown that all variables are statistically significant in almost all quantiles. The overall analysis demonstrates that Renewable electricity output, final consumption expenses, and mineral rents are negatively related to economic growth. They statistically hamper economic growth because their increased usage tends to reduce economic growth in the economy. At the same time, Electricity production and Oil rents are useful components that help escalate economic growth in the country. They statistically increase the growth levels in the economy. The graphical presentation of all variables' estimated quantiles from BSQR is illustrated in Figure 4 below.

The results imply that certain factors are responsible for promoting sustainable performance. According to the estimated findings, renewable electricity production is

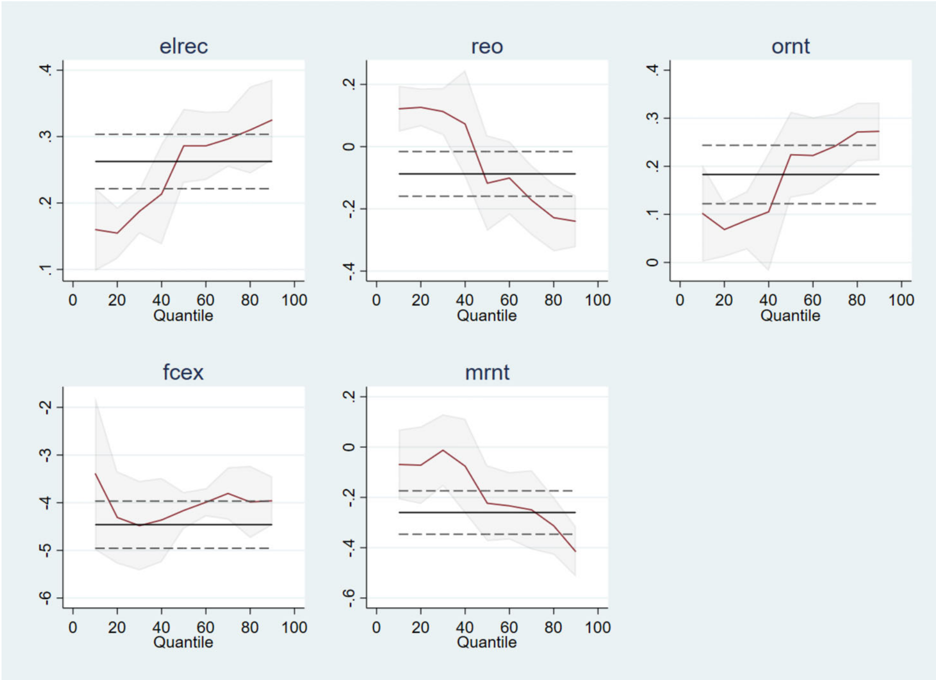

Figure 4. Quantiles from BSQR.
Source: Authors estimation.

positively associated with economic growth in BRICS economies. The nexus outcome is significant to the findings of the following studies (Asratie, 2022; Ohler & Fetters, 2014; Sahlian et al., 2021). The possible significance of the result can be documented as increasing renewable electricity production creates more jobs and employment opportunities which substantially helps stimulate the economy and increases growth. Therefore, the impact is positive between ELREC and GDP in BRICS. Second, the impact of RELO on GDP is negative, indicating that increasing renewable electricity output increases energy prices, which have an inverse relationship with economic growth in the country. According to the knowledge of the authors, the nexus outcome is novel to the empirical literature as prior studies focused on assessing the impact of RELO on CO2 emissions (Murshed et al., 2022). Third, the role of Oil rents on GDP is positive in BRICS economies. This nexus result is consistent with the results of (Balsalobre-Lorente et al., 2023; Okoye et al., 2022). They indicate that revenues generated from oil sources can be useful in the investment of infrastructure, education, etc., which can positively contribute to economic growth (Berger, 2022; Ferrat et al., 2021; Gao et al., 2021). Fourth, the impact of mineral rents is negative in BRICS nations. The nexus is comparable to the findings of (Namahoro et al., 2023). This signifies that the extraction of mineral resources negatively impacts the environment and slows down economic activity, causing a fall in economic growth levels. Moreover, the income generated from mineral rents is invested in financial activities rather than economic activities that could excite the growth of the economy. Lastly, final consumption expenses negatively impact the GDP in BRICS. The nexus result is novel to the pragmatic literature as prior studies explored the positive impact between FCEX and GDP. However, the present study shows the long-run association between previously said variables which is in line with the findings of (Hong & Lim Choon Seng, 2019). This indicates that FCEX is a household expenditure that does not contribute to the productive capacity or economic output that ultimately shows an inverse association with GDP.

5. Conclusions and policy implications

The study inspects the impact of resource rents, clean energy, and consumption expenses on economic growth in BRICS nations. The study utilizes a re-organized sample period from 1989 to the recent year 2021 using Quantile on Quantile regressions for evaluating resource energy and sustainable growth nexus. The research on assessing the determinants of GDP in BRICS is significant because it helps policy regulators and academicians to understand these factors for sustainable policy revamping. The study uses the Pesaran CIPS unit root, Westerlund Cointegration technique, MMQR, and BSQR regressions. The pre-estimation analysis demonstrated that the information on countries is irregularly distributed. At the same time, unit root and cointegration tests depicted the existence of strong unit roots with the long-run association among variables. Then the regression analysis signifies the impact of independent variables on the dependent variable (GDP), which showed reliable estimates following the robustness check. According to the estimates, Renewable electricity output (REO), Final consumption expenses (FCEX), and mineral rents (MRNT) are negatively related to economic growth. They hamper economic development because their increased usage tends to reduce economic growth in the economy. At the same time, Electricity production (ELREC) and Oil rents (ORNT) are beneficial components that help appreciate economic growth in the country as they increase the progression levels in the economy. The diverse impact of REO, ELREC, FCEX, ORNT, and MRNT could be explained by the fact that specific policies and incentives impact the variables and sustainable growth in the country since sustainable development is a multifactored and complex phenomenon in which several factors play their role in the promotion of economic progression. Moreover, the differences in political and economic structures, diversity in resource endowments, and other critical factors impact the variables in panel data analysis. Therefore, the study suggests that the following recommendations might be beneficial for promoting sustainable economic development. First, governments must incentivize renewable energy to enhance its usage more than conventional energy. Alongside this, tax cuts and financial incentives by governments to businesses for promoting renewable energy are needed. This promotion of renewable energy production will be useful for creating job opportunities in the economy that will meaningfully contribute to sustainable economic development. At the international level, BRICS needs corporations to promote renewable energy and efficient resource management through sharing technological practices and R&D efforts. Second, investment and R&D in education and innovative technology are required to promote economic sustainability. Efficient resource management is necessary for encouraging economic growth. Because it will not only be beneficial for sustainable progression but also promotes a sustainable environment. Third, economic diversification also has a significant role in promoting economic growth. Because it limits the reliance on one sector/resource and converts into multi-sector growth by developing new technologies and industries in the country, it helps in the well-organized management of resources for promoting economic growth and development in the country. Also, government institutions play an important role in the effective and efficient implementation and management of resources. It attracts investment opportunities and encourages growth in the country. In the end, each country adopts and implements sustainable measures according to its needs for supporting sustainable economic growth and development, which is beneficial for a sustainable environment.

5.1. Study limitations

It explores the nexus between resource rents, clean energy, and consumption expenses on economic growth, which is limited in BRICS nations. The limitations include that the study with these specific factors can be assessed in other world economies. Second, there are several possible factors affecting economic growth, whereas the study has observed a few imperative factors for research purposes. The inclusion of other effective factors could be useful in this regard. Therefore, for purposes, the study can be extended with the inclusion of other factors like corruption, institutional quality, business environment, etc., for a more comprehensive analysis of the determinants of GDP. Third, the Quantile regressions assume that the data used is linear. However, in reality, the independent factors have a significant non-linear impact on economic growth that might affect the research outcomes.

So, the nexus studied in BRICS is complex and multifaceted. However, the interpretations, conclusions, and policy suggestions are documented while keeping in mind the above mentioned limitations to provide valuable insights for policy recommendations.

Note

1. Visit: World Development Indicators (WDI) at https://databank.worldbank.org/source/world-development-indicators#

Disclosure statement

No potential conflict of interest was reported by the authors.

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