IJEEP
INTERNATIONAL JOURNAL OF ENERGY ECONOMICS AND POLICY
EJ EconJournals
ISSN: 2146-4553

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2026, 16(1), 1-7.

EJ EconJournals

Natural Resource Rents and Carbon Intensity Nexus in Saudi Arabia: Disaggregated Analyses

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Received: 12 May 2025 **Accepted:** 06 October 2025 **DOI:** https://doi.org/10.32479/ijeep.20455

ABSTRACT

Natural Resource Rents (NRR) can shape carbon emissions and Carbon Intensity (CI) in a resource-rich economy. However, NRR from each natural resource does not necessarily have the same effect on CI. Thus, this research aims to estimate the effects of oil, natural gas, mineral, and forest rents on CI in the resource-rich economy of Saudi Arabia by using the cointegration technique for a period of 1980-2023. The findings reveal that economic growth increases CI. Moreover, oil and natural gas rents exert a positive long-run effect on CI. However, mineral and forest rents could not affect CI in the long run. Furthermore, NRR from all investigated sources increases CI in the short run. These results emphasize the need for targeted policy measures for each source of NRR to reduce their environmental concerns. For this purpose, it is advised to diversify the Saudi economy from NRR.

Keywords: Carbon Intensity, Natural Resource Rents, Carbon Emissions, Economic Growth
JEL Classifications: Q32, Q58, O44

1. INTRODUCTION

Carbon Intensity (CI) captures the amount of carbon emissions per unit of production (Gao et al., 2025). The increasing CI is an indicator of a country's worse environmental performance, which has emerged due to energy inefficiency and can result in environmental degradation. In a resource-rich Saudi economy, it is important to understand the determinants of CI due to its heavy reliance on fossil fuels for both domestic consumption and export revenues. Oil and natural gas are fossil fuels, and their production and consumption are excessively carbon-intensive, which could raise carbon emissions and CI. The Saudi economy has large proven reserves of petroleum and heavily relies on hydrocarbon resources to achieve its economic growth (Shahid et al., 2025). The oil sector is historically supported by expansive energy subsidies, underpriced domestic energy, and large-scale infrastructure development in the Kingdom (Gasim and Matar, 2023). On the whole, Natural Resource Rents (NRR) have contributed to rapid industrialization and economic growth in Saudi Arabia, which is responsible for excessive energy consumption and inefficiencies in energy usage as well. Thus, over-reliance on NRR can raise environmental concerns in the Kingdom.

Resource curse theory explains that natural resources may lead to higher inefficiencies in energy consumption due to institutional problems and rent-seeking behavior in any economy (Singh et al., 2024). Thus, NRR may be responsible for higher growth in energy consumption compared to growth of national output, which could raise CI. Moreover, the availability of low-cost energy in resource-rich economies can reduce the incentives for energy conservation and technological innovation, which can further raise CI. This phenomenon is more important for the Saudi economy, carrying a significant share of Gross Domestic Product (GDP) and government revenues from NRR (Alabdulwahab, 2021). In addition, oil price subsidies and low local energy prices could raise further environmental problems by increasing CI.

On the positive aspects, NRR can be invested in renewable energy infrastructure and innovations (Abbas et al., 2024), which could help in increasing carbon efficiency and reducing CI. For instance, Saudi Vision 2030 prioritizes energy efficiency and economic diversification as a national goal to invest in NRR in carbon-efficient technologies in modernized industries and also in clean technologies (Selim and Alshareef, 2025). The Saudi Energy Efficiency Program (SEEP) aims to increase investment in renewable energies (Belaïd and Massié, 2023). Thus, the Kingdom is targeting to decrease dependence on fossil fuels and to enhance Renewable Energy Consumption (REC), which could help this economy to enhance its energy and carbon productivity. In this way, NRR can help the Kingdom to finance a clean energy transition to reduce CI.

Keeping in mind both expected positive and negative aspects of NRR on CI and the environment, it looks pertinent to empirically investigate the role of NRR on CI in Saudi Arabia. Some Saudi studies analyzed the impact of NRR on CO_2 emissions (Agboola et al., 2021) and ecological footprint (Ben-Salha and Zmami, 2023). Nevertheless, the Saudi literature could not focus on the aspect of CI. NRR is significantly contributing to Saudi GDP, along with its contribution to carbon emissions. Thus, it is more important to estimate the net effect of NRR on CI (carbon emissions divided by GDP) as suggested by Özkan et al. (2025). Therefore, this research aims to investigate the effect of NRR on CI. To increase the novelty of the research as suggested by Bilgili et al. (2023), disaggregated effects of NRR from oil, natural gas, mineral, and forest sectors on CI are investigated by using a large time sample from 1980 to 2023. The results of the study would provide more insight into the NRR and CI relationship to float the sector-specific policies.

2. LITERATURE REVIEW

The investigation of the nexus between NRR and CI is scant in the literature. However, a growing interest has been observed in the recent literature to empirically investigate the nexus between NRR and environmental proxies. For instance, in a global level study, Bosah et al. (2023) examined 159 countries using a period from 2000 to 2019 and indicated that economic development promoted environmental sustainability. However, energy consumption and NRR raised environmental degradation. Moreover, causality results also confirmed these effects. Nwani et al. (2023) scrutinized the nexus between NRR and production and consumption-based emissions in developing economies from 1995 to 2017. The authors found that GDP significantly raised production-based emissions monotonically. However, the Environmental Kuznets Curve (EKC) was corroborated by consumption-based emissions. Moreover, NRR and Energy Intensity (EI) significantly contributed to emissions in both cases. Furthermore, NRR showed significant predictive power for future GDP, EI, and emissions in India, Nigeria, and Mexico.

Cai et al. (2023) analyzed BRICS countries and confirmed that NRR raised CO2 emissions. However, after a threshold level, this relationship became weak. Moreover, GDP and R&D investments played their differentiated roles in different countries to determine emission levels. In the context of emerging economies, Fu et al. (2023) explored the asymmetric environmental effects of REC, GDP growth, and NRR in BRICS and revealed that NRR, GDP growth, and fiscal policy expansion raised emissions in lower emission quantiles. However, REC helped reduce emissions at higher quantiles. Ganda (2022) investigated the interactive effects between Financial Development (FD) and NRR on emissions in BRICS economies and validated the EKC. Moreover, FD and NRR elevated emissions. However, their interactions with institutional factors helped mitigate emissions. Moreover, interactions with trade and technological innovation also had a mitigating effect on emissions.

Amin et al. (2025) explored the BRICS economies by incorporating green finance and R&D in the model and concluded that NRR and GDP elevated emissions. Nevertheless, R&D and green finance mitigated environmental degradation. Furthermore, the bidirectional causality among variables was also reported, which emphasized the interconnectedness of sustainability drivers. Sachan et al. (2025) examined the NRR, human capital, and emissions nexus in BRICS from 1992 to 2019 and found that human capital reduced emissions from NRR. Irfan et al. (2025) examined the BRICS economies and found that forestry, fishing, trade, and NRR contributed to emissions. However, government effectiveness reduced emissions.

Chen et al. (2023) explored E-7 economies and confirmed that institutional quality helped reduce carbon emissions in quantile analyses. Moreover, sustainable management of NRR and energy productivity improvements helped reduce emissions. However, GDP growth contributed to emissions, and REC reduced this effect. Khaddage-Soboh et al. (2023) analyzed G-7 developed economies from 1990 to 2020 and showed a nonlinear association between NRR and CO_2 emissions. NRR reduced emissions. However, this relationship became statistically insignificant or positive at higher quantiles. Moreover, environmental regulations, REC, and taxation reduced emissions. Gyamfi et al. (2022) examined the ecological impacts of NRR in G7 economies, and the results indicated that NRR and fossil fuels contributed to environmental degradation in most quantiles. However, REC consistently improved environmental quality in all quantiles. Moreover, Granger causality analysis revealed that NRR caused REC, which suggested a potential for redirecting NRR toward sustainable investments.

Tufail et al. (2021) probed the effects of fiscal decentralization and NRR on environmental outcomes in 7 OECD countries from 1990 to 2018 and revealed that fiscal decentralization mitigated emissions in the long run. Moreover, GDP and NRR raised emissions. However, institutional quality played a mitigating role in these relationships. Safdar et al. (2022) analyzed South Asia from 1996 to 2020 and revealed that governance significantly reduced Greenhouse Gas (GHG) emissions and positively influenced GDP growth. Moreover, NRR exacerbated GHG emissions. However, the interaction of NRR with good governance mitigated these adverse effects. Voumik et al. (2023) investigated South Asia and found that urbanization, industrialization, and GDP increased emissions. However, NRR and electrification reduced emissions. Thus, NRR financed cleaner energy and greener infrastructure to support a clean environment.

Ullah et al. (2021) explored 15 renewable energy user countries from 1996 to 2018 and discovered that REC reduced the ecological footprint. However, NRR increased the ecological footprint. Focusing on the MENA, Bilgili et al. (2023) disaggregated NRR into forests, oil, and minerals rents and found that forest rents improved the environment. However, oil and mineral rents worsened it. Further, economic growth and fossil fuel usage increased emissions, and REC reduced them. Saqib et al. (2022) examined the GCC and reported that GDP expansion and non-REC raised CO2 emissions. However, FD and REC mitigated environmental degradation. In addition, causality analysis supported a bidirectional relationship between energy, FD, and emissions. Sibanda et al. (2023) explored Sub-Saharan Africa from 1994 to 2020 and found that NRR was positively correlated with environmental degradation, which was found due to weak implementation of environmental regulations. Moreover, the EKC was corroborated.

Zuo et al. (2021) examined 90 Belt and Road Initiative (BRI) countries and concluded that NRR deteriorated environmental quality. However, technological innovation mitigated ecological footprints. Moreover, the interaction between NRR and technological innovation also helped reduce ecological degradation. Kadir et al. (2025) examined 15 resource-rich African countries from 1990 to 2021 and concluded the resource curse hypothesis, as NRR raised emissions in the presence of weak institutional quality. However, the stringent rule of law, REC, and energy efficiency reduced emissions. Guan et al. (2025) explored the connection between NRR, FD, and Global Value Chain (GVC) in 60 countries from 1996 to 2018 and found that these variables raised environmental degradation in all quantiles. Qamruzzaman (2025) investigated eight resource-rich countries and found that income from NRR increased CO_2 emissions. However, technological innovation mitigated the environmental impacts of NRR. Moreover, higher education reduced emissions and ecological footprints. Additionally, financial inclusion fostered economic growth but contributed to environmental degradation.

In a country-specific analysis, Fan et al. (2023) investigated China from 1988 to 2018 and found that NRR and energy use raised the ecological footprint and CO_2 emissions. Moreover, a bidirectional relationship between industrialization and energy consumption was also reported. From a subnational perspective, Shen et al. (2021) analyzed 30 provinces in China from 1995 to 2017 and affirmed that energy consumption, NRR, and FD exacerbated emissions. However, green investments helped reduce them. Similarly, regional evidence was provided by Huang and Guo (2023) by investigating 30 Chinese provinces. The authors found that NRR and transportation infrastructure raised CO_2 emissions. Moreover, green investment initially raised emissions and reduced them over time. Raihan et al. (2025) focused on China to evaluate the effects of NRR from the mineral sector, REC, and energy efficiency on carbon emissions and revealed that REC and energy efficiency significantly reduced emissions. However, economic growth contributed to emissions.

Zhu et al. (2025) analyzed the effects of forest rents and governance on China's ecological footprint and reported that forest rents increased environmental degradation in lower quantiles, and this effect was mitigated by high levels of government effectiveness. Moreover, fossil fuels and foreign investments also contributed to environmental degradation. However, strong governance moderated these relationships. In the Indian context, Özkan et al. (2025) investigated the linkages between EI, NRR, and CI by using data from 1970 to 2020 and indicated that NRR and REC helped reduce emissions. However, EI and GDP growth exacerbated CI. Wada (2025) analyzed Japan's GHG emissions from 1970 to 2018 and found the EKC hypothesis in Japan. Furthermore, declining NRR and population mitigated emissions. In the context of Saudi Arabia, Agboola et al. (2021) explored the causality between NRR and CO_2 emissions and affirmed that energy consumption, total NRR, and economic growth significantly degraded the environment.

Huang et al. (2021) studied the US from 1995 to 2015 in quantile analysis and demonstrated that FD, urbanization, and NRR raised long-run carbon emissions in all quantiles. In the same way, some short-run evidences were also reported. Akadiri et al. (2024) investigated Nigeria in Granger causality and found that financial globalization and NRR caused emissions. Thus, the authors suggested that both financial flows and extraction sectors contributed to environmental degradation. Shang et al. (2025) assessed Malaysia from 1990 to 2022 and found that decreasing oil rents increased GHG emissions and increasing mineral rents reduced GHG emissions. Moreover, increasing natural gas and coal rents and REC reduced GHG emissions.

The reviewed studies reflect the importance of NRR in determining the environment. However, the testing of the effect of NRR on CI is scant in the literature and absent in Saudi Arabia. Thus, this research fills this gap.

3. METHODOLOGY

GDP is a direct component of CI, and increasing GDP can reduce CI (Gao et al., 2025). However, increasing GDP can contribute to carbon emissions through the scale effect of increasing industrialization and energy consumption (Grossman and Krueger, 1991), which can increase CI consequently. Thus, NRR can contribute to both GDP and carbon emissions. The Saudi economy's GDP is heavily reliant on the revenues from NRR (Shahid et al., 2025). Thus, NRR can potentially determine the CI in Saudi Arabia. Further, NRR can potentially contribute to emissions. The revenues from NRR are mostly generated from extractive industries in resource-rich countries, and extractive industries are typically energy-intensive and carbon-emitting. For instance, oil and natural gas carry carbon-intensive production processes (Dixit et al., 2023), which can significantly increase carbon emissions. Moreover, the combustion of these fossil fuels is responsible for heavy carbon emissions in industrial usage and consumption-related activities. For instance, Saudi electricity generation is heavily dependent on oil (Al-Ismail et al., 2023), and the combustion of oil to generate electricity may raise massive emissions. Furthermore, the Saudi transport sector is heavily reliant on oil energy (Gasim et al., 2023). Thus, oil rents can potentially contribute to carbon emissions from the production and consumption sides. On the other hand, Saudi GDP is significantly dependent on oil revenues (Alabdulwahab, 2021). So, oil revenues could affect CI from both sides of CI, which are GDP and carbon emissions. Likewise, mineral, forest, and natural gas rents can also affect carbon emissions due to heavy machinery utilized in their extraction and energy-intensive refining processes. Thus, all types of NRR can affect carbon emissions and GDP, and their net effects are empirical questions, which are going to be tested with the following model:

$$CI_t = f(Y_t, OR_t, NGR_t, MR_t, FR_t) \quad (1)$$

CI_t is a natural logarithm of carbon intensity. OR_t, NGR_t, MR_t, and FR_t are natural logarithms of oil, natural gas, mineral, and forest rents, which are taken into percentages of the GDP. Y_t is per capita GDP in constant Saudi Riyals. Data is sourced from the World Bank (2025) for the period 1980-2023. After discussing the model, all variables in this model should be stationary to be utilized for cointegration analysis. For this purpose, Ng and Perron's (2001) methodology is applied, providing robust estimates in the case of a small sample. This technique will be applied through the following statistics:

$$MZ_a^d = \left[\frac{Y_T^d}{T}\right]^2 / 2K - f_0 / 2K \quad (2)$$

$$MSB^d = \left[\frac{k}{f_0}\right]^{1/2} \quad (3)$$

$$MZ_t^d = MZ_a^d . MSB^d \quad (4)$$

$$MPT_T^d = [c^2.K + \frac{1-c}{T}].\frac{Y_T^d}{f_0} \quad (5)$$

Equations 2-5 will be tested for a null hypothesis of non-stationarity, and their rejection may ensure the stationarity of the series. Afterward, we can move to cointegration analysis. Pesaran et al.'s (2001) autoregressive distributive lag methodology is applied for this purpose. This methodology is superior to other cointegration techniques by solving the endogeneity by utilizing an autoregressive process. Further, it can generate robust estimates with a mixed order of integration. The ARDL can be defined for equation 1 in the following way:

$$\begin{aligned}\Delta CI_t =& \varnothing_0 + \varnothing_{11}CI_{t-1} + \varnothing_{12}Y_{t-1} + \varnothing_{13}OR_{t-1} \\ &+ \varnothing_{14}NGR_{t-1} + \varnothing_{15}MR_{t-1} + \varnothing_{16}FR_{t-1} \\ &+ \sum\nolimits_{i=1}^{j} \varnothing_{21i}\Delta CI_{t-i} + \sum\nolimits_{i=0}^{j} \varnothing_{22i}\Delta Y_{t-i} + \\ &\sum\nolimits_{i=0}^{j} \varnothing_{23i}\Delta OR_{t-i} + \sum\nolimits_{i=0}^{j} \varnothing_{24i}\Delta NGR_{t-i} \\ &+ \sum\nolimits_{i=0}^{j} \varnothing_{25i}\Delta MR_{t-i} + \sum\nolimits_{i=0}^{j} \varnothing_{26i}\Delta FR_{t-i} + u_{1t}\end{aligned} \quad (6)$$

Equation 6 is first regressed to choose the optimum lag length by using AIC. Then, the Bound test can be applied to test the null hypothesis of no cointegration. After ensuring the presence of cointegration in equation 6, the long run can be captured by normalizing ($\varnothing_{11}$, $\varnothing_{12}$, $\varnothing_{13}$, $\varnothing_{14}$, $\varnothing_{15}$, $\varnothing_{16}$) with $\varnothing_{11}$. Later, one-year lagged variables in equation 6 can be replaced with the error correction term (ECT_{t-1}) to proceed with short-run analysis in the following way:

$$\begin{aligned}\Delta CI_t =& \varnothing_{20}ECT_{t-1} + \sum\nolimits_{i=1}^{j} \varnothing_{21i}\Delta CI_{t-i} + \sum\nolimits_{i=0}^{j} \varnothing_{22i}\Delta Y_{t-i} \\ &+ \sum\nolimits_{i=0}^{j} \varnothing_{23i}\Delta OR_{t-i} + \sum\nolimits_{i=0}^{j} \varnothing_{24i}\Delta NGR_{t-i} + \\ &\sum\nolimits_{i=0}^{j} \varnothing_{25i}\Delta MR_{t-i} + \sum\nolimits_{i=0}^{j} \varnothing_{26i}\Delta FR_{t-i} + u_{2t}\end{aligned} \quad (7)$$

Equation 7 can be first tested for short-run relationships in the model by observing the parameter of ECT_{t-1}. In the case of a negative parameter, the short-run relationship will be validated, and the rest estimated parameters can be interpreted for short-run effects.

4. DATA ANALYSIS

To proceed to cointegration analysis, the variables must be stationary. So, Ng and Perron's (2001) test is applied and reported in Table 1. All variables exhibit non-stationarity at their level forms as per the estimated statistics, which fail to reject the null hypothesis. However, this hypothesis is rejected for all series due to their differences. Thus, it indicates that these series become stationary after differencing, and the order of integration is one, which is fine to proceed with cointegration analysis.

After stationarity analysis, the Bound test is applied to the model and presented in Table 2. The estimated F-value is sufficiently high to reject the null hypothesis. Thus, the results suggest a long-run connection in the model. Furthermore, the diagnostic tests specify that the estimated statistics are sufficiently low and their p-values are more than 0.1 (10% level of significance), which indicates the model is robust without any econometric problem and is also well-specified.

As per the chosen ARDL model in equation 6, the long-run results are estimated by following the normalizing procedure, and the results are reported in Table 3. The parameter of Y_t is positive (1.5214) and statistically significant. Thus, a 1% increase in

Table 1: Unit root test

Variables	MZa	MZt	MSB	MPT
CI_t	−5.0993	−1.5046	0.2987	17.8425
Y_t	−11.3474	−2.3823	0.2126	8.3117
OR_t	−11.1615	−2.3451	0.2128	8.5352
NGR_t	−7.5320	−1.9516	0.2624	12.4103
MR_t	−14.5507	−2.7020	0.1881	6.4935
FR_t	−13.1248	−2.5698	0.1983	7.1665
ΔCI_t	−25.2644**	−3.5757	0.1433	3.7044
ΔY_t	−18.5943*	−3.0478	0.1660	5.1515
ΔOR_t	−21.2321*	−3.4892	0.1401	4.2075
ΔNGR_t	−24.9312**	−3.5500	0.1442	3.7663
ΔMR_t	−18.4100*	−3.0451	0.1675	5.1259
ΔFR_t	−23.8536*	−3.4599	0.1469	4.0108

* and **show stationarity at 5% and 1%

Table 2: Cointegration test

Dependent variable	Bound test	Diagnostic tests			
	F-value	Heteroscedasticity	Serial correlation	Normality	Functional Form
ΔCI_t	7.1524	1.3965 (0.2587)	0.2159 (0.8156)	0.3674 (0.7951)	1.9647 (0.1874)

Probability values

GDP per capita could increase CI by 1.5214%. The coefficient of OR_t is also positive (0.1658), and a 1% increase in oil rents may increase CI by 0.1658%. Similarly, the coefficient of NGR_t is positive (0.1452), and a 1% increase in natural gas rents may increase CI by 0.1452%. However, the effects of MR_t and FR_t are statistically insignificant. Thus, mineral and forest rents could not affect CI in the long run.

Based on the selected model and chosen optimal lag length, the short-run results are stated in Table 4. The ECT_{t-1} coefficient is −0.4152, which is also statistically significant. Thus, the model is adjusted to the long-run path from any short-run fluctuation with a speed of 41.52% in a year, which validates the short-run relationship among hypothesized variables. So, <2 and a half years are needed to be adjusted in the long run equilibrium.

As per the estimated coefficients, ΔCI_{t-1} has a positive (0.6151) effect on the carbon intensity of the current year. Thus, a 1% increase in CI may increase CI in the subsequent year by 0.6151%. The parameter of ΔY_t is positive (1.2541), which indicates that a 1% increase in GDP per capita may increase CI by 1.2541%. Moreover, the coefficients of ΔOR_t and ΔOR_{t-1} are positive (0.1244 and 0.0954). Thus, a 1% increase in oil rents may increase CI by 0.1244% and 0.0954% in the current and subsequent years, respectively. The coefficient of ΔNGR_t is also positive (0.1352), and a 1% increase in natural gas rents may increase CI by 0.1352%. The effects of mineral and forest rents are also found to be positive and significant. 1% increase in mineral and forest rents may increase CI by 0.0079% and 0.0587%, respectively.

Table 3: Long run estimates

Predictor	Coefficient	Standard error	t-statistic	P-value
Y_t	1.5214	0.6432	2.3652	0.0320
OR_t	0.1658	0.0365	4.5412	0.0000
NGR_t	0.1452	0.0434	3.3485	0.0000
MR_t	0.0954	0.2297	0.4154	0.6037
FR_t	−0.3541	0.2368	−1.4952	0.1342
Intercept	19.5412	8.4397	2.3154	0.0323

Table 4: Short run estimates

Predictor	Coefficient	Standard error	t-statistic	P-value
ΔCI_{t-1}	0.6151	0.1656	3.7152	0.0000
ΔY_t	1.2541	0.2686	4.6684	0.0000
ΔOR_t	0.1244	0.0533	2.3355	0.0009
ΔOR_{t-1}	0.0954	0.0261	3.6541	0.0000
ΔNGR_t	0.1352	0.0326	4.1526	0.0000
ΔMR_t	0.0079	0.0019	4.0574	0.0000
ΔFR_t	0.0587	0.0151	3.8789	0.0000
ECT_{t-1}	−0.4152	0.0594	−6.9847	0.0000

5. DISCUSSION

The results show that increasing GDP per capita is raising CI. The increasing GDP has the potential to reduce CI. However, the rate of increasing carbon emissions due to GDP growth is found more than the increasing GDP in the country in our results. Thus, carbon emissions per unit of economic output are increasing. Moreover, this result corroborates that increasing GDP has a dominant scale effect on emissions. For instance, economic growth would stimulate the industrial sector production and such consumption activities, which are increasing energy consumption and pollution. In the Saudi economy, energy usage is mostly from fossil fuels. Consequently, increasing any type of economic activity is expected to increase carbon emissions. Moreover, most GDP is contributed by the resource sector, and this result is also in line with the resource curse hypothesis by damaging the environment with the economic growth of a resource-rich Saudi economy.

The results show that oil and natural gas rents are responsible for increasing CI in Saudi Arabia. These natural resources are major contributors to the GDP and have the potential to reduce CI. However, the results validate that oil and natural gas rents contribute to emissions more than GDP. Saudi Arabia is the largest oil producer globally. The extraction of oil is heavily carbon-intensive as heavy machinery is used in the extraction of oil, which consumes a significant amount of fossil fuels in the Kingdom. Besides, converting raw oil into usable products also needs a lot of energy consumption for processing, which is carbon-intensive in nature. Thus, oil extraction and its associated industry are responsible for increasing carbon emissions and CI, respectively. Moreover, the oil sector also supports carbon-intensive petrochemical industries and the transport sector. In addition, most electricity generation is from oil, which releases massive carbon emissions due to oil combustion. Lastly, oil rents support the income of the economy, which is responsible for emissions from the consumption side of the economy. Similarly, mineral and natural gas production and their industrial usage are also responsible for increasing carbon emissions and CI. Forest rents contribute to increased CI in our short-run results. Forests are a big source of carbon sink, and deforestation for seeking forest rents could release carbon emissions, which can contribute to increasing CI.

6. CONCLUSION

Economic growth and NRR have a great potential to contribute to increasing carbon emissions and CI in the resource-rich Saudi economy. Thus, this research investigates the effects of economic growth and NRR on CI in Saudi Arabia by using a sample period of 1980-2023. Moreover, the disaggregated effects of NRR from mineral, oil, natural gas, and forest sectors are captured on CI by using the ARDL cointegration technique. Cointegration and short-run associations are validated in the hypothesized model.

In the long run, economic growth raises CI, which validates the scale effect in Saudi Arabia. It reflects that the economic growth of this economy is responsible for the growth of carbon emissions more than GDP growth, which is responsible for increasing carbon emissions per unit of economic output. Moreover, oil and natural gas rents have long-run positive effects on CI. Thus, both fossil fuel rents are responsible for environmental degradation by releasing carbon emissions more than their contribution to GDP. Oil and natural gas rents are carbon-intensive in their extraction and processing of consumable products. Furthermore, both fossil fuels are heavily utilized in electricity production and are also used extensively in the transport sector. Thus, these fuels are releasing a significant amount of carbon emissions and are increasing CI. Lastly, all NRRs have positive effects on CI in the short run. Mineral extraction and processing also need a lot of energy, which is primarily sourced from fossil fuels in the Kingdom. Moreover, deforestation to earn forest rents is responsible for releasing carbon emissions due to the destruction of forest reservoirs and carbon sinks.

The results show that economic growth is increasing CI. To reduce the environmental effect of growth, the Kingdom should diversify from NRR to cleaner sectors. So, the contribution of non-carbon growth can be enhanced. Saudi Arabia is progressively working on an economic diversification policy as per its Vision 2030, but still, this process needs to accelerate to save the environment of the economy from the natural resource sector. Oil and natural gas rents are increasing CI in the long run. To reduce this effect, clean energy should be used in the extraction and processing of these resources. Moreover, the consumption of oil and natural gas is also responsible for massive carbon emissions. So, subsidies on the use of these fuels should be removed on an urgent basis, and oil and natural gas consumption should be taxed to reduce the environmental effects associated with their consumption. The revenues from these taxes should be invested in renewable energy infrastructure. So, fossil fuel consumption could be replaced with REC in the Kingdom. An economic diversification policy should be adopted to reduce the share of NRR from the oil and natural gas sectors, which can reduce the environmental effects of these fossil fuels. Mineral and forest rents are also contributing to increasing CI. Thus, deforestation should be reduced to preserve the carbon sinks in forest areas. Moreover, mineral extraction should also be reduced to diminish its effect on CI. Additionally, the Kingdom should promote energy-efficient technologies to reduce CI at an aggregate level and should also promote REC by providing subsidies on clean energy sources. In this regard, public and private partnerships should be promoted to install renewable infrastructure. Lastly, NRR should be invested in renewable infrastructure and the transformation of the energy-efficient sector to achieve a smooth economic diversification from the oil and natural gas sectors.

7. FUNDING

The author extends his appreciation to Prince Sattam bin Abdulaziz University for funding this research work through the project number (PSAU/2024/02/28831).

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