

Article

Are Natural Resources a Curse for Green Growth in OECD Countries? The Moderating Role of Green Innovations and Environmental Regulations

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Abstract

This study empirically examines the impact of natural resource rents (NRR), a proxy for economic benefits and costs of natural resources, on green growth (GG) in Organization for Economic Co-operation and Development (OECD) countries from 1996 to 2020, while accounting for the moderating roles of green innovations and environmental regulations. Using the Common Correlated Effects Mean Group (CCEMG) and Augmented Mean Group (AMG) estimators as our baseline model, the analysis reveals a significantly negative association between natural resource rents and green growth in OECD countries, consistent with the resource curse hypothesis, which reflects heightened economic, institutional, and environmental risks associated with resource reliance. Furthermore, the results indicate that green innovations and environmental regulations not only promote green growth but also weaken the adverse association between natural resource rents and green growth, thereby suggesting their positive roles in managing resource-related risks. These findings remain robust across alternative variable definitions and model specifications. Overall, the empirical evidence highlights the importance of adopting policy measures, such as increased investment in sustainable technology research and development and providing incentives for firms to implement environmentally friendly practices, to manage resource-related risks and support the transition toward sustainable development.

Keywords: green growth; natural resource rents; green innovations; environmental regulations; OECD; CCEMG; AMG; resource-related risks



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1. Introduction

Natural resources are widely recognized as an important driver of economic development, as they generate substantial revenues that can be used to finance infrastructure, healthcare, and education, thereby improving welfare and supporting economic growth. However, natural resource extraction and utilization are also associated with a range of economic, environmental, and institutional risks. Heavy reliance on natural resources can increase vulnerability to commodity price volatility, weaken investment incentives, and

heighten exposure to external shocks. In addition, intensive resource extraction may contribute to environmental degradation, including pollution, deforestation, and the depletion of natural capital, thereby constraining long-term sustainability (Ahakwa and Tackie 2024).

These challenges have led to an ongoing debate in the literature regarding whether natural resources ultimately promote or hinder sustainable economic development. While resource endowments can generate economic benefits, their economic utilization may also create structural and governance-related distortions. Resource-dependent economies are often exposed to risks such as exchange rate volatility, reduced diversification, and rent-seeking behavior, which may undermine economic performance over time (Erdoğan et al. 2020). These mechanisms are closely linked to the resource curse hypothesis, or the “paradox of plenty,” which suggests that natural resources may hinder rather than promote development (Sachs and Warner 1995; Lashitew and Werker 2020).

In empirical research, the role of natural resources is commonly captured through natural resource rents (NRR), which are defined as the difference between the value of extracted resources and the cost of extraction (Barma et al. 2012; Chen et al. 2022). Measured as a percentage of GDP, NRR reflects the economic importance of natural resources and provides a comparable indicator across countries. Unlike purely physical measures of resource endowment, this measure captures both the availability of natural resources and the extent to which they are economically utilized, making it particularly useful for cross-country analyses of resource-related economic and environmental outcomes.

From a sustainability perspective, the implications of natural resources extend beyond economic performance to include environmental and institutional dimensions. This underscores the importance of examining how natural resources influence not only economic outcomes but also the sustainability of growth. To address the challenges associated with resource use, the concept of green growth has gained increasing attention, emphasizing the need to achieve economic development while preserving environmental quality and natural capital. While sustainable economic development encompasses economic, social, and environmental dimensions, green growth focuses more specifically on achieving economic expansion in a manner that minimizes environmental degradation. In particular, it emphasizes improving resource efficiency, reducing emissions, and promoting sustainable production and consumption patterns (OECD 2018). Within this framework, the relationship between natural resources and green growth becomes particularly important, as resource-based activities are closely linked to environmental risks and sustainability outcomes.

The extent to which natural resources promote or hinder green growth may depend on how resource-related risks are managed. In this regard, green innovations and environmental regulations play critical roles. Green innovations, through the development of environmentally friendly technologies and processes, can enhance resource efficiency and reduce environmental impacts (Rennings 2000; Dutz and Sharma 2012). Environmental regulations, including policy stringency and environmental taxation, can further support sustainable development by encouraging cleaner production and internalizing environmental costs (Cheng et al. 2017; Khan et al. 2022). These mechanisms may help mitigate the risks associated with natural resource use and influence the overall relationship between natural resources and green growth.

Although previous studies have examined the economic effects of natural resource rents (e.g., Erdoğan et al. 2020), there is a lack of empirical evidence on their impact on green growth, especially in OECD countries that are typically viewed as high-income and resource-rich economies. Moreover, the moderating roles of green innovations and environmental regulations in shaping this relationship remain underexplored, leaving a gap in understanding how resource wealth is associated with green growth outcomes and broader sustainable development objectives in advanced economies.

To address this gap, this study investigates the impact of natural resource rents on green growth in OECD countries over the period 1996–2020, while accounting for the moderating roles of green innovation and environmental regulations. To construct our sample for the study, we mainly obtain relevant country-level data (e.g., proxy for green growth) from the World Bank Open Data and OECD databases,¹ merge these datasets using consistent country and year identifiers, and exclude observations with missing values for any variables required in the regression analysis. This process yields the final sample used for empirical analysis.

Using the CCEMG and AMG estimators in our baseline model, we find a significantly negative association between green growth and natural resource rents, supporting the resource curse hypothesis in OECD countries. Our empirical evidence also indicates that green innovations and environmental regulations (proxied by the environmental stringency index and environmental taxation) not only promote green growth but also weaken the adverse association between natural resource rents and green growth. These findings remain robust across an alternative measure of green growth and various model specifications designed to address potential endogeneity and other econometric concerns.²

Our study contributes to academic literature in several important ways. First, our study speaks to ongoing debates regarding the association between natural resource rents and green growth by providing new empirical evidence in OECD countries, where existing findings remain limited and inconclusive. While prior studies (e.g., Du et al. 2020; He and Mou 2020; Liu et al. 2023) often focus on developing economies or on individual countries and small groups of advanced economies (such as G7 or EU countries), this study employs a broader OECD panel, and therefore allows for more generalizable insights across high-income economies with diverse resource endowments, institutional quality, and environmental policy frameworks. By focusing on advanced economies, the study extends the relevance of the resource curse literature beyond its traditional focus on developing countries and provides new evidence on whether resource-related risks persist in more institutionally developed contexts.

Second, the study advances extant literature by explicitly examining the joint moderating roles of green innovation and environmental regulations in shaping the association between natural resource rents and green growth. While existing studies typically consider these factors in isolation, this paper adopts an integrated framework that captures their combined effects. In doing so, it provides deeper insights into the mechanisms through which technological progress and policy interventions interact to mitigate the adverse impacts of resource dependence. The findings highlight that green innovation and environmental regulations not only promote green growth but also play a critical role in managing resource-related risks, such as vulnerability to resource dependence and long-term sustainability challenges, by weakening the negative effects of natural resource rents.

Third, from a methodological perspective, by employing a comprehensive green growth index over an extended period, this study provides a more nuanced assessment of sustainable development dynamics than analyses relying on narrow or short-term indicators. Additionally, this study also employs a comprehensive empirical strategy that combines multiple estimation techniques and robustness checks to enhance the reliability of the findings. Specifically, the use of CCEMG and AMG estimators accounts for cross-sectional dependence and heterogeneity across countries, while additional analyses using the Dumitrescu and Hurlin (2012) panel Granger causality test, system GMM, propensity score matching (PSM), instrumental variable estimation (IV regression), sensitivity analyses (including weighted least squares (WLS)), the cross-sectional autoregressive distributed lag (CS-ARDL) model, as well as an alternative measure of green growth, help address potential endogeneity and specification concerns. This multi-method approach provides a

more robust and comprehensive assessment of the association between natural resource rents and green growth in OECD economies. Given the heterogeneous nature of OECD economies and the mixed integration properties of the variables, the empirical analysis focuses on persistent dynamic associations while accounting for cross-sectional dependence, slope heterogeneity, and heterogeneous adjustment dynamics across countries. It is worth noting that the study acknowledges the possibility of feedback mechanisms among the variables and therefore interprets the empirical findings as dynamic associations rather than strictly one-directional causal relationships.

Finally, from a practical perspective, our results underscore the importance of effective environmental policies and technological innovations in reducing the risks associated with resource reliance and in transforming natural resource wealth into sustainable economic prosperity. These insights offer valuable guidance for resource-rich OECD countries seeking to avoid the resource curse and enhance resilience in the transition toward green growth.

The remainder of the paper is organized as follows: Section 2 introduces the background information of the study, reviews the extant literature, and develops the hypotheses; Section 3 describes the sample construction, research design, and variables; Section 4 presents the main empirical results; and Section 5 concludes the paper.

2. Background Information and Hypotheses Development

2.1. Background Introduction

Green growth represents a paradigm that reconciles economic expansion with environmental sustainability by promoting the efficient allocation of resources and mitigating emissions associated with their utilization, thereby fostering long-term ecological balance (Hao et al. 2021). The concept integrates the three interdependent dimensions of dynamic growth: environmental, social, and governance, emphasizing the need to sustain economic progress while preserving natural capital (Liu and Hong 2024). Within this framework, the role of natural resources becomes particularly important, as their extraction and utilization are closely linked to environmental and sustainability outcomes.

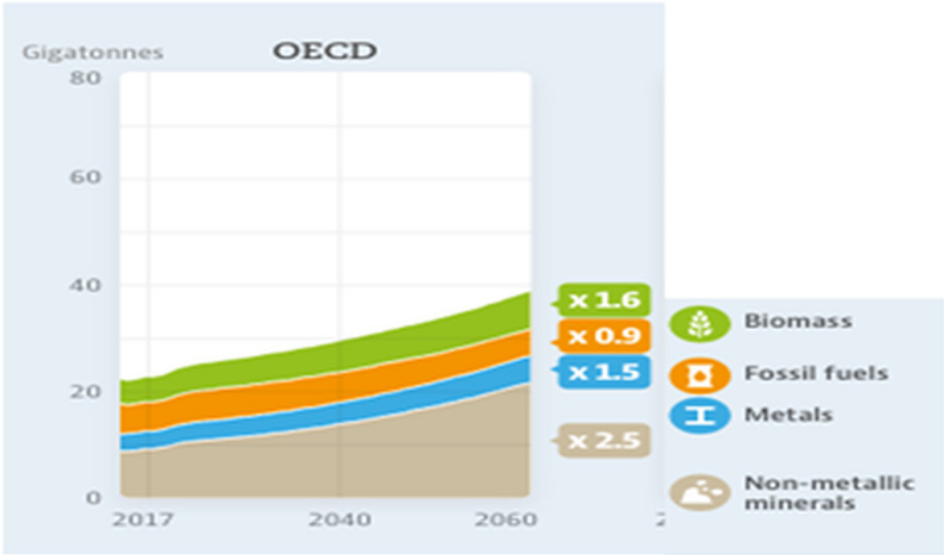
The extraction and processing of natural resources, particularly fossil fuels and minerals, pose significant economic, environmental, and sustainability-related risks, as they are estimated to account for approximately 90% of global biodiversity loss and nearly 50% of greenhouse gas (GHG) emissions (Oberle et al. 2019). These risks include heightened exposure to environmental degradation, resource depletion, and structural vulnerabilities, which can undermine long-term economic resilience and policy effectiveness. As shown in Figure 1, combustion of natural resources constitutes a primary source of GHG emissions, with biomass and fossil fuel burning exhibiting an upward trajectory across OECD countries.

At the same time, OECD countries exhibit considerable variation in both green growth performance and reliance on natural resources. As shown in Figure 2, green growth has generally improved over time, although substantial cross-country differences persist. Among the countries, Ireland achieved the highest rate of green growth, whereas Greece consistently recorded the lowest. Similarly, Figure 3 indicates that natural resource rents are unevenly distributed, with countries such as Chile and Norway exhibiting relatively high levels. These patterns suggest that the relationship between natural resources and green growth is not uniform and may depend on country-specific conditions.

Importantly, the trajectory of green growth does not follow a standardized path. It is shaped by a range of contextual factors, including institutional quality, policy frameworks, technological development, and the management of natural resource-related risks. These considerations are consistent with the broader objectives of the United Nations Sustainable Development Goals (SDGs), particularly SDG 13 (Climate Action) and SDG 7

(Affordable and Clean Energy), which emphasize both environmental sustainability and economic resilience.

Taken together, these observations highlight that natural resources may be positively or negatively associated with green growth, depending on how resource-related risks are managed and how effectively economies adopt supportive policies and technologies. This motivates the need to examine not only the direct relationship between natural resource rents and green growth, but also the roles of green innovations and environmental regulations in shaping this relationship.



Source: Global Material Resources Outlook to 2060

Figure 1. Natural Resource Extraction in OECD.

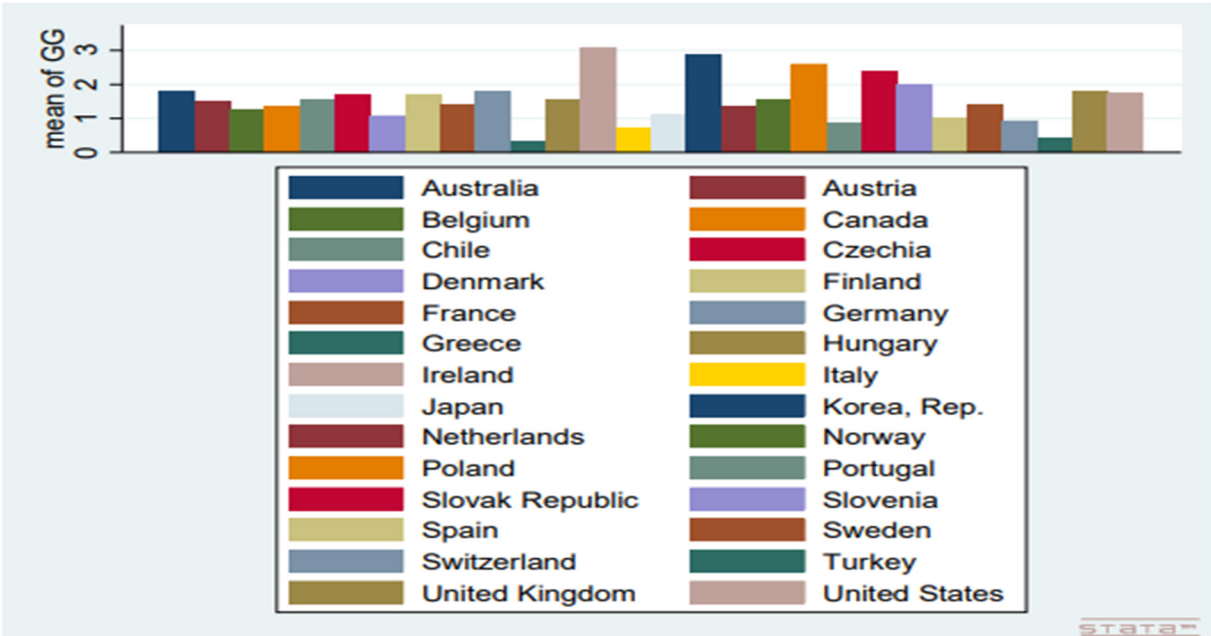


Figure 2. Average Green Growth in OECD from 1996 to 2020.

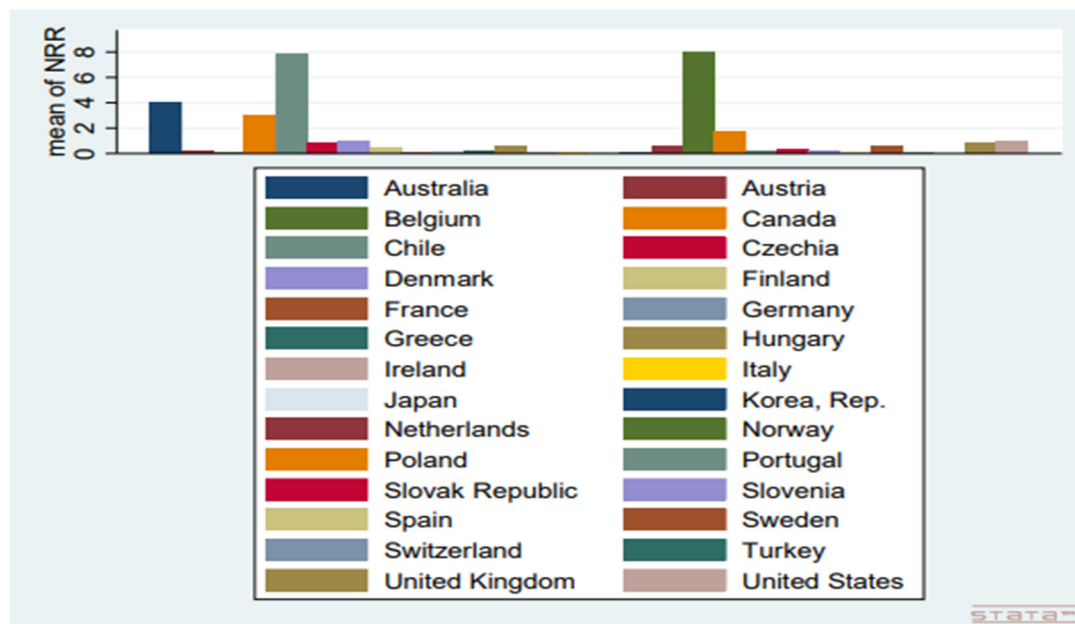


Figure 3. Average Natural Resource Rent in OECD from 1996 to 2020.

2.2. Literature Review and Hypotheses Development

2.2.1. Green Growth and Natural Resource Rent

Natural resource rents play an important role in shaping economic performance, but their implications for green growth remain debated. Prior studies identify at least three principal channels through which natural resource rents may adversely affect economic growth (Corden and Neary 1982; Van der Ploeg 2011).

The first is the rent-seeking channel, which emphasizes the role of political institutions in shaping the so-called “resource curse.” Rent-seeking behavior involves attempts to secure financial gains without corresponding productivity improvements, often through the manipulation of political or economic environments, thereby diverting resources from productive activities (Deacon and Rode 2015; Qiang and Jian 2020).

The second channel is the crowding-out mechanism, which posits a dual effect of natural resource rents on domestic economies. Rising resource rents may initially increase domestic income and stimulate investment; however, they can also trigger inflationary pressures by raising domestic prices, wages, and the real effective exchange rate. These can lead to Dutch disease, whereby resource rents crowd out other productive sectors, particularly manufacturing, and increase economic vulnerability to sector-specific shocks (Abbas et al. 2022).

The third channel is the Dutch disease hypothesis, which specifically attributes resource-driven exchange rate appreciation to a decline in competitiveness of manufacturing exports and other tradable goods. Proponents of this theory argue that long-term economic growth is predominantly driven by manufacturing exports rather than resource exports. Consequently, a resource boom that undermines manufacturing output is expected to impede overall economic performance (Van der Ploeg and Venables 2013).

These mechanisms also have important implications for green growth. By altering economic structure and incentives, natural resource rents may limit investment in environmentally sustainable sectors and increase reliance on resource-intensive activities.

Empirical evidence corroborates these theoretical channels. Du et al. (2020), in a provincial-level study of China, documented the existence of a “resource curse,” whereby resource-rich provinces exhibited lower levels of high-quality economic development relative to less resource-endowed provinces. Similarly, He and Mou (2020) found that a

booming resource sector in China exerted positive spillovers on the service industry while simultaneously exerting adverse effects on the manufacturing sector, thereby exemplifying the Dutch disease mechanism.

Comparable trends are also evident among OECD countries. Heavy reliance on natural resources frequently results in overexploitation, resource depletion, and heightened intergenerational scarcity, thus reinforcing the resource curse hypothesis (Razzaq et al. 2021). Nevertheless, some studies suggest that natural resources can constitute a blessing when accompanied by robust financial institutions. Wei et al. (2020) provided strong evidence from G7 countries that financial markets can effectively transform resource rents into drivers of financial development and economic growth, thereby mitigating the adverse effects traditionally associated with resource abundance.

Despite these insights, the extant literature is largely concentrated on developing and emerging economies. In contrast, relatively limited attention has been given to OECD countries, where stronger institutional frameworks and environmental policies may alter the nature of the relationship between resources and green growth. Therefore, it remains unclear whether the resource curse hypothesis holds in advanced economies characterized by higher levels of economic development and regulatory capacity.

Taken together, these findings suggest that the association between natural resource rents and green growth remains theoretically ambiguous and context dependent. This motivates the need to empirically examine the relationship in the context of OECD countries. Accordingly, we propose the following hypothesis:

H₁. *There is a negative association between green growth and natural resource rent in OECD countries.*

2.2.2. Green Growth and Green Innovations

Green innovations refer to the development of processes, techniques, and products that reduce environmental impacts and improve resource efficiency (Rennings 2000; Rennings et al. 2004). By integrating both technological and non-technological changes, eco-innovation contributes to environmental sustainability and supports the transition toward a green economy (Yu et al. 2023).

Green innovations play an important role in promoting green growth by enhancing resource efficiency and reducing environmental externalities associated with economic activity. In particular, environmentally friendly technologies can lower emissions, improve energy efficiency, and support more sustainable production processes (Fernandes et al. 2021; Fang 2023). These improvements are especially relevant in resource-dependent economies, where production activities are often associated with higher environmental pressures.

In this context, green innovations may also help mitigate the adverse effects of natural resource utilization. For example, green patents, representing environmentally friendly technological advancements, serve as an important indicator of technological progress and contribute to pollution reduction and sustainable economic development (Li et al. 2023). The adoption of cleaner technologies can reduce the environmental burden associated with resource extraction and promote more efficient use of natural resources (Hassan et al. 2025).

Furthermore, the effectiveness of natural resource use is closely linked to broader institutional and technological conditions. As highlighted by Kaznacheev (2013), it is not resource endowment itself but the quality of institutions and innovation capacity that determines whether resource-rich economies achieve sustainable development outcomes.

However, most existing studies focus primarily on the direct effects of green innovation, with limited attention to its interaction with natural resource dependence. Specifically, empirical evidence on whether green innovation moderates the relationship between natural resource rents and green growth remains scarce, especially in OECD countries.

These considerations suggest that green innovations are positively associated with green growth but may also weaken the negative impact of natural resource rents by improving efficiency and reducing environmental pressures. Based on this reasoning, we develop the following hypotheses.

H₂. *There is a positive association between green growth and green innovations in OECD countries.*

H₃. *Green innovations moderate the negative association between green growth and natural resource rents in OECD countries.*

2.2.3. Green Growth and Environmental Regulations

Environmental regulations play a critical role in shaping the relationship between natural resources and sustainable economic outcomes. Evidence suggests that the impact of natural resources is not uniform and may depend on the strength of institutional and policy frameworks. For instance, [Yu et al. \(2023\)](#), using a Quantile Autoregressive Distributed Lag (Q-ARDL) framework, report that the resource-curse hypothesis holds at lower and middle levels of economic activity, while a resource-blessing effect emerges at higher levels. This finding highlights that effective governance and regulatory frameworks can influence whether natural resources contribute positively to economic performance.

Environmental regulations, such as pollution taxes, subsidies, and policy stringency measures, are widely recognized as key instruments for addressing environmental externalities associated with economic activity. These policies encourage firms to adopt cleaner technologies, improve resource efficiency, and reduce emissions ([Cheng et al. 2017](#); [Khan et al. 2022](#)). Empirical evidence supports this view. For example, [Arimura et al. \(2008\)](#) finds that environmental regulations significantly improve environmental quality, while [Bhowmik et al. \(2024\)](#) show that stringent policies reduce CO₂ emissions through technological adoption. Similarly, [Khaddage-Soboh et al. \(2023\)](#) emphasize the importance of environmental taxation and regulatory frameworks in promoting sustainability.

In addition to their direct environmental effects, regulatory frameworks also influence how natural resource rents are utilized. Weak governance may lead to inefficient allocation of resource revenues, whereas strong institutional structures can channel these revenues into productive and sustainable investments. As highlighted by [Ross \(2001\)](#) and [Aytaç et al. \(2016\)](#), resource wealth can weaken governance through taxation, spending, and repression effects; however, these adverse outcomes can be mitigated through effective institutional and regulatory arrangements. Consistent with this view, [Liu et al. \(2023\)](#) show that institutional reforms can reduce the negative effects associated with resource dependence.

Environmental regulations also complement broader policy tools such as green finance, which facilitates the allocation of resource revenues toward sustainable projects. However, the effectiveness of these mechanisms depends on the strength of governance and regulatory quality ([Liang et al. 2024](#)).

Nevertheless, prior studies have not fully examined the extent to which environmental regulations moderate the relationship between natural resource rents and green growth, particularly in OECD countries. Given the relatively advanced regulatory frameworks in these economies, it is important to assess whether environmental policies can effectively offset the adverse effects of resource dependence.

Overall, these insights suggest that environmental regulations may promote green growth, as well as playing a crucial role in weakening the adverse effects of natural resource rents by improving resource allocation and reducing environmental pressures. Based on the preceding discussion, we develop the following hypotheses.

H₄. *There is a positive association between green growth and environmental regulations in OECD countries.*

H₅. *Environmental regulations moderate the association between green growth and natural resource rents in OECD countries.*

While the hypotheses are developed based on theoretically expected directions of association, the relationships among the variables may also involve dynamic interactions across countries and over time.

Figure 4 summarizes the conceptual framework used in this study.

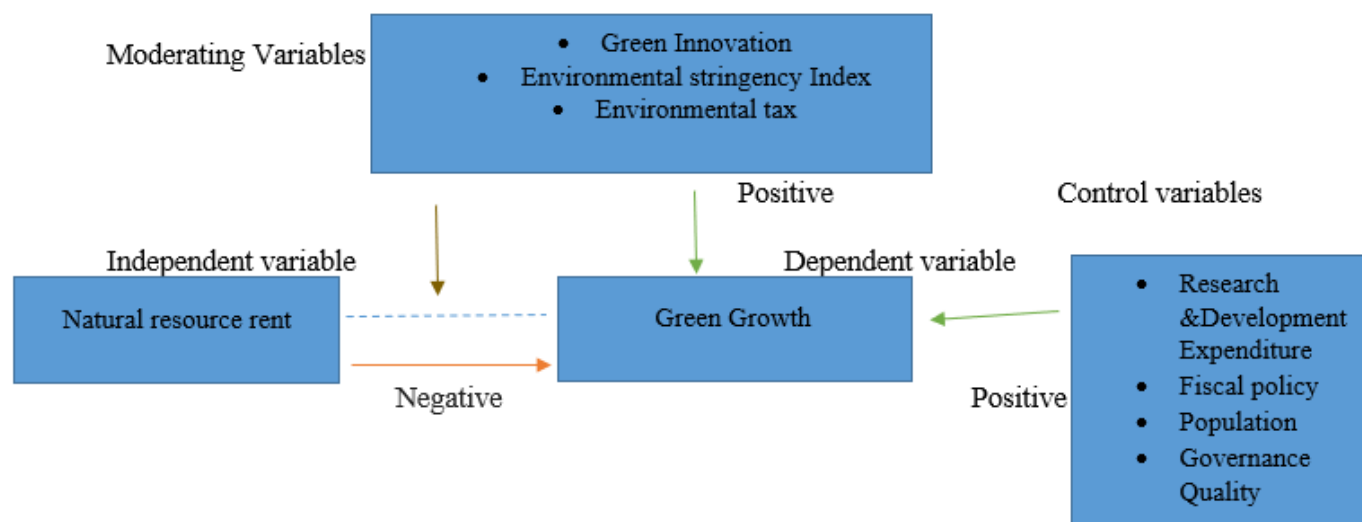


Figure 4. Conceptual Framework.

3. Sample Construction and Research Methodologies

3.1. Sample Construction

Our sample construction begins with identifying a total of 725 country-year observations from 29 OECD countries over the period 1996–2020.³ From the OECD databases, we obtain annual data on green innovations and environmental regulations. Since these databases provide information on certain environmental regulation indexes only up to 2020, our sample period ends there.

Moreover, we collect data on natural resource rents, green growth, and other country-level control variables from the World Bank Open Data. We merge these datasets using consistent country and year identifiers and exclude 220 observations with missing values for any variables required in the regression analysis. This process yields an unbalanced panel with 505 country-year observations as our final sample. Inspection of the missing data indicates that exclusions are not concentrated in specific countries or time periods. Appendices A.1 and A.2 report the distribution of observations across countries and years in the final sample. Specifically, the number of observations per country ranges from 14 to 21 in the final sample, suggesting a relatively balanced distribution across countries. Similarly, the year-wise distribution of observations remains highly stable throughout the sample period, with annual observations ranging from 19 to 21 across years.

It is worth noting that the majority of countries in our sample are classified as high-income, with only one classified as upper-middle-income, according to the World Bank's 2024 income thresholds.⁴ Out of the 29 countries, 11 are members of the G20, which is considered as the largest group of major economies globally. Please refer to Appendix B for additional information on the income level of a country in our sample.

3.2. Research Methodologies

3.2.1. Regression Model

To test the first hypothesis regarding the association between green growth and natural resource rents, we regress green growth on natural resource rents and a set of country-level control variables using the following model:

$$GG_{it} = \alpha_0 + \beta_1 NRR_{it} + \beta_2 R\&D_{it} + \beta_3 EXP_{it} + \beta_4 POP_{it} + \beta_5 GQ_{it} + \varepsilon_{it} \quad (Model\ 1)$$

The dependent variable, green growth (GG), is proxied by the World Bank's Adjusted Net Saving (ANS) indicator, which adjusts traditional national savings for investment in human capital, depletion of natural resources, and environmental degradation. As part of the robustness tests, we also obtain another proxy for green growth (RN) from the World Bank Open Data, which measures the percentage of renewable energy consumption in total energy use.⁵ The variable of interest, natural resource rents (NRR), is defined as the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents, expressed as a percentage of GDP.⁶ Control variables include R&D expenditure as a percentage of GDP (R&D), general government final consumption expenditure as a percentage of GDP (EXP), population growth as a percentage of GDP (POP), and governance quality (GQ).

We include R&D spending as a control because it promotes the invention of sustainable technologies that help reduce greenhouse gas emissions and encourage green growth (Lee and Min 2015; Petrović and Lobanov 2020; Borojo 2024; Aziz and Bakoben 2024). Similarly, higher government expenditure, particularly on environmental conservation as part of fiscal policy, improves environmental quality by reducing pollution and thereby promotes green growth (Katircioglu and Katircioglu 2018; Ozyilmaz et al. 2023; Meng 2024). In contrast, population growth tends to exert pressure on resources, increasing extraction and environmental pollution, which deteriorates green growth (Xuan et al. 2023; Aller et al. 2015; Aziz and Bakoben 2024). Finally, governance quality reflects institutional effectiveness, which provides a sound institutional framework for fostering green growth (Wang et al. 2023; Teklie and Yağmur 2024; Zhao and Xu 2024). Table 1 provides detailed variable definitions. To mitigate the influence of outliers, all continuous variables are winsorized at the 1st and 99th percentiles.

To test Hypotheses 2–5, we extend Model 1 by introducing each moderating variable separately and interacting it with the variable of interest (NRR). Specifically, we consider one proxy for green innovations (INV) and two proxies for environmental regulations (ESPI and ET). The regression models are as follows:

$$GG_{it} = \alpha_0 + \beta_1 NRR_{it} + \beta_2 INV_{it} + \beta_3 NRR_{it} * INV_{it} + \beta_4 R\&D_{it} + \beta_5 EXP_{it} + \beta_6 POP_{it} + \beta_7 GQ_{it} + \varepsilon_{it} \quad (Model\ 2)$$

$$GG_{it} = \alpha_0 + \beta_1 NRR_{it} + \beta_2 ESPI_{it} + \beta_3 NRR_{it} * ESPI_{it} + \beta_4 R\&D_{it} + \beta_5 EXP_{it} + \beta_6 POP_{it} + \beta_7 GQ_{it} + \varepsilon_{it} \quad (Model\ 3)$$

$$GG_{it} = \alpha_0 + \beta_1 NRR_{it} + \beta_2 ET_{it} + \beta_3 NRR_{it} * ET_{it} + \beta_4 R\&D_{it} + \beta_5 EXP_{it} + \beta_6 POP_{it} + \beta_7 GQ_{it} + \varepsilon_{it} \quad (Model\ 4)$$

The dependent, key independent, and control variables in Models 2–4 are the same as the ones in Model 1. The moderating variables are green innovations (INV), environmental policy stringency (ESPI), and environmental taxation (ET), where ESPI and ET serve as two different proxies for environmental regulations.

The empirical models are designed to examine persistent dynamic associations among the variables while accounting for cross-country heterogeneity and common shocks across OECD economies.

Table 1. Variable Description.

Variable Name	Definition	Acronym	Sources
Green Growth	Adjusted net saving *	GG	World Bank
Alternative measure of green growth	Percentage of renewable energy consumption in total energy use	RN	World Bank
Natural resource rents	Total natural resource rents are the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents,% GDP	NRR	World Bank
Green Innovations	Development of environment-related technologies, % all technologies	INV	OECD
Environmental Policy Stringency index	The Environmental Policy Stringency Index is based on the stringency of 13 environmental policy instruments, primarily related to climate and air pollution. This index ranges from 0 (indicating no stringency) to 6 (indicating the highest degree of stringency).	ESPI	OECD
Environmental tax	Environmentally related taxes, % GDP	ET	OECD
Expenditure on research & development	Expenditure on research & development, % GDP	R&D	World Bank
Fiscal policy	General government final consumption expenditure, % GDP	EXP	World Bank
Population growth	Annual population growth rate (%)	POP	World Bank
Governance Quality	1. Voice and Accountability 2. Political Stability and Absence of Violence/Terrorism 3. Government Effectiveness 4. Regulatory Quality 5. Rule of Law 6. Control of Corruption Combining these six governance indicators and forming a governance quality index by applying Principal component analysis (PCA)	GQ	World Bank

* GG = GNS–DPC + CEE–RND–DCD/GNI. GNS = Gross National Saving. DPC = Depreciation of produced capital. CEE = Government expenditure on education. RND = Rent from the natural resource depletion. DCD = Damages from CO₂ emissions. GNI = Gross national income (Source: Miao et al. 2023). The governance quality index (GQ) is constructed using principal component analysis (PCA) based on six World Governance Indicators. The first principal component has an eigenvalue of 5.56 and explains approximately 92% of the total variance, indicating that a single component captures the vast majority of information across the six indicators. In addition, all variables exhibit similar positive loadings (ranging from 0.39 to 0.41), suggesting a consistent contribution to the underlying governance construct. The scree plot further confirms that only the first component should be retained. Therefore, using a single composite index is appropriate and ensures a parsimonious and representative measure of governance quality.

3.2.2. Further Decomposition of the Empirical Analyses

Cross-Sectional Dependence and Slope Heterogeneity Tests

Given the strong economic ties and geographic proximity among OECD countries, it is likely that our data exhibits cross-sectional dependence (CSD). Such interconnections imply that shocks in one country may spill over to others, making it essential to account for these influences in the analysis. Addressing CSD is important for three reasons: (1) it ensures the validity of our estimates, (2) it helps identify common shocks and policy contagion across countries, and (3) it guides the choice of appropriate econometric methods (Akyuz et al. 2023). In addition, testing for slope heterogeneity is important, as the effects of independent variables on the dependent variable may vary across countries in the panel. Such heterogeneity is particularly relevant in the OECD context because countries differ substantially in institutional quality, environmental policy frameworks, resource dependence, and technological development.

Panel Unit Root and Other Relevant Tests

Panel unit root tests are conducted to examine the stochastic properties of the variables and to ensure that none of the series are integrated of order two, $I(2)$, which would undermine the use of heterogeneous dynamic panel estimators. Identifying the order of integration is important for selecting appropriate subsequent diagnostic tests, including panel cointegration tests, and for assessing whether the estimated relationships exhibit persistent dynamic co-movement rather than purely spurious association. Accordingly, the empirical analysis focuses on persistent dynamic associations and heterogeneous adjustment processes across OECD countries rather than relying on a strict homogeneous cointegration-equilibrium framework.

Dynamic Heterogeneous Panel Estimation Using CCEMG and AMG Estimators

The study applies the Common Correlated Effects Mean Group (CCEMG) estimator and the Augmented Mean Group (AMG) estimator to account for cross-sectional dependence, slope heterogeneity, and unobserved common factors across OECD countries. The CCEMG method, designed to address complex multifactor error structures, and the AMG estimator, developed by Eberhardt and Bond (2009), both estimate country-specific regressions before averaging coefficients across groups. Employing CCEMG and AMG in panel data analysis offers several advantages: (1) correcting for cross-sectional dependence and unobserved common factors, (2) allowing for heterogeneity in the modeled relationships, (3) improving the robustness and reliability of coefficient estimates, and (4) addressing heterogeneous adjustment dynamics and potential structural breaks in the data. Compared to alternative second-generation panel techniques, such as pooled common correlated effects (CCEP) or pooled estimation approaches that impose homogeneous coefficients, CCEMG and AMG allow for full heterogeneity in slope coefficients and intercepts across countries, which is particularly important in this study given the diversity of OECD economies in terms of institutional structures, environmental policies, resource dependence, and technological development. Unlike pooled approaches that impose common slope coefficients, these estimators capture country-specific dynamics while effectively controlling for unobserved common factors, thereby providing more flexible estimation frameworks for assessing persistent cross-country dynamic associations across heterogeneous economies. Although both CCEMG and AMG estimators address cross-sectional dependence and heterogeneity, they rely on different approaches for modeling unobserved common factors and heterogeneous adjustment processes. Employing both estimators therefore reduces dependence on a single estimation approach and allows assessment of whether the estimated dynamic associations remain stable across alternative heterogeneous panel frameworks.

4. Empirical Results and Discussions

4.1. Descriptive Statistics and Correlation Matrix

Table 2 reports the descriptive statistics (in Panel A) and correlation matrix (in Panel B) for the variables. As illustrated in Panel A, Green growth (GG) ranges from a minimum of -4.75 to a maximum of 6.45 , while natural resource rents (NRR) vary between 0.002 and 11.34 . Among all variables, green innovations (INV) and government expenditure (EXP) exhibit the greatest dispersion, indicating substantial cross-country heterogeneity. Both green innovations (INV) and the environmental policy stringency index (ESPI) record minimum values of zero, suggesting that in some countries these factors are either negligible or not effectively implemented. Government expenditure (EXP) displays the highest maximum value, reaching 27.05 .

Table 2. Descriptive Statistics and Correlation Matrix.

Panel A. Descriptive Statistics										
	Obs	Mean	Std. dev.	Min	P25	P50	P75	Max		
GG	505	1.32	1.92	−4.75	2.67	0.47	1.69	6.45		
RN	495	14.51	6.18	0.6	5.1	9.2	21.5	31.4		
NRR	505	1.12	2.25	0.002	0.15	0.06	0.28	11.34		
INV	505	9.56	3.98	1.76	0.63	0.28	0.85	24.64		
ESPI	505	1.88	0.98	0.05	1.11	1.70	2.70	3.91		
ET	505	2.48	0.80	0.81	2.04	2.47	2.89	5.06		
R&D	505	0.046	0.041	0	0.02	0.04	0.05	0.22		
EXP	505	18.93	3.93	10.03	17.14	19.24	21.31	27.05		
POP	505	9.80	1.18	7.59	8.97	9.40	10.87	12.61		
GQ	505	0.002	0.99	−2.75	−0.71	0.10	0.83	1.48		
Panel B. Correlation Matrix										
	GG	RN	NRR	INV	ESPI	ET	R&D	EXP	POP	GQ
GG	1.00									
RN	0.19	1.00								
NRR	−0.05	−0.03	1.00							
INV	0.22	0.18	−0.04	1.00						
ESPI	0.21	0.25	0.09	0.34	1.00					
ET	0.08	0.12	0.04	0.24	0.22	1.00				
R&D	−0.06	0.19	0.09	0.31	0.36	−0.03	1.00			
EXP	−0.40	0.10	0.18	0.36	0.06	0.17	0.10	1.00		
POP	−0.09	−0.22	−0.09	0.04	0.01	−0.04	0.09	−0.24	1.00	
GQ	0.11	0.26	0.30	−0.03	0.16	−0.14	0.14	0.16	−0.12	1.00

Note: This table reports the descriptive statistics (Panel A) and correlation matrix (Panel B) for the variables used in the analysis. GG is green growth; RN is renewable energy consumption; NRR is natural resource rent; INV is green innovations; ESPI is Environmental Policy Stringency index; ET is environmental tax; R&D is research & development expenditure; EXP is fiscal policy; POP is population growth; GQ is governance quality.

Moreover, the analysis of correlation matrix in Panel B provides some preliminary insights into the relationships among the variables and are broadly consistent with the study's hypotheses. For example, green growth (GG), as well as the alternative proxy for green growth (RN), shows positive correlations with green innovations (INV) and environmental policy stringency (ESPI), suggesting that technological development and stronger environmental policies are associated with improved environmental performance. In contrast, natural resource rents (NRR) exhibit a slightly negative correlation with both proxies for green growth, providing initial support for the resource curse hypothesis. The pairwise correlations among the explanatory variables are generally modest. The highest correlation (0.36) is observed between environmental policy stringency (ESPI) and R&D expenditure (R&D), which remains well below commonly used multicollinearity thresholds. Moderate correlations between green innovations, environmental regulation, and R&D are expected, as countries with stronger environmental policies often invest more heavily in technological innovations. Overall, the correlation matrix does not indicate serious multicollinearity concerns and supports the suitability of the variables for regression analysis.

4.2. Cross-Sectional Dependent Test, Slope Heterogeneity Test, Panel Cointegration Test, and Dynamic Heterogeneous Panel Estimation Using CCEMG and AMG Estimators

Table 3 reports the results of the Pesaran cross-dependence test (Pesaran 2004, 2015). The p -values are close to zero for all variables, strongly indicating that the data are correlated across panel groups. Stated differently, there is significant cross-sectional dependence among all variables of interest.

Table 3. Cross-sectional Dependence Test.

	GG	NRR	INV	ESPI	ET	R&D	EXP	POP	GQ
CD Test	43.01 ***	10.79 ***	17.14 ***	24.12 ***	10.12 ***	10.23 ***	27.15 ***	10.02 ***	13.07 ***

Note: This table reports the results of the Pesaran cross-sectional dependence (CD) test. The null hypothesis is cross-sectional independence. Rejection of the null indicates the presence of cross-sectional dependence among panel units. GG is green growth; NRR is natural resource rent; INV is green innovations; ESPI is Environmental Policy Stringency index; ET is environmental tax; R&D is research & development expenditure; EXP is fiscal policy; POP is population growth; GQ is governance quality. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 4 presents the results of the Pesaran and Yamagata (2008) slope heterogeneity test. The null hypothesis of homogeneity is rejected at the 10% significance level, indicating that statistically significant heterogeneity exists across the data.

Table 4. Slope Heterogeneity Test.

	Delta	p -Value
Slope Homogeneity	1.29	0.08 *
Slope Homogeneity (Adjusted)	1.76	0.05 *

Note: This table reports the results of the Pesaran and Yamagata (2008) slope heterogeneity test. The null hypothesis is slope homogeneity. Rejection of the null indicates the presence of heterogeneity across panel units. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 5 presents the results of the Pesaran (2007) CIPS unit root test. Specifically, Table 5 shows that green growth (GG), natural resource rents (NRR), R&D spending (R&D), population growth (POP), governance quality (GQ), and government expenditure (EXP) are stationary at levels, indicating that they do not require additional differencing to achieve stationarity; in contrast, green innovations (INV), the environmental policy stringency index (ESPI), and environmental taxation (ET) are non-stationary at levels but become stationary after first differencing. This mixed integration structure suggests that the empirical framework should not be interpreted as a conventional homogeneous cointegrated system driven entirely by common stochastic trends. Instead, the analysis focuses on identifying persistent dynamic associations within a heterogeneous panel framework. Importantly, none of the variables are integrated of order two, $I(2)$, thereby supporting the applicability of the adopted second-generation panel estimators.

As the unit root results from Table 5 indicate a mixture of $I(0)$ and $I(1)$ variables, we conduct the Westerlund (2007) panel cointegration test to assess whether the estimated relationships exhibit persistent dynamic co-movement rather than purely spurious association. The Westerlund test evaluates the null hypothesis of no cointegration against the alternative that stable dynamic relationships exist among the variables. The results, as reported in Table 6, show that the group-mean statistics (G_t and G_a) and panel statistics (P_t and P_a) are all statistically significant at the 1% level, leading to the rejection of the null hypothesis of no cointegration. Given the mixed integration properties of the variables, these findings are interpreted cautiously as evidence of persistent dynamic association and co-movement across panel units rather than definitive proof of a unique homogeneous cointegrating equilibrium relationship. Economically, these findings suggest that the variables

exhibit stable medium- to long-horizon dynamic interdependence across OECD countries rather than evolving independently over time. Overall, the findings support the presence of meaningful dynamic linkages among the variables within the heterogeneous OECD panel framework.

Table 5. Panel Unit Root Tests.

	I(0)	I(1)
GG	−8.62 ***	
NRR	−3.48 ***	
INV	−0.54	−3.07 ***
ESPI	8.10	−7.90 ***
ET	−0.67	−9.28 ***
R&D	−3.04 ***	
EXP	−2.83 ***	
POP	−2.78 ***	
GQ	−2.40 ***	

Note: This table reports the results of the Pesaran (2007) CIPS unit root test. The null hypothesis is the presence of a unit root. Rejection of the null indicates stationarity. I(0) and I(1) denote stationarity at levels and first differences, respectively. GG is green growth; NRR is natural resource rent; INV is green innovations; ESPI is Environmental Policy Stringency index; ET is environmental tax; R&D is research & development expenditure; EXP is fiscal policy; POP is population growth; GQ is governance quality. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 6. Westerlund (2007) Panel Cointegration Test.

	Statistics	Z-Value
Gt	−4.55 ***	−3.34 ***
Ga	−5.07 ***	−4.54 ***
Pt	−5.13 ***	−4.27 ***
Pa	−5.17 ***	−4.01 ***

Note: The table reports the results of the Westerlund (2007) panel cointegration test based on group-mean (Gt, Ga) and panel (Pt, Pa) statistics. The null hypothesis is no cointegration. Rejection of the null indicates evidence of persistent dynamic co-movement among the variables. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 7 reports the main results for the study; columns (1), (2), and (3)–(4) present results related to Models 1, 2, and 3–4, which test hypotheses 1, 2–3, and 4–5, respectively. Column (1) reveals a significantly negative association between NRR and GG ($p < 0.05$ under both CCEMG and AMG models). Quantitatively, a 1-unit increase in NRR corresponds to an approximate 0.05-unit decline in GG under the CCEMG model and a 0.06-unit decline under the AMG model. To assess economic significance, we express these effects relative to the sample mean of GG. Specifically, holding other factors constant, moving from the first to the third quartile of NRR is associated with a reduction in GG equivalent to approximately 4.9% and 5.9% of the sample mean under the CCEMG and AMG models, respectively.⁷ These findings validate hypothesis 1 and support the resource curse hypothesis in OECD countries, suggesting that greater reliance on natural resource rents is associated with heightened environmental and sustainability-related risks. These results are consistent with prior studies (Joshua et al. 2020; Li et al. 2021; Miao et al. 2023). While our findings align with extant literature that supports the resource curse hypothesis, they offer important insights for OECD economies. Unlike studies related to developing countries, where weak institutions drive adverse effects, our results show that even in advanced economies, natural resource rents can hinder green growth. This suggests that strong institutions alone may not offset environmental risks. In contrast to Wei et al. (2020), who find a resource blessing

effect, our results indicate that resource rents continue to impose ecological constraints despite economic advantages. Crucially, resource-rich OECD nations often face structural challenges such as rent-seeking, reliance on cheap labor, and resource-based exports, which can result in underutilized resources and declining rents, ultimately constraining economic prosperity. Moreover, the pursuit of short-term profits from continued resource exploration incentivizes overexploitation, despite its adverse impact on ecosystems. It is worth noting that the results remain qualitatively unchanged even when we incorporate one or more moderating variables into the regression in additional analyses (additional analyses available upon request). All control variables display coefficients with the anticipated signs.

Table 7. Dynamic Heterogeneous Panel Estimation using CCEMG and AMG estimators.

	(1)	(2)	(3)	(4)
	Model 1	Model 2	Model 3	Model 4
CCEMG				
NRR	−0.05 ** (−2.01)	−0.03 ** (−1.98)	−0.04 ** (−2.08)	−0.03 ** (−1.99)
INV		0.02 * (1.89)		
ESPI			0.02 ** (1.99)	
ET				0.01 ** (2.42)
NRR × INV		0.01 ** (2.50)		
NRR × ESPI			0.01 ** (2.31)	
NRR × ET				0.03 ** (2.47)
R&D	0.001 ** (2.51)	0.01 *** (2.74)	0.1 (1.54)	0.01 * (1.95)
EXP	1.11 * (1.68)	−1.10 (−0.81)	1.11 (1.32)	0.01 ** (2.01)
POP	−0.01 * (−1.89)	−0.02 (−1.03)	−0.11 (−1.07)	−0.01 ** (−1.98)
GQ	0.03 * (1.89)	0.01 ** (2.01)	0.04 (1.34)	0.02 (1.49)
Constant	7.25 ** (2.31)	7.01 *** (3.99)	8.1 *** (8.77)	7.4 *** (6.54)
Observations	505	505	505	505
AMG				
NRR	−0.06 ** (−2.41)	−0.031 ** (−1.99)	−0.04 ** (−2.08)	−0.03 * (−1.91)
INV		0.01 * (1.82)		
ESPI			0.02 ** (2.09)	
ET				0.01 ** (2.12)
NRR × INV		0.02 ** (2.30)		
NRR × ESPI			0.03 ** (2.41)	
NRR × ET				0.04 ** (2.29)
R&D	0.001 ** (2.01)	0.14 (0.74)	0.11 (1.54)	0.01 (0.85)
EXP	1.10 * (1.88)	−1.00 (−0.81)	1.11 (1.32)	0.01 * (1.86)
POP	−0.01 (−1.33)	−0.02 * (−1.83)	−0.11 (−1.07)	−0.01 * (−1.83)
GQ	0.001 ** (2.09)	0.01 (1.01)	0.04 (1.34)	0.001 * (1.78)
Constant	7.21 *** (3.11)	6.01 *** (3.23)	7.33 *** (9.17)	6.91 *** (5.34)
Observations	505	505	505	505

Note: This table reports the dynamic heterogeneous panel estimation results using the Common Correlated Effects Mean Group (CCEMG) and Augmented Mean Group (AMG) estimators. GG is green growth; NRR is natural resource rent; INV is green innovations; ESPI is Environmental Policy Stringency index; ET is environmental tax; R&D is research & development expenditure; EXP is fiscal policy; POP is population growth; GQ is governance quality. Values in parentheses are t-statistics. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

We next turn to the results of Model 2 to examine the association between green innovations (INV) and green growth (GG), as well as its moderating role in the association between natural resource rents (NRR) and green growth (GG). Column (2) shows significantly positive coefficients for INV itself ($p < 0.1$ under both CCEMG and AMG models) and for its interaction with NRR, $\text{NRR} \times \text{INV}$ (at $p < 0.05$ under both CCEMG and AMG models). Quantitatively, on average, a 1-unit increase in INV is associated with an approximately 0.31-unit increase in GG under the CCEMG model and a 0.32-unit increase in GG under the AMG model;⁸ while NRR itself is inversely associated with GG, the positive interaction term ($\text{NRR} \times \text{INV}$) indicates that this negative effect becomes weaker as the level of INV increases. Specifically, each 1-unit increase in INV reduces the adverse effect of NRR on GG by approximately 0.01-unit under the CCEMG model and a 0.02-unit under the AMG model, respectively. These findings indicate that INV is positively associated with GG and weakens the negative association between NRR and GG, thus validating both hypotheses 2 and 3. This moderating effect extends the literature by showing that green innovation helps reduce the negative impact of resource rents on green growth. While prior studies (e.g., Rennings 2000; Yu et al. 2023) focus on its direct environmental benefits, our results indicate that innovation also reshapes the relationship between resource rents and green growth. This implies that technological progress not only promotes green growth but also weakens the adverse association between natural resources and green growth, an aspect that has received limited attention in prior research. From a practical perspective, green innovations encompass new or modified processes, techniques, practices, systems, and products designed to prevent or minimize environmental harm (Rennings 2000; Rennings et al. 2004). Eco-innovation further facilitates economic development by integrating both technological and non-technological changes, thereby enhancing environmentally oriented economic performance (Yu et al. 2023).

Lastly, we move on to the results of Models 3 and 4 to examine the association between environmental regulations, proxied by the environmental policy stringency index (ESPI) and environmental taxes (ET), on green growth (GG), as well as its moderating role in the association between natural resource rents (NRR) and green growth (GG). Similar to column (2), columns (3) and (4) show significantly positive coefficients for both ESPI ($p < 0.05$ under both CCEMG and AMG models) and ET ($p < 0.05$ under both CCEMG and AMG models), as well as for their interactions with NRR, $\text{NRR} \times \text{ESPI}$ ($p < 0.05$ under both CCEMG and AMG models) and $\text{NRR} \times \text{ET}$ ($p < 0.05$ under both CCEMG and AMG models). Using the CCEMG model as an example, the marginal effects of ESPI and ET on GG indicate that, on average, a 1-unit increase in ESPI and ET is associated with approximately 0.031- and 0.044- unit increases in GG, respectively;⁹ while NRR alone is negatively associated with GG, the positive interaction terms ($\text{NRR} \times \text{ESPI}$ and $\text{NRR} \times \text{ET}$) indicate that this negative effect becomes weaker as the levels of ESPI and ET increase. Specifically, each 1-unit increase in ESPI and ET reduces the adverse effect of NRR on GG by approximately a 0.01-unit and 0.03-unit increase in GG, respectively. The marginal effects under the AMG model are broadly consistent with those under the CCEMG model. Overall, the empirical evidence suggests that both ESPI and ET are positively associated with GG and weaken the negative association between NRR and GG, similar to the effect observed with INV. These findings thus lend support to Hypotheses 4 and 5. This further underscores the role of policy frameworks in managing the environmental implications of resource use. While prior studies (e.g., Cheng et al. 2017; Bhowmik et al. 2024) focus on the direct environmental benefits of regulation, our results show that such policies also reshape the NRR-GG nexus. In the OECD context, where enforcement is relatively strong, environmental regulations appear to internalize the externalities of resource extraction and support greener growth outcomes. From a practical perspective, stricter environmental regulations encourage firms

to adopt cleaner technologies and practices, thereby promoting more sustainable extraction and use of natural resources, as well as reducing environmental and sustainability-related risks associated with excessive resource exploitation. These findings are consistent with prior studies highlighting the positive role of policy frameworks in promoting sustainable development and managing resource-related risks (Cheng et al. 2017; Chien et al. 2024; Doğan et al. 2022; Fernandes et al. 2021; Bhowmik et al. 2024; Caijuan et al. 2024; Okombi and Babouama 2024).

It is worth noting that there exist some variations in the magnitude and statistical significance of some control variables across models, which could potentially be attributed to several factors. First, the introduction of interaction terms changes the interpretation of coefficients, as they represent conditional rather than unconditional effects. Second, the use of heterogeneous panel estimators such as CCEMG and AMG allows slope coefficients to vary across countries, which may lead to changes in the estimated average effects when model specifications differ. Third, some moderating variables share explanatory power with control variables, leading to a potential concern of multicollinearity issue within the empirical model. For instance, green innovations are closely related to R&D expenditure, while environmental regulation measures may overlap with governance and fiscal policy variables. To ensure that the variations in the magnitude and statistical significance of some control variables are not driven by multicollinearity issues in our regression model, we conduct a variance inflation factor (VIF) test, and the results from the VIF test, reported in Appendix C, confirm that multicollinearity is within acceptable limits.¹⁰ Importantly, despite these variations, the coefficients of the key variables, natural resource rents and their interaction terms, remain consistent in sign and statistical significance. Additionally, we re-estimate all models using median-based indicator transformations of the moderating variables and obtain qualitatively identical findings (reported in Appendix D), reinforcing the robustness of our results. These variations are also consistent with the heterogeneous dynamic nature of OECD economies, where the magnitude of estimated associations may differ across specifications and adjustment processes.

Moreover, we observe relatively large constant terms across models. However, this does not indicate model misspecification but reflects the scaling and composite nature of the dependent variable, green growth (GG), measured by adjusted net savings (ANS). As a macro-level indicator combining savings, human capital investment, and environmental depletion, ANS is not centered around zero. In addition, the constant represents the value of GG when all explanatory variables equal zero, which is not economically meaningful. In CCEMG and AMG estimations, the intercept also captures unobserved country-specific effects and the average baseline level of green growth across OECD countries. Therefore, the magnitude of the constant reflects underlying structural factors rather than a problem with the model.

4.3. Additional Causality Analysis

While the baseline results, reported in Table 7, establish significant relationships among the variables, they do not provide information on the direction of causality. To address this limitation, we further examine the dynamic interactions among the variables using a panel Granger causality analysis. Specifically, we employ the Dumitrescu and Hurlin (2012) panel Granger causality test, which accounts for cross-sectional heterogeneity across OECD countries. This approach enables us to examine the direction of predictive causality and potential bidirectional relationships among natural resource rents, green growth, and other explanatory variables.

The results, reported in Table 8, provide evidence of bidirectional predictive causality between natural resource rents (NRR) and green growth (GG), indicating dynamic interde-

pendence between these variables. Similarly, green innovation (INV) exhibits bidirectional predictive causality with GG. In contrast, environmental policy stringency (ESPI) and environmental taxes (ET) display unidirectional causality toward GG, suggesting that policy variables are more strongly associated with subsequent changes in green growth rather than the reverse relationship. Overall, these findings highlight the complex and interdependent nature of the relationships among the key variables. For ease of interpretation, Figure 5 provides a visual summary of the significant causal relationships identified by the Dumitrescu and Hurlin (2012) panel Granger causality test. The figure illustrates both the direction and significance of the causal linkages among the key variables.

Table 8. Dumitrescu and Hurlin (2012) Panel Granger Causality Test.

Null Hypothesis	W-Bar	Z-Bar	Z-Bar Tilde
NRR does not Granger-cause GG	2.32	4.95 *** (0.000)	3.74 *** (0.000)
GG does not Granger-cause NRR	2.4	5.52 *** (0.000)	4.22 *** (0.000)
INV does not Granger-cause GG	2.11	4.36 *** (0.000)	3.26 *** (0.000)
GG does not Granger-cause INV	2.10	4.00 *** (0.000)	2.96 *** (0.000)
ESPI does not Granger-cause GG	2.80	6.74 *** (0.000)	5.22 *** (0.000)
GG does not Granger-cause ESPI	0.811	0.70 (0.48)	0.92 (0.35)
ET does not Granger-cause GG	2.71	6.40 *** (0.000)	4.94 *** (0.000)
GG does not Granger-cause ET	1.46	1.72 (0.19)	1.08 (0.27)
R&D does not Granger-cause GG	2.67	6.30 *** (0.000)	5.01 *** (0.000)
GG does not Granger-cause R&D	1.91	3.31 (0.18)	2.47 (0.29)
EXP does not Granger-cause GG	3.64	5.52 *** (0.000)	4.93 *** (0.000)
GG does not Granger-cause EXP	0.89	−0.37 (0.70)	−0.65 (0.51)
POP does not Granger-cause GG	2.61	4.34 *** (0.000)	5.10 *** (0.000)
GG does not Granger-cause POP	0.87	−0.33 (0.89)	−0.56 (0.53)
GQ does not Granger-cause GG	2.46	5.26 *** (0.000)	4.06 *** (0.000)
GG does not Granger-cause GQ	0.83	0.62 (0.53)	0.85 (0.39)

Note: This table reports the results of the Dumitrescu and Hurlin (2012) panel Granger causality test. The null hypothesis is no Granger causality. Rejection of the null indicates the presence of causality for at least some panel units. GG is green growth; NRR is natural resource rent; INV is green innovations; ESPI is Environmental Policy Stringency index; ET is environmental tax; R&D is research & development expenditure; EXP is fiscal policy; POP is population growth; GQ is governance quality. Values in parentheses represent *p*-values. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

These results also suggest potential simultaneity among certain variables and further support the presence of bidirectional relationships, reinforcing the need for additional robustness checks to address endogeneity and reverse causality concerns. These issues are partially addressed in our empirical framework through the use of CCEMG and AMG estimators, as well as additional robustness checks including GMM and instrumental variable estimation.

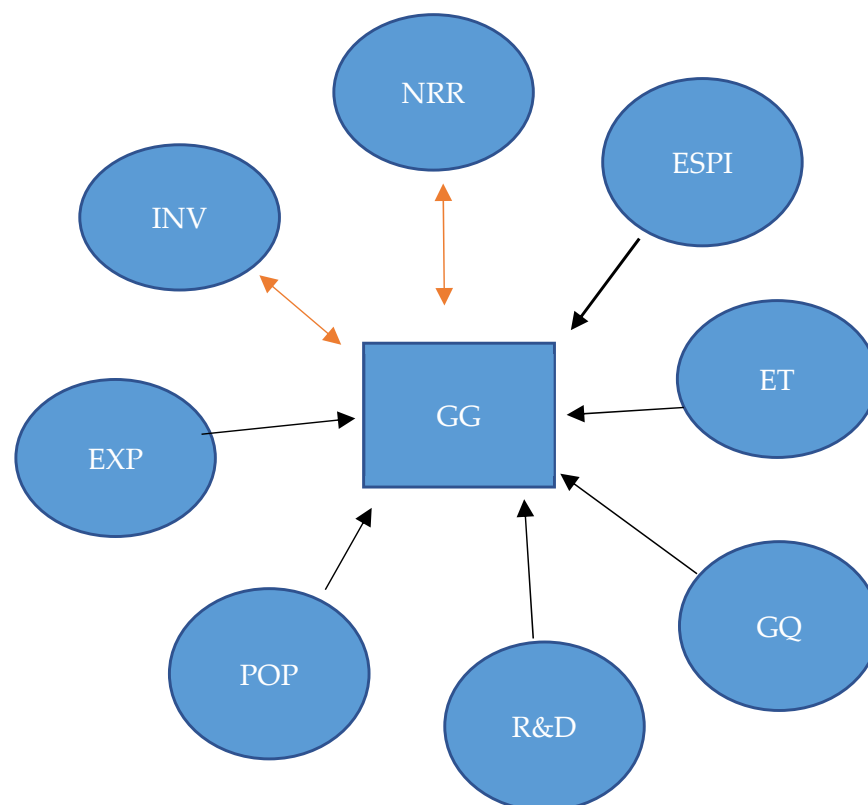


Figure 5. Visual Summary of the Dumitrescu and Hurlin (2012) Panel Granger Causality Test Results. Note: A double-headed arrow ($\leftrightarrow$) denotes statistically significant bidirectional Granger causality, whereas a single-headed arrow ($\rightarrow$) denotes statistically significant unidirectional Granger causality toward green growth (GG). All causal relationships shown in the figure are statistically significant at the 1% level.

4.4. Robustness Tests

To ensure that our main findings are not driven by potential econometric issues, we conduct a series of robustness tests.

4.4.1. Endogeneity Concerns

Although the baseline estimators account for cross-sectional dependence and heterogeneity, potential endogeneity may still arise from simultaneity, omitted variables, and measurement errors. Therefore, the following analyses employ additional approaches, including system generalized method of moments (GMM), propensity score matching (PSM), and instrumental variable (IV) estimation, to examine whether the estimated dynamic associations remain robust under alternative identification strategies.

Generalized Method of Moments (GMM)

To mitigate the endogeneity concerns, we first employ the two-step system GMM estimator, which includes the lagged value of GG in the regression models, and the results are reported in Table 9. The validity of the system GMM estimates is evaluated using several diagnostic tests. The Arellano–Bond test shows significant AR(1) but insignificant AR(2) statistics, indicating the absence of second-order serial correlation and supporting the validity of the lagged instruments. In addition, the Sargan test of overidentifying restrictions yields p -values ranging from 0.22 to 0.78, suggesting that the null hypothesis of instrument validity cannot be rejected. Although the magnitude of coefficients differs from those obtained using CCEMG and AMG estimators, this is expected because system GMM captures short-run dynamic effects through the inclusion of the lagged dependent

variable, whereas CCEMG and AMG primarily capture persistent dynamic associations across countries. Importantly, the signs and statistical significance of the key variables remain consistent across estimators, confirming the robustness of the results presented in Table 7. It is also worth noting that the coefficient on the lagged dependent variable in model 1 exceeds unity, indicating strong persistence in green growth. While this could suggest non-stationary dynamics, it may also reflect the cumulative nature of adjusted net savings and the limitations of dynamic panel estimation. With the inclusion of green innovation and environmental regulation in models 2 to 4, the coefficient declines, suggesting that these factors help explain part of the persistence in green growth rather than implying a shift from divergence to convergence.

Table 9. Two-Step System GMM Test.

	(1)	(2)	(3)	(4)
	Model 1	Model 2	Model 3	Model 4
I.GG	1.06 * (1.96)	0.60 * (1.86)	0.34 * (1.95)	0.41 ** (1.98)
NRR	−0.31 ** (−1.98)	−0.30 ** (−1.99)	−0.20 * (−1.96)	−0.29 * (−1.90)
INV		0.13 ** (1.99)		
ESPI			0.09 * (1.96)	
ET				0.04 ** (1.99)
NRR × INV		0.03 * (1.91)		
NRR × ESPI			0.02 ** (2.75)	
NRR × ET				0.05 *** (2.69)
R&D	0.13 (1.17)	0.04 ** (2.10)	−11.12 (−0.81)	0.08 * (1.96)
EXP	0.31 (1.03)	−0.86 (−0.13)	−0.75 (−0.03)	0.06 * (1.96)
POP	−0.01 (−1.06)	−0.01 ** (−2.21)	−0.22 (−1.03)	−0.01 ** (−1.99)
GQ	0.07 * (1.91)	0.05 ** (2.01)	0.09 (1.21)	0.04 ** (2.22)
AR(1)	0.02	0.01	0.01	0.03
AR(2)	0.51	0.17	0.14	0.12
Sargan test	0.22	0.32	0.78	0.26
Observations	364	364	362	356

Note: This table reports the results of the two-step system GMM estimation. The numbers in parentheses are t-statistics. AR(1) and AR(2) refer to first- and second-order serial correlation tests. The Sargan test evaluates the validity of instruments; failure to reject the null indicates valid instruments. GG is green growth; NRR is natural resource rent; INV is green innovations; ESPI is Environmental Policy Stringency index; ET is environmental tax; R&D is research & development expenditure; EXP is fiscal policy; POP is population growth; GQ is governance quality. The numbers in parentheses are t-statistics. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Propensity Score Matching (PSM)

Although Propensity Score Matching (PSM) is more commonly used in micro-level studies, it can also be applied in macro-level analyses to improve comparability across countries. In this study, we also apply the Propensity Score Matching (PSM) method as a robustness check to reduce selection bias by matching countries with similar observable characteristics. Specifically, we first divide countries into a control group (with values below the median) and a treatment group (with values above the median) for NRR, INV, ESPI, and ET for models 1 to 4, respectively. While this approach simplifies continuous variables, it provides a practical way to distinguish between relatively high and low levels and ensures sufficient observations in each group. Next, we estimate propensity scores using a logit regression, where the dependent variable is a dummy equal to 1 if the value exceeds the

median and 0 otherwise for NRR, INV, ESPI, and ET, and all control variables are included as independent variables. We employ replacement matching, allowing a control country to be matched with more than one treatment country. Finally, we conduct a post-matching regression, ensuring that the difference in scores between treatment and matched control groups does not exceed a 5% significance level. After the matching process, we re-estimate the empirical analyses, with the results reported in columns (1)–(4) of Table 10. As shown, the results are consistent with those in Table 7. Specifically, NRR alone is negatively associated with GG, while INV, ESPI, and ET individually exhibit positive associations with GG. Moreover, the presence of INV, ESPI, or ET mitigates the adverse effect of NRR on GG. Overall, the application of PSM helps address endogeneity concerns by reducing observable selection bias, although it does not eliminate bias from unobserved factors.

Table 10. Propensity Score Matching (PSM).

	(1)	(2)	(3)	(4)
	Model 1	Model 2	Model 3	Model 4
NRR	−0.11 ** (−2.11)	−0.12 ** (−2.07)	−0.11 ** (−2.01)	−0.12 ** (−2.01)
INV		0.06 * (1.69)		
ESPI			0.05 ** (2.00)	
ET				0.08 ** (1.98)
NRR × INV		0.15 ** (1.98)		
NRR × ESPI			0.07 ** (2.03)	
NRR × ET				0.06 ** (1.99)
R&D	0.01 * (1.87)	1.31 (0.27)	1.31 (0.27)	1.31 (0.27)
EXP	−0.26 (−1.34)	−0.26 (−1.34)	−0.26 (−1.34)	−0.26 (−1.34)
POP	−0.03 * (−1.69)	−0.09 (−1.59)	−0.09 ** (−1.99)	−0.09 * (−1.87)
GQ	0.01 ** (2.15)	0.02 (1.35)	0.02 * (1.95)	0.02 (1.45)
Constant	7.34 ** (2.29)	6.24 ** (2.09)	5.54 ** (2.31)	6.34 ** (2.09)
Adjusted R ²	0.31	0.34	0.29	0.33
Observations	264	260	251	261

Note: This table reports the results of the propensity score matching (PSM) estimation. Treatment and control groups are defined based on median values of key variables. GG is green growth; NRR is natural resource rent; INV is green innovations; ESPI is Environmental Policy Stringency index; ET is environmental tax; R&D is research & development expenditure; EXP is fiscal policy; POP is population growth; GQ is governance quality. The numbers in parentheses are t-statistics. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Instrumental Variable Approach (IV Regression)

To further address potential endogeneity concerns, we employ an instrumental variable (IV) approach using land area (measured in acres), obtained from the World Bank database, as an instrument for natural resource rents. Larger land endowments are typically associated with greater availability of natural resources, thereby influencing resource rents. Meanwhile, land area is largely determined by geographical factors and is plausibly exogenous to economic and policy conditions related to green growth. Crucially, it is unlikely to be systematically correlated with the error term in the green growth equation, as it is not directly linked to unobserved determinants of green growth. Therefore, conditional on relevant controls, land area is expected to affect green growth primarily through its impact on natural resource rents, satisfying the relevance and exclusion restrictions required for a valid instrument. In the first-stage regression, we regress natural resource rents (NRR)

on land area and the full set of controls to obtain the fitted values of NRR. In the second stage, we replace NRR with its fitted values (Instrumented NRR) and re-estimate all models. Table 11 presents the second-stage results of the IV estimation. As shown in the table, the coefficients on the key variables, including instrumented natural resource rents, green innovation (INV), environmental policy stringency (ESPI), environmental taxation (ET), and the corresponding interaction terms, remain consistent in both sign and statistical significance with those reported in Table 7, further validating the robustness of our main findings.

Table 11. Instrumental Variable Approach (IV Regression).

	(1)	(2)	(3)	(4)
	Model 1	Model 2	Model 3	Model 4
Instrumented NRR	−0.065 * (−1.91)	−0.053 * (−1.88)	−0.066 * (−1.78)	−0.047 * (−1.77)
INV		0.053 * (1.68)		
ESPI			0.032 * (1.86)	
ET				0.015 * (1.72)
NRR × INV		0.022 * (1.70)		
NRR × ESPI			0.002 * (1.71)	
NRR × ET				0.021 ** (1.97)
R&D	0.01 * (1.71)	0.02 * (1.74)	0.01 (1.34)	0.01 (1.25)
EXP	0.11 * (1.68)	0.10 (1.31)	0.11 (1.22)	0.10 * (1.71)
POP	−0.01 * (−1.77)	−0.02 * (−1.63)	−0.01 (−1.55)	−0.01 (−1.43)
GQ	0.031 ** (1.99)	0.020 * (1.81)	0.01 (1.24)	0.02 (1.27)
Constant	6.95 * (1.91)	7.12 * (1.79)	7.21 *** (3.14)	7.21 ** (2.54)
Observations	505	505	505	505

Note: This table reports the results of the instrumental variable (IV) estimation. GG is green growth; Instrumented NRR represents the predicted values of natural resource rents obtained from the first-stage regression, using land area (including inland water bodies and coastal areas) as an instrument; INV is green innovations; ESPI is Environmental Policy Stringency index; ET is environmental tax; R&D is research & development expenditure; EXP is fiscal policy; POP is population growth; GQ is governance quality. The numbers in parentheses are t-statistics. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

4.4.2. Alternative Measure of Green Growth

As previously discussed, our main findings may be driven by a potential mechanical correlation between adjusted net savings (ANS) and natural resource rents (NRR). To address this concern, we conduct an additional analysis using an alternative proxy for green growth, namely the percentage of renewable energy consumption in total energy use (RN), obtained from the World Bank database.¹¹ This adjustment reduces our sample to 495 country-year observations. The results, reported in Table 12, indicate that the coefficients on the key variables, including natural resource rents, three proxies of moderating variables (INV, ESPI, and ET), and their interaction terms, remain consistent in both sign and statistical significance, thereby reinforcing the robustness of our findings. It is worth noting that the larger coefficient magnitudes observed under the renewable energy proxy likely reflect the more direct environmental orientation of renewable energy consumption relative to the broader sustainability-oriented nature of adjusted net savings.

Table 12. Alternative Measure of Green Growth (RN).

	(1)	(2)	(3)	(4)
	Model 1	Model 2	Model 3	Model 4
CCEMG				
NRR	−0.51 *** (−2.89)	−0.57 *** (−2.77)	−0.61 *** (−2.88)	−0.57 *** (−2.81)
INV		0.25 ** (2.18)		
ESPI			0.02 * (1.67)	
ET				0.02 * (1.82)
NRR × INV		0.09 * (1.78)		
NRR × ESPI			0.13 ** (2.13)	
NRR × ET				0.11 ** (2.36)
R&D	0.001 * (1.67)	0.001 * (1.87)	0.002 * (1.77)	0.001 * (1.87)
EXP	0.01 ** (2.35)	0.01 ** (2.31)	0.02 * (1.91)	0.01 ** (2.21)
POP	−1.02 * (−1.89)	−1.01 ** (−2.42)	−1.02 * (−1.89)	−1.01 ** (−2.21)
GQ	0.02 * (1.91)	0.01 ** (1.99)	0.01 ** (2.01)	0.02 * (1.88)
Constant	13.32 *** (2.97)	14.01 *** (3.01)	11.62 *** (3.79)	11.29 *** (4.71)
Observations	495	495	495	495
AMG				
NRR	−0.52 *** (−3.21)	−0.50 *** (−4.66)	−0.55 *** (−3.23)	−0.61 *** (−3.63)
INV		0.25 ** (2.18)		
ESPI			0.02 * (1.67)	
ET				0.02 * (1.82)
NRR × INV		0.07 * (1.88)		
NRR × ESPI			0.11 ** (2.43)	
NRR × ET				0.21 *** (2.96)
R&D	0.001 * (1.88)	0.001 * (1.87)	0.002 * (1.81)	0.001 * (1.77)
EXP	0.02 * (1.93)	0.01 * (1.81)	0.02 * (1.91)	0.01 ** (2.21)
POP	−1.02 * (−1.89)	−1.01 * (−2.02)	−1.02 * (−1.89)	−1.01 * (−1.92)
GQ	0.01 * (1.81)	0.01 * (1.89)	0.01 * (1.91)	0.02 * (1.79)
Constant	11.88 *** (2.77)	12.66 *** (5.22)	11.81 *** (4.99)	12.01 *** (3.88)
Observations	495	495	495	495

Note: This table reports the results using an alternative measure of green growth (RN), defined as renewable energy consumption, as the dependent variable. NRR is natural resource rent; INV is green innovations; ESPI is Environmental Policy Stringency index; ET is environmental tax; R&D is research & development expenditure; EXP is fiscal policy; POP is population growth; GQ is governance quality. The numbers in parentheses are t-statistics. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

4.4.3. Sensitivity Analyses and Weighted Least Square (WLS)

Because natural resource rents exhibit substantial dispersion across OECD countries, we conduct additional sensitivity analyses to assess whether the results are disproportionately driven by extreme observations or leverage points. Specifically, as shown in Figure 3, several countries (e.g., Chile, Norway, Australia, and Canada) exhibit substantially higher levels of natural resource rents compared to the rest of the sample. To ensure that our main results are not driven by these high-NRR countries, we conduct a sensitivity analysis by excluding observations from those countries. The results, reported in Appendix E.1, remain

qualitatively unchanged. Similarly, we also conduct another sensitivity analysis by excluding observations from low-NRR countries (e.g., Belgium, France, Germany, Italy) and find identical results (reported in Appendix E.2) to our main findings from Table 7.¹² To further examine cross-country heterogeneity, we divide the sample into two subgroups based on the median value of natural resource rents (NRR), distinguishing between resource-rich and resource-poor countries. The results, reported in Appendix E.3, indicate that the estimated relationships remain quantitatively similar across the two subsamples, suggesting that these mechanisms operate in a broadly consistent manner across both resource-rich and resource-poor countries. Furthermore, to verify that our findings are not disproportionately influenced by countries with larger numbers of observations, we re-estimate all models using weighted least squares (WLS), where weights are based on the number of observations per country. The results, reported in Appendix E.4, again remain robust and qualitatively identical. Collectively, these analyses reduce concerns that the estimated associations are driven primarily by extreme observations or leverage effects within the sample.

4.4.4. Cross-Sectional Autoregressive Distributed Lag (CS-ARDL) Model

To further assess the robustness of our findings, we employ the Cross-Sectional Autoregressive Distributed Lag (CS-ARDL) model, which accounts for cross-sectional dependence and heterogeneous adjustment dynamics across countries. The results, reported in Table 13, are qualitatively consistent with the baseline CCEMG and AMG estimations, with NRR remaining negatively significant and INV, ESPI, ET, as well as their interaction terms, remaining positively significant. Moreover, the error correction term (ECT) is negative and statistically significant across all specifications, suggesting stable dynamic adjustments following short-run deviations. Taken together with the significant Westerlund (2007) cointegration results, these findings provide supporting evidence of persistent dynamic co-movement among the variables. Given the mixed integration properties of the variables, however, the results are interpreted cautiously as evidence of persistent dynamic association rather than definitive proof of a strict homogeneous cointegration-equilibrium relationship.

Table 13. CS-ARDL Dynamic Robustness Analysis.

	(1)	(2)	(3)	(4)
	Model 1	Model 2	Model 3	Model 4
Long-run Estimates				
NRR	−0.06 ** (−2.47)	−0.07 * (−1.78)	−0.07 ** (−2.19)	−0.08 * (−1.86)
INV		0.03 * (1.94)		
ESPI			0.04 ** (2.04)	
ET				0.04 * (1.93)
NRR × INV		0.01 * (1.88)		
NRR × ESPI			0.02 ** (2.33)	
NRR × ET				0.01 * (1.86)
R&D	1.01 * (1.65)	1.09 * (1.78)	0.08 * (1.81)	0.009 * (1.69)
EXP	0.01 * (1.81)	0.03 (1.13)	0.01 * (1.90)	0.08 (1.19)
POP	−0.02 ** (−2.45)	−0.01 * (−1.81)	−0.02 * (−1.79)	−0.004 (−1.17)
GQ	0.002 * (1.88)	0.01 (1.09)	0.01 * (1.91)	0.01 * (1.70)

Table 13. Cont.

Short-run Estimates				
D.NRR	−0.10 * (−1.81)	−0.11 * (−1.78)	−0.10 * (−1.68)	−0.11 * (−1.72)
D.INV		0.01 * (1.73)		
D.ESPI			0.06 (1.54)	
D.ET				0.05 * (1.88)
D.NRR × INV		0.06 * (1.67)		
D.NRR × ESPI			0.01 (1.49)	
D.NRR × ET				0.04 * (1.77)
D.R&D	0.01 (1.22)	1.03 * (1.83)	1.03 * (1.71)	1.01 (1.00)
D.EXP	1.09 (1.33)	1.13 (1.11)	1.13 (0.11)	1.23 (1.05)
D.POP	−0.05 * (−1.91)	−0.04 (−0.15)	−0.01 * (−1.65)	−1.09 (−0.98)
D.GQ	0.10 (1.00)	0.03 (0.06)	0.08 (1.00)	0.03 (0.97)
ECT	−0.09 ** (−1.98)	−0.08 ** (−2.31)	−0.09 ** (−2.43)	−0.08 ** (−2.25)

Note: This table reports the results of the Cross-Sectional Autoregressive Distributed Lag (CS-ARDL) estimation. The upper panel presents the estimated medium- to long-horizon dynamic associations, while the lower panel reports short-run dynamic estimates. ECT denotes the error-correction term. A negative and statistically significant ECT suggests stable dynamic adjustments following short-run deviations. GG is green growth; NRR is natural resource rent; INV is green innovations; ESPI is Environmental Policy Stringency index; ET is environmental tax; R&D is research & development expenditure; EXP is fiscal policy; POP is population growth; GQ is governance quality. Values in parentheses are t-statistics. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

4.4.5. Structural Break and Nonlinearity Considerations

Given that macroeconomic relationships may be subject to structural changes and nonlinear dynamics, we further assess the robustness of our results by accounting for these potential issues. To capture structural shifts, we re-estimate all the empirical analyses by introducing a dummy variable (Post 2015) representing the post-2015 period associated with the Paris Agreement, a major global environmental policy change, and interacting this dummy with the key variables in Models 1–4. A structural break may be suggested if the Post 2015 dummy variable and its interaction terms are statistically significant, indicating that the estimated relationships differ between the pre- and post-2015 periods. The results, reported in Appendix F, do not provide evidence of material structural changes in the estimated relationships. Specifically, NRR remains negatively associated with green growth, while INV, ESPI, ET, and their corresponding interaction terms remain positively associated with green growth under both CCEMG and AMG estimators. More importantly, the majority of the coefficients on the Post 2015 dummy variable and its interaction terms are statistically insignificant, suggesting that the estimated relationships do not differ materially between the pre- and post-2015 periods. Overall, the evidence reported in Appendix F suggests that the main findings are robust to potential structural changes associated with the Paris Agreement and that structural breaks do not materially affect the estimated relationships.

Regarding nonlinearity, while the relationship between natural resource rents and green growth may exhibit nonlinear dynamics, the focus of this study is on average dynamic associations within a linear framework. The use of second-generation panel estimators such as CCEMG and AMG allows for cross-country heterogeneity, which partially mitigates this concern. Overall, the stability of the results across specifications supports the validity of the linear modeling approach adopted in this study. Nevertheless, exploring potential

nonlinearities and threshold effects, particularly regarding environmental regulation and resource dependence, remains an important avenue for future research.

4.4.6. Robustness Analysis Using Driscoll–Kraay Robust Standard Errors

To further ensure that our findings are not sensitive to the estimation of standard errors, we re-estimate the baseline models using Driscoll–Kraay robust standard errors, which are robust to heteroskedasticity, serial correlation, and cross-sectional dependence in panel data. Compared with conventional covariance estimators, the Driscoll–Kraay approach provides more reliable statistical inference when residuals exhibit cross-sectional dependence, a common feature of macroeconomic panel datasets (Driscoll and Kraay 1998; Hoechle 2007). The results, reported in Appendix G, remain qualitatively consistent with the baseline findings, with the key variables preserving their signs and statistical significance. These findings provide additional support for the robustness of the empirical results.

To sum up, although the magnitude of several coefficients varies across robustness specifications, the overall direction and statistical significance of the key variables remain broadly consistent. These differences in coefficient magnitude are expected because the alternative estimators capture different dimensions of the underlying relationships. For example, the system GMM estimator incorporates lagged dependent variables and therefore reflects short-run dynamic adjustments, whereas CCEMG and AMG estimators primarily capture heterogeneous cross-country dynamic associations while accounting for unobserved common factors. Similarly, the instrumental variable approach partially addresses endogeneity concerns, while propensity score matching improves comparability across countries with similar observable characteristics. In addition, the alternative proxy for green growth captures a different dimension of environmentally sustainable economic performance. Accordingly, variations in coefficient magnitude across specifications reflect differences in model structure, adjustment dynamics, and measurement approaches rather than instability in the core empirical relationships. Importantly, the consistency in the signs and statistical significance of the key variables across estimation techniques strengthens confidence in the robustness of the main findings.

5. Conclusions

Using CCEMG and AMG estimators, this study investigates the association between green growth (GG) and natural resource rents (NRR) in OECD countries from 1996 to 2020, considering the moderating roles of green innovations (INV) and environmental regulations (ESPI and ET). The findings reveal a negative association between natural resource rents (NRR) and green growth (GG), supporting the resource curse hypothesis, as well as highlighting the economic, institutional, and environmental risks associated with resource dependence. Additionally, the empirical evidence suggests that green innovations (INV) and environmental regulations (ESPI and ET) not only promote green growth (GG) but also weaken the adverse association between natural resource rents (NRR) and green growth (GG), thereby suggesting their positive roles in managing the resource-related risks. The main findings remain robust across alternative variable definitions and model specifications.

From a policy perspective, the findings suggest that governments should adopt targeted policy instruments to mitigate resource-related risks and promote green growth. Specifically, policies that support green innovation, such as R&D subsidies, tax incentives for clean technologies, and support for green patents, can enhance the capacity of firms to adopt environmentally sustainable practices. In addition, environmental regulations, including carbon pricing mechanisms, environmental taxes, and stricter policy stringency measures, can help internalize environmental externalities and reduce the ad-

verse sustainability-related risks associated with resource dependence. Together, these policy tools can facilitate the transition toward more sustainable economic systems in resource-rich OECD countries. Importantly, the effectiveness of these policies may vary across countries. Resource-intensive economies require stronger regulation and greater investment in green innovation to offset environmental damage, whereas less resource-dependent countries may benefit more from preventive strategies that promote sustainable practices and early technological adoption. Overall, the interaction between economic, technological, and environmental factors highlights the need for integrated policy approaches that combine innovation support with regulatory measures.

Despite its contributions, this study is subject to several limitations that also help delineate the scope and contribution of the analysis. First, as the study relies on aggregate country-level data, it may overlook within-country heterogeneity and sector-specific dynamics. However, this aggregation enables a consistent cross-country comparison across OECD economies, which is essential for identifying generalizable patterns in the relationship between natural resource rents and green growth. Second, although advanced econometric techniques such as CCEMG and AMG are employed, potential endogeneity concerns may still persist. Nevertheless, the use of multiple robustness checks strengthens the credibility of the findings and supports the validity of the identified relationships. In addition, because the variables exhibit mixed integration properties, the findings should be interpreted as evidence of persistent heterogeneous dynamic associations rather than as a strict homogeneous cointegration-equilibrium relationship. Third, the proxy for green growth, the Adjusted Net Saving (ANS) indicator, may not fully capture the multidimensional nature of green growth. To address this concern, the study incorporates an alternative proxy based on renewable energy consumption, which yields consistent results and reinforces the robustness of the conclusions. In addition, the proxy for green innovation primarily captures the intensity of environmental technologies rather than their quality or effectiveness. Alternative innovation measures, such as patent citations or innovation efficiency indicators, may provide additional insights and could be explored in future studies. Fourth, although this study accounts for potential structural changes using policy-based dummy variables, formal structural break tests are not explicitly implemented. In addition, the analysis is conducted within a linear framework, which may not fully capture potential nonlinear dynamics. Future research may employ formal structural break tests and nonlinear panel models to further explore these aspects. Although the study incorporates dynamic panel techniques and Granger causality analysis, additional lag structures and alternative dynamic specifications may provide further insights into the temporal interactions among the variables. Fifth, the focus on OECD countries limits the generalizability of the findings to developing economies. However, this focus represents a key contribution of the study, as it provides new insights into the NRR-GG nexus within advanced economies characterized by stronger institutional frameworks and environmental policies. Finally, while this study focuses on natural resource rents as a measure of the economic utilization of natural resources, alternative operationalizations, such as export-based resource dependence, may capture different dimensions of resource reliance. Future research may further explore these alternative measures.

Future research could extend this analysis to non-OECD countries, incorporate governance indicators as moderators, and employ other alternative measures of green growth to provide a more comprehensive understanding of the NRR-GG nexus, including the economic, environmental, and institutional risks associated with resource dependence.

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Appendix A

Appendix A.1. Sample Distribution by Countries

Country	Freq.	Percent	Cum.
Australia	17	3.37	3.37
Austria	14	2.77	6.14
Belgium	16	3.17	9.31
Canada	18	3.56	12.87
Chile	19	3.76	16.63
Czechia	17	3.37	20
Denmark	14	2.77	22.77
Finland	18	3.56	26.34
France	21	4.16	30.5
Germany	18	3.56	34.06
Greece	17	3.37	37.43
Hungary	14	2.77	40.2
Ireland	16	3.17	43.37
Italy	20	3.96	47.33
Japan	18	3.56	50.89
Korea, Rep.	17	3.37	54.26
Netherlands	19	3.76	58.02
New Zealand	16	3.17	61.19
Norway	20	3.96	65.15
Poland	20	3.96	69.11
Portugal	18	3.56	72.67
Slovak Republic	18	3.56	76.24
Slovenia	18	3.56	79.8
Spain	18	3.56	83.37
Sweden	15	2.97	86.34
Switzerland	19	3.76	90.1
Turkey	14	2.77	92.87
United Kingdom	18	3.56	96.44
United States	18	3.56	100
Total	505	100	

Appendix A.2. Sample Distribution by Years

Year	Frequency	Percent	Cumulative Percent
1996	21	4.16	4.16
1997	20	3.96	8.12
1998	19	3.76	11.88
1999	21	4.16	16.04
2000	20	3.96	20.00
2001	19	3.76	23.76
2002	21	4.16	27.92
2003	20	3.96	31.88
2004	20	3.96	35.84
2005	21	4.16	40.00
2006	20	3.96	43.96
2007	21	4.16	48.12
2008	20	3.96	52.08
2009	20	3.96	56.04
2010	21	4.16	60.20
2011	21	4.16	64.36
2012	19	3.76	68.12
2013	20	3.96	72.08
2014	20	3.96	76.04
2015	20	3.96	80.00
2016	19	3.76	83.76
2017	21	4.16	87.92
2018	20	3.96	91.88
2019	20	3.96	95.84
2020	21	4.16	100.00
Total	505	100.00	

Appendix B. Income-Level of Countries in Our Sample

No.	Country	Region	Income Level	G20
1	Australia	Asia-Pacific	High-income	Yes
2	Austria	Western Europe	High-income	
3	Belgium	Western Europe	High-income	
4	Canada	North America	High-income	Yes
5	Chile	Latin America	High-income	
6	Czech Republic (Czechia)	Central/Eastern Europe	High-income	
7	Denmark	Nordic	High-income	
8	Finland	Nordic	High-income	
9	France	Western Europe	High-income	Yes
10	Germany	Western Europe	High-income	Yes
11	Greece	Southern Europe	High-income	

No.	Country	Region	Income Level	G20
12	Hungary	Central/Eastern Europe	High-income	
13	Ireland	Western Europe	High-income	
14	Italy	Southern Europe	High-income	Yes
15	Japan	Asia-Pacific	High-income	Yes
16	South Korea (Republic of Korea)	Asia-Pacific	High-income	Yes
17	Netherlands	Western Europe	High-income	
18	New Zealand	Asia-Pacific	High-income	
19	Norway	Nordic	High-income	
20	Poland	Central/Eastern Europe	High-income	
21	Portugal	Southern Europe	High-income	
22	Slovak Republic	Central/Eastern Europe	High-income	
23	Slovenia	Central/Eastern Europe	High-income	
24	Spain	Southern Europe	High-income	
25	Sweden	Nordic	High-income	
26	Switzerland	Western Europe	High-income	
27	Türkiye	Eurasia	Upper-middle income	Yes
28	United Kingdom	Western Europe	High-income	Yes
29	United States	North America	High-income	Yes

Appendix C. Variance Inflation Factor (VIF) Test

	VIF			
	Model 1	Model 2	Model 3	Model 4
NRR	1.12	5.25	5.56	5.87
INV		1.53		
ESPI			1.46	
ET				1.97
NRR × INV		6.56		
NRR × ESPI			6.59	
NRR × ET				7.06
R&D	1.31	1.34	1.46	1.36
EXP	1.35	1.56	1.45	1.65
POP	1.12	1.13	1.15	1.42
GQ	1.29	1.33	1.31	1.41
Mean value	1.03	2.71	2.71	2.96

Appendix D. Median-Based Indicator Transformations of the Moderating Variables

	(1)	(2)	(3)	(4)
	Model 1	Model 2	Model 3	Model 4
CCEMG				
NRR	−0.05 ** (−1.99)	−0.043 ** (−2.21)	−0.040 * (−1.87)	−0.039 * (−1.85)
INV_half		0.110 * (1.78)		
ESPI_half			0.057 * (1.66)	
ET_half				0.040 * (1.65)
INV_half × NRR		0.051 * (1.88)		
ESPI_half × NRR			0.031 * (1.69)	
ET_half × NRR				0.031 * (1.65)
R&D	0.001 ** (2.51)	0.01 * (1.67)	0.11 (1.54)	0.01 * (1.65)
EXP	1.11 * (1.68)	0.01 * (1.81)	0.11 (1.40)	0.01 * (1.86)
POP	−0.01 * (1.89)	−0.02 * (−1.75)	−0.12 (−1.57)	−0.01 * (−1.79)
GQ	0.03 * (1.89)	0.01 (1.51)	0.04 (1.54)	0.001 * (1.78)
Constant	7.25 *** (3.31)	6.20 ** (2.27)	7.20 * (1.87)	6.91 ** (2.20)
Observations	505	505	505	505
AMG				
NRR	−0.049 ** (−2.41)	−0.039 * (−1.81)	−0.043 ** (−2.02)	−0.035 * (−1.77)
INV_half		0.12 * (1.68)		
ESPI_half			0.034 * (1.88)	
ET_half				0.032 * (1.69)
INV_half × NRR		0.043 * (1.96)		
ESPI_half × NRR			0.029 * (1.83)	
ET_half × NRR				0.029 * (1.94)
R&D	0.001 ** (2.11)	0.01 * (1.78)	0.15 (1.34)	0.002 * (1.82)
EXP	1.10 * (1.88)	1.09 * (1.69)	0.01 (1.63)	0.01 (1.29)
POP	−0.01 (1.33)	−0.02 ** (−1.98)	−0.19 (−1.61)	−0.03 ** (−1.99)
GQ	0.001 ** (2.09)	0.003 * (1.62)	0.01 (1.62)	0.001 * (1.84)
Constant	7.21 *** (3.11)	6.89 *** (4.52)	7.17 ** (2.09)	6.73 *** (5.83)
Observations	505	505	505	505

Appendix E

Appendix E.1. Sensitivity Analysis Excluding High-NRR Countries

	(1)	(2)	(3)	(4)
	Model 1	Model 2	Model 3	Model 4
CCEMG				
NRR	−0.041 ** (−2.10)	−0.03 ** (−2.39)	−0.03 ** (−2.33)	0.02 * (−1.87)
INV		0.01 * (1.91)		
ESPI			0.01 * (1.77)	
ET				0.02 * (1.92)
NRR × INV		0.01 * (1.82)		
NRR × ESPI			0.01 * (1.92)	
NRR × ET				0.01 * (1.73)
R&D	0.001 * (1.75)	0.01 * (1.80)	0.01 (1.44)	0.01 * (1.80)
EXP	1.07 * (1.88)	0.01 * (1.70)	0.11 (1.32)	0.01 (1.71)
POP	−0.03 * (−1.92)	−0.01 * (−1.70)	−0.01 (−1.09)	−0.01 * (−1.89)
GQ	0.02 * (1.81)	0.01 * (1.69)	0.01 * (1.65)	0.01 (1.62)
Constant	7.20 *** (3.39)	7.19 *** (4.01)	7.30 *** (4.56)	7.38 *** (2.89)
Observations	431	431	431	431
AMG				
NRR	−0.05 *** (−3.20)	−0.02 ** (−2.39)	−0.039 ** (−2.40)	0.029 * (−1.88)
INV		0.02 * (1.89)		
ESPI			0.03 * (1.99)	
ET				0.02 * (1.92)
NRR × INV		0.01 * (1.92)		
NRR × ESPI			0.01 ** (2.32)	
NRR × ET				0.01 ** (2.13)
R&D	0.001 * (1.95)	0.01 * (1.80)	0.01 (1.54)	0.01 * (1.70)
EXP	1.08 * (1.88)	0.09 (1.20)	0.11 (1.42)	0.03 (1.61)
POP	−0.01 * (−1.72)	−0.03 * (−1.70)	−0.01 * (−1.77)	−0.01 * (−1.68)
GQ	0.01 * (1.81)	0.01 * (1.63)	0.01 * (1.79)	0.01 * (1.32)
Constant	7.19 *** (4.32)	6.00 ** (5.21)	7.28 *** (4.97)	6.89 *** (6.01)
Observations	431	431	431	431

Appendix E.2. Sensitivity Analysis Excluding Low-NRR Countries

	(1)	(2)	(3)	(4)
	Model 1	Model 2	Model 3	Model 4
CCEMG				
NRR	−0.061 ** (−2.31)	−0.056 ** (−2.41)	−0.060 ** (−2.43)	−0.058 ** (−2.03)
INV		0.02 * (1.73)		
ESPI			0.04 * (1.89)	
ET				0.01 * (1.81)
NRR × INV		0.01 * (1.79)		
NRR × ESPI			0.01 * (1.79)	
NRR × ET				0.02 * (1.81)
R&D	0.001 * (1.74)	0.02 * (1.87)	0.01 * (1.83)	0.01 * (1.96)
EXP	1.08 * (1.90)	0.05 (1.60)	0.02 (1.60)	0.01 (1.31)
POP	−0.01 * (−1.76)	−0.02 * (−1.84)	−0.01 * (−1.91)	−0.01 * (−1.91)
GQ	0.02 * (1.91)	0.02 * (1.87)	0.03 * (1.79)	0.01 * (1.85)
Constant	7.01 ** (2.21)	7.19 ** (2.32)	7.31 ** (2.31)	7.19 ** (2.47)
Observations	430	430	430	430
AMG				
NRR	−0.07 *** (−2.73)	−0.041 *** (−2.61)	−0.05 ** (−2.25)	−0.04 ** (−2.19)
INV		0.01 * (1.93)		
ESPI			0.03 ** (1.99)	
ET				0.02 ** (2.41)
NRR × INV		0.02 ** (1.99)		
NRR × ESPI			0.01 ** (2.39)	
NRR × ET				0.01 * (1.81)
R&D	0.002 * (1.83)	0.02 * (1.77)	0.01 * (1.87)	0.01 * (1.99)
EXP	1.08 * (1.89)	0.07 (1.50)	0.02 (1.30)	0.01 * (1.65)
POP	−0.02 * (−1.79)	−0.02 * (−1.94)	−0.01 * (−1.93)	−0.01 * (−1.84)
GQ	0.04 * (1.81)	0.02 * (1.87)	0.05 * (1.79)	0.01 * (1.85)
Constant	7.01 *** (2.62)	6.94 *** (2.61)	7.03 ** (2.43)	7.03 ** (2.54)
Observations	430	430	430	430

Appendix E.3. Sub-Sample Analyses Based on the Median Value of NRR

Panel A. For Sub-sample with Above Median Value NRR				
	(1)	(2)	(3)	(4)
	Model 1	Model 2	Model 3	Model 4
CCEMG				
NRR	−0.07 * (−1.87)	−0.08 * (−1.79)	−0.07 ** (−2.13)	−0.09 * (−1.82)
INV		0.01 * (1.81)		
ESPI			0.01 * (1.81)	
ET				0.02 * (1.81)
NRR × INV		0.03 ** (2.02)		
NRR × ESPI			0.05 ** (2.07)	
NRR × ET				0.04 * (1.93)
R&D	0.001 (1.61)	0.01 * (1.70)	0.01 (1.44)	0.01 * (1.70)
EXP	1.09 (1.58)	0.09 * (1.80)	0.11 (1.32)	0.01 * (1.71)
POP	−0.03 * (−1.72)	−0.01 * (−1.68)	−0.01 (−1.59)	−0.01 * (−1.79)
GQ	0.05 * (1.71)	0.06 * (1.79)	0.03 * (1.75)	0.04 (1.62)
Constant	5.20 *** (5.39)	6.29 *** (4.21)	6.10 *** (4.59)	5.38 *** (3.89)
Observations	253	253	253	253
AMG				
NRR	−0.07 ** (−2.17)	−0.08 * (−1.83)	−0.07 * (−1.75)	−0.06 ** (−2.13)
INV		0.01 * (1.73)		
ESPI			0.01 * (1.75)	
ET				0.02 * (1.93)
NRR × INV		0.02 ** (2.12)		
NRR × ESPI			0.05 * (1.87)	
NRR × ET				0.04 * (1.89)
R&D	0.01 * (1.72)	0.01 * (1.69)	0.01 (1.21)	0.01 * (1.71)
EXP	1.09 (1.58)	0.09 * (1.73)	0.11 (1.22)	0.01 * (1.81)
POP	−0.03 * (−1.72)	−0.01 (−1.61)	−0.01 (−1.66)	−0.01 * (−1.79)
GQ	0.02 * (1.81)	0.02 ** (1.99)	0.03 * (1.77)	0.03 (1.43)
Constant	6.10 *** (4.49)	5.19 *** (4.41)	5.20 *** (5.59)	5.38 *** (4.29)
Observations	253	253	253	253

Panel B. For Sub-sample with Below Median Value NRR				
	(1)	(2)	(3)	(4)
	Model 1	Model 2	Model 3	Model 4
CCEMG				
NRR	−0.05 ** (−2.12)	−0.06 ** (−2.41)	−0.06 * (−1.73)	−0.05 ** (−2.23)
INV		0.02 ** (2.17)		
ESPI			0.03 * (1.81)	
ET				0.01 * (1.72)
NRR × INV		0.02 * (1.89)		
NRR × ESPI			0.01 * (1.73)	
NRR × ET				0.04 * (1.82)
R&D	0.02 * (1.72)	0.01 * (1.77)	0.01 * (1.77)	0.01 * (1.91)
EXP	1.08 * (1.90)	0.02 * (1.70)	0.02 (1.50)	0.01 ** (1.98)
POP	−0.01 * (−1.86)	−0.02 * (−1.75)	−0.01 * (−1.91)	−0.01 * (−1.91)
GQ	0.02 * (1.91)	0.02 * (1.87)	0.01 * (1.81)	0.01 * (1.83)
Constant	5.01 *** (6.21)	6.02 ** (2.12)	5.21 *** (7.31)	5.19 *** (6.37)
Observations	252	252	252	252
AMG				
NRR	−0.06 ** (−2.11)	−0.05 ** (−2.26)	−0.04 * (−1.83)	−0.05 ** (−2.13)
INV		0.02 * (1.87)		
ESPI			0.03 * (1.89)	
ET				0.01 ** (2.10)
NRR × INV		0.02 * (1.90)		
NRR × ESPI			0.01 * (1.74)	
NRR × ET				0.04 * (1.82)
R&D	0.02 * (1.73)	0.01 * (1.77)	0.01 (1.62)	0.01 * (1.86)
EXP	1.08 (1.60)	0.02 * (1.90)	0.02 * (1.71)	0.01 * (1.92)
POP	−0.01 * (−1.89)	−0.02 * (−1.79)	−0.01 * (−1.83)	−0.01 * (−1.91)
GQ	0.02 * (1.91)	0.02 * (1.87)	0.01 * (1.81)	0.01 * (1.83)
Constant	6.09 *** (5.01)	6.82 *** (7.10)	6.01 ** (2.21)	5.89 ** (2.42)
Observations	252	252	252	252

Appendix E.4. Weighted Least Square Method

	(1)	(2)	(3)	(4)
	Model 1	Model 2	Model 3	Model 4
NRR	−0.053 *** (−5.31)	−0.029 ** (−2.34)	−0.041 ** (−2.34)	−0.031 ** (−2.47)
INV		0.013 * (1.97)		
ESPI			0.024 ** (2.33)	
ET				0.02 ** (2.39)
NRR × INV		0.024 * (1.89)		
NRR × ESPI			0.031 ** (2.21)	
NRR × ET				0.043 * (2.01)
R&D	0.001 * (1.91)	0.004 * (1.64)	0.01 (1.22)	0.01 (0.79)
EXP	1.101 * (1.95)	−0.09 (−0.22)	1.01 (1.01)	0.013 * (1.93)
POP	−0.019 (−1.00)	−0.023 ** (−1.97)	−0.011 (−0.03)	−0.010 * (−1.96)
GQ	0.001 ** (2.23)	0.012 (0.02)	0.03 (1.20)	0.001 * (1.89)
Constant	6.97 ** (2.50)	6.21 ** (2.33)	7.06 *** (5.61)	6.81 ** (2.31)

Appendix F. Structural Break Test

	(1)	(2)	(3)	(4)
	Model 1	Model 2	Model 3	Model 4
CCEMG				
NRR	−0.025 ** (−1.99)	−0.019 * (−1.92)	−0.018 * (−1.89)	−0.029 * (−1.77)
INV		0.03 * (1.82)		
ESPI			0.001 * (1.69)	
ET				0.02 * (1.69)
NRR × INV		0.01 * (1.67)		
NRR × ESPI			0.005 * (1.88)	
NRR × ET				0.01 * (1.77)
R&D	0.01 * (1.89)	0.01 (1.55)	0.01 * (1.77)	0.01 * (1.72)
EXP	0.02 * (1.77)	0.10 (1.01)	0.01 * (1.77)	0.01 * (1.81)
POP	−0.01 * (−1.88)	−0.01 (−1.46)	−0.01 (−1.37)	−0.01 * (−1.91)
GQ	0.01 * (1.81)	0.01 * (1.71)	0.01 (1.54)	0.01 * (1.69)
Post 2015	2.52 (1.60)	2.33 (1.62)	3.31 * (1.74)	3.07 (1.61)
NRR × Post 2015	−1.08 (−1.61)	−0.07 (−1.13)	−0.051 * (−1.65)	−1.09 (−1.54)
INV × Post 2015		1.09 (1.59)		
ESPI × Post 2015			1.006 (1.57)	
ET × Post 2015				0.005 (1.61)

NRR × INV × Post 2015		1.07 (1.58)		
NRR × ESPI × Post 2015			0.04 (1.60)	
NRR × ET × Post 2015				0.001 (1.58)
R&D × Post 2015	0.001 * (1.83)	0.01 (1.13)	0.02 (1.37)	0.01 (1.37)
EXP × Post 2015	0.01 (1.57)	0.10 (0.61)	0.01 (1.60)	0.01 (1.59)
POP × Post 2015	−0.01 * (−1.79)	−0.01 (−1.46)	−0.01 (−1.37)	−0.01 * (−1.78)
GQ × Post 2015	0.01 * (1.87)	0.01 (1.51)	0.01 (1.61)	0.01 * (1.69)
Observations	505	505	505	505
AMG				
NRR	−0.03 ** (−2.09)	−0.02 * (−1.77)	−0.01 * (−1.89)	−0.03 * (−1.69)
INV		0.04 * (1.82)		
ESPI			0.05 * (1.69)	
ET				0.02 ** (1.98)
NRR × INV		0.01 ** (2.21)		
NRR × ESPI			0.03 ** (2.03)	
NRR × ET				0.03 * (1.77)
R&D	0.01 * (1.86)	0.01 (1.61)	0.01 (1.62)	0.01 * (1.89)
EXP	1.02 (1.38)	0.09 (1.23)	0.01 * (1.88)	0.01 * (1.79)
POP	−0.01 * (−1.89)	−0.02 (−1.61)	−0.01 * (−1.88)	−0.01 (−1.01)
GQ	0.01 * (1.81)	0.01 * (1.83)	0.01 * (1.67)	0.01 (1.21)
Post 2015	3.37 (1.51)	3.19 * (1.72)	4.22 (1.61)	4.87 (1.11)
NRR × Post 2015	−1.08 (−1.21)	−1.08 (−1.60)	−0.04 * (−1.67)	−0.03 (−1.54)
INV × Post 2015		1.05 (1.42)		
ESPI × Post 2015			1.03 (1.52)	
ET × Post 2015				0.01 (1.67)
NRR × INV × Post 2015		1.07 (1.33)		
NRR × ESPI × Post 2015			0.01 (1.08)	
NRR × ET × Post 2015				1.09 (1.59)
R&D × Post 2015	1.01 * (1.06)	0.01 * (1.77)	0.01 (1.22)	0.01 * (1.89)
EXP × Post 2015	1.02 (1.21)	1.02 (1.11)	0.01 * (1.77)	0.01 (1.62)
POP × Post 2015	−0.01 ** (−1.98)	−0.01 (−1.21)	−1.01 (−1.23)	−1.01 (−1.62)
GQ × Post 2015	0.01 (1.51)	0.01 * (1.73)	1.01 (1.34)	0.01 (1.01)
Observations	505	505	505	505

Appendix G. Dynamic Heterogeneous Panel Estimation Using Driscoll-Kraay Standard Errors

	(1)	(2)	(3)	(4)
	Model 1	Model 2	Model 3	Model 4
Driscoll-Kraay Standard Error Method				
NRR	−0.18 ** (−1.97)	−0.14 * (−1.87)	−0.16 * (−1.89)	−0.13 * (−1.70)
INV		0.09 ** (1.97)		
ESPI			0.06 ** (2.09)	
ET				0.11 ** (2.15)
NRR × INV		0.04 * (1.69)		
NRR × ESPI			0.05 ** (1.98)	
NRR × ET				0.01 * (1.81)
R&D	0.11 * (1.91)	0.01 (1.10)	1.01 (0.71)	0.14 * (1.96)
EXP	0.21 * (1.77)	1.06 (1.13)	1.05 (1.13)	0.08 * (1.76)
POP	−0.01 ** (−2.16)	−0.01 * (−1.87)	−0.21 (−1.03)	−0.01 (−1.07)
GQ	0.03 * (1.71)	0.05 * (1.91)	0.01 (1.11)	0.01 (1.32)
Constant	9.21 *** (2.89)	8.42 *** (4.66)	7.43 *** (3.44)	8.81 *** (2.99)
Observations	505	505	505	505

Notes

- ¹ To be accurate, we mainly adopt one of the World Bank sustainability indicators, Adjusted Net Saving (ANS), as a proxy for green growth in our baseline model. ANS measures the net accumulation of national wealth after accounting for investments in human capital, natural resource depletion, and environmental damages. Unlike conventional growth indicators such as GDP, ANS incorporates environmental and resource considerations, reflecting whether economic activity enhances or depletes a country's productive base. In this sense, ANS captures the balance between economic growth and environmental costs, making it well suited to measure green growth. Accordingly, ANS has been frequently used as a proxy for environmentally sustainable or "green growth" (e.g., Miao et al. 2023). In addition, prior panel studies have shown that ANS performs comparably to broader sustainability-oriented indicators in capturing environmentally adjusted economic performance, particularly in cross-country settings where multidimensional sustainability measures are limited or inconsistently available (OECD 2018; Miao et al. 2023; Liu and Hong 2024). While alternative proxies for green growth, such as CO₂ emissions, renewable energy consumption, or composite indices, are commonly used, they often capture only specific aspects of environmentally oriented economic performance. In contrast, adjusted net savings (ANS) provides a more comprehensive measure by integrating economic growth with environmental degradation, resource depletion, and human capital investment. This allows ANS to reflect the quality of growth rather than its level alone. Although ANS is a composite indicator and may involve measurement assumptions, its broad coverage and cross-country availability make it well suited for panel analysis. To address potential limitations of ANS, this study also employs an alternative proxy for green growth as part of our robustness tests.
- ² To be accurate, although the magnitude of some coefficients from the robustness tests differ from those obtained from the baseline model, the signs and statistical significance of the key variables remain consistent across estimation techniques. This consistency provides additional support for the robustness of the main findings.
- ³ The OECD had 29 member countries in 1996, our sample starting year, and expanded to 37 by 2020. To maintain consistency, we restrict our empirical analysis to the initial 29 countries.
- ⁴ According to the World Bank's 2024 income thresholds, a country is classified as a high-income country if its GNI per capita is larger than \$14,004, whereas a country is classified as an upper-middle-income country if its GNI per capita between \$4516 and \$14,004.
- ⁵ Our sample for the specific robustness test will be reduced to 495 country-year observations due to additional missing values for the alternative measure of green growth (RN).

- ⁶ The reduction in natural resource depletion in calculating ANS may bring concerns on the potential natural link that country with higher natural resource rents will tend to have lower ANS and thus needs some further clarifications on the two concepts. The reduction in natural resource depletion is not equivalent to a reduction in natural resource rents because the two concepts capture different dimensions of resource use. Natural resource rents measure the economic value generated from extraction (i.e., revenues net of extraction costs), whereas resource depletion reflects the loss of natural capital associated with that extraction. These measures are determined by different factors, including market prices, extraction efficiency, and valuation methods. As a result, higher resource rents do not necessarily imply greater depletion, nor does lower depletion imply lower rents. Consequently, there is no inherent inverse or mechanical relationship between the two variables. To further assess the robustness of our findings, we employ an alternative proxy for green growth, namely the percentage of renewable energy consumption in total energy use (RN), as part of our robustness tests. Additionally, as previously stated, natural resource depletion and natural resource rents capture different dimensions of resource use. Since our objective in the study is to test one of the economic consequences of natural resources (e.g., its impact on green growth), natural resource rents are a more appropriate proxy for the independent variable. We thank the anonymous reviewers for raising these important concerns.
- ⁷ The reduction of 4.9% and 5.9% are calculated as $-(0.28 - 0.15) \times 0.05/1.32$ and $-(0.28 - 0.15) \times 0.06/1.32$, respectively, where 0.28 and 0.15 represent the third and first quartiles of NRR, 0.05 and 0.06 are the estimated coefficients of NRR from the CCEMG and AMG models, and 1.32 is the sample mean of GG.
- ⁸ The marginal effects of 0.031 and 0.032 are calculated as $0.02 + 0.01 \times 1.12$ and $0.01 + 0.02 \times 1.12$, respectively, where 1.12 represents the sample mean of NRR.
- ⁹ The marginal effects of 0.031 and 0.044 are calculated as $0.02 + 0.01 \times 1.12$ and $0.01 + 0.03 \times 1.12$, respectively, where 1.12 represents the sample mean of NRR.
- ¹⁰ To be more specific, none of the variables have a VIF value over 10 and the average VIF values for all empirical models are less than 3.
- ¹¹ Although renewable energy consumption is not a comprehensive measure of green growth, it captures an important environmental dimension of sustainable development that is closely related to green growth. Accordingly, this robustness analysis should be interpreted as examining whether the main findings remain consistent when an alternative environmental sustainability indicator is employed rather than as a replacement for the primary green growth measure.
- ¹² These additional analyses also provide insights into cross-country heterogeneity. The stability of the results after excluding both high- and low-NRR countries suggests that both the negative effect of natural resource rents on green growth and the moderating roles of green innovation and environmental regulations are broadly consistent across OECD economies. This indicates that these mechanisms operate similarly in both resource-rich and resource-poor countries.

References

- Abbas, Shujaat, Faheem Ur Rehman, Shabeer Khan, Mohd Ziaur Rehman, Wadi B. Alonazi, and Abul Ala Noman. 2022. Crowding-Out Effect of Natural Resources on Domestic Investment: The Importance of Information Communication and Technology (ICT) and Control of Corruption in the Middle East and Central Asia. *Sustainability* 14: 13392. [\[CrossRef\]](#)
- Ahakwa, Isaac, and Evelyn Agba Tackie. 2024. Natural Resources as a Double-Edged Sword towards Ecological Quality: Can Environmental Regulations and Green Human Capital rectify the Adverse Impacts? *Journal of Cleaner Production* 457: 142436. [\[CrossRef\]](#)
- Akyuz, Mert, Ghislain Nono Gueye, and Cagin Karul. 2023. Revisiting the Long-Run Relationship Between Inward/Outward FDI and Income Inequality: New Evidence from the OECD. *International Economic Journal* 37: 220–44. [\[CrossRef\]](#)
- Aller, Carlos, Lorenzo Ductor, and Maria Jesus Herrerias. 2015. The World Trade Network and the Environment. *Energy Economics* 52: 55–68. [\[CrossRef\]](#)
- Arimura, Toshi H., Akira Hibiki, and Hajime Katayama. 2008. Is a Voluntary Approach an Effective Environmental Policy Instrument?: A Case for Environmental Management Systems. *Journal of Environmental Economics and Management* 55: 281–95. [\[CrossRef\]](#)
- Aytaç, S. Erdem, Michael Mousseau, and Ömer Faruk Örsün. 2016. Why Some Countries Are Immune from the Resource Curse: The Role of Economic Norms. *Democratization* 23: 71–92.
- Aziz, Ghazala, and Hussam Buzaid M. Bakoben. 2024. Environmental Decentralization and Green Economic Growth: Do Renewable Energy Development Play Any Role? *Energy Strategy Reviews* 54: 101459. [\[CrossRef\]](#)
- Barma, Naazneen, Kai Kaiser, and Tuan Minh Le, eds. 2012. *Rents to Riches?: The Political Economy of Natural Resource-Led Development*. Washington, DC: World Bank Publications.
- Bhowmik, Roni, Arshian Sharif, Ahsan Anwar, Qasim Raza Syed, Phan The Cong, and Ngo Ngan Ha. 2024. Does Environmental Policy Stringency Alter the Natural Resources–Emissions Nexus? Evidence from G-7 Countries. *Geoscience Frontiers* 15: 101874. [\[CrossRef\]](#)

- Borojo, Dinkneh Gebre. 2024. The Heterogeneous Impacts of Environmental Technologies and Research and Development Spending on Green Growth in Emerging Economies: The Moderating Role of Financial Globalization. *Frontiers in Environmental Science* 12: 1351861. [\[CrossRef\]](#)
- Caijuan, Gong, Farah Durani, Afshan Hamid, Qasim Raza Syed, Kay Hooi Keoy, and Ahsan Anwar. 2024. Navigating the Green Growth Spectrum: Exploring the Synergy Between Geopolitical Risk, Environmental Policy Stringency, and Green Production Practices. *Energy & Environment* 37: 826–52. [\[CrossRef\]](#)
- Chen, Fu, Liyun Wang, Qiaojing Gu, Mingyue Wang, and Xuanwen Ding. 2022. Nexus Between Natural Resources, Financial Development, Green Innovation and Environmental Sustainability in China: Fresh Insight from Novel Quantile ARDL. *Resources Policy* 79: 102955. [\[CrossRef\]](#)
- Cheng, Zhonghua, Lianshui Li, and Jun Liu. 2017. The Emissions Reduction Effect and Technical Progress Effect of Environmental Regulation Policy Tools. *Journal of Cleaner Production* 149: 191–205. [\[CrossRef\]](#)
- Chien, FengSheng, Ching-Chi Hsu, Massoud Moslehpour, Muhammad Sadiq, Bushra Tufail, and Thanh Quang Ngo. 2024. A Step Toward Sustainable Development: The Nexus of Environmental Sustainability, Technological Advancement and Green Finance: Evidence from Indonesia. *Environment, Development and Sustainability* 26: 11581–602.
- Corden, W. Max, and J. Peter Neary. 1982. Booming Sector and De-industrialisation in a Small Open Economy. *The Economic Journal* 92: 825–48. [\[CrossRef\]](#)
- Deacon, Robert T., and Ashwin Rode. 2015. Rent Seeking and the Resource Curse. In *Companion to the Political Economy of Rent Seeking*. Cheltenham: Edward Elgar Publishing.
- Doğan, Buhari, Lan Khanh Chu, Sudeshna Ghosh, Huong Hoang Diep Truong, and Daniel Balsalobre-Lorente. 2022. How Environmental Taxes and Carbon Emissions Are Related in the G7 Economies? *Renewable Energy* 187: 645–56. [\[CrossRef\]](#)
- Driscoll, John C., and Aart C. Kraay. 1998. Consistent covariance matrix estimation with spatially dependent panel data. *Review of Economics and Statistics* 80: 549–60. [\[CrossRef\]](#)
- Du, Jianguo, Jing Zhang, and Xingwei Li. 2020. What Is the Mechanism of Resource Dependence and High-Quality Economic Development? An Empirical Test from China. *Sustainability* 12: 8144. [\[CrossRef\]](#)
- Dumitrescu, Elena-Ivona, and Christophe Hurlin. 2012. Testing for Granger Non-causality in Heterogeneous Panels. *Economic Modelling* 29: 1450–60. [\[CrossRef\]](#)
- Dutz, Mark A., and Siddharth Sharma. 2012. *Green Growth, Technology and Innovation*. World Bank Policy Research Working Paper No. 5932. Washington, DC: World Bank.
- Eberhardt, Markus, and Stephen Bond. 2009. *Cross-Section Dependence in Nonstationary Panel Models: A Novel Estimator*. MPRA Paper, No. 17692. Munich: University Library of Munich.
- Erdoğan, Seyfettin, Durmuş Çağrı Yıldırım, and Ayfer Gedikli. 2020. Natural Resource Abundance, Financial Development and Economic Growth: An Investigation on Next-11 Countries. *Resources Policy* 65: 101559. [\[CrossRef\]](#)
- Fang, Zhen. 2023. Assessing the Impact of Renewable Energy Investment, Green Technology Innovation, and Industrialization on Sustainable Development: A Case Study of China. *Renewable Energy* 205: 772–82. [\[CrossRef\]](#)
- Fernandes, Cristina I., Pedro Mota Veiga, João J. M. Ferreira, and Mathew Hughes. 2021. Green Growth Versus Economic Growth: Do Sustainable Technology Transfer and Innovations Lead to an Imperfect Choice? *Business Strategy and the Environment* 30: 2021–37. [\[CrossRef\]](#)
- Hao, Lin-Na, Muhammad Umar, Zeeshan Khan, and Wajid Ali. 2021. Green Growth and Low Carbon Emission in G7 Countries: How Critical the Network of Environmental Taxes, Renewable Energy and Human Capital Is? *Science of the Total Environment* 752: 141853. [\[CrossRef\]](#) [\[PubMed\]](#)
- Hassan, Abul, Ridwan Lanre Ibrahim, Lukman Raimi, Olatunde Julius Omokanmi, and Abdul Rahman Bin S. Senathirajah. 2025. Balancing Growth and Sustainability: Can Green Innovation Curb the Ecological Impact of Resource-Rich Economies? *Sustainability* 17: 4579. [\[CrossRef\]](#)
- He, Xiaoping, and Dunguo Mou. 2020. Impacts of Mineral Resources: Evidence from County Economies in China. *Energy Policy* 136: 111088. [\[CrossRef\]](#)
- Hoechle, Daniel. 2007. Robust standard errors for panel regressions with cross-sectional dependence. *The Stata Journal* 7: 281–312. [\[CrossRef\]](#)
- Joshua, Udi, Festus Victor Bekun, and Samuel Asumadu Sarkodie. 2020. New Insight into the Causal Linkage Between Economic Expansion, FDI, Coal Consumption, Pollutant Emissions and Urbanization in South Africa. *Environmental Science and Pollution Research* 27: 18013–24. [\[CrossRef\]](#) [\[PubMed\]](#)
- Katircioglu, Salih, and Setareh Katircioglu. 2018. Testing the Role of Fiscal Policy in the Environmental Degradation: The Case of Turkey. *Environmental Science and Pollution Research* 25: 5616–30. [\[CrossRef\]](#) [\[PubMed\]](#)
- Kaznacheev, Peter. 2013. *Resource Rents and Economic Growth: Economic and Institutional Development in Countries with a High Share of Income from the Sale of Natural Resources. Analysis and Recommendations Based on International Experience*. EconStor Research Reports, No. 121950. Kiel: ZBW—Leibniz Information Centre for Economics.

- Khaddage-Soboh, Nada, Adnan Safi, Muhammad Faisal Rasheed, and Amir Hasnaoui. 2023. Examining the Role of Natural Resource Rent, Environmental Regulations, and Environmental Taxes in Sustainable Development: Evidence from G-7 Economies. *Resources Policy* 86: 104071. [\[CrossRef\]](#)
- Khan, Irfan, Abdurashed Zakari, Munir Ahmad, Muhammad Irfan, and Fujun Hou. 2022. Linking Energy Transitions, Energy Consumption, and Environmental Sustainability in OECD Countries. *Gondwana Research* 103: 445–57. [\[CrossRef\]](#)
- Lashitew, Addisu, and Eric Werker. 2020. *Are Natural Resources a Curse, a Blessing, or a Double-Edged Sword?* Washington, DC: Global Economy and Development Brief, Brookings Institution.
- Lee, Ki-Hoon, and Byung Min. 2015. Green R&D for Eco-Innovation and Its Impact on Carbon Emissions and Firm Performance. *Journal of Cleaner Production* 108: 534–42. [\[CrossRef\]](#)
- Li, Claire J., Asif Razzaq, Muhammad Irfan, and Adeel Luqman. 2023. Green Innovation, Environmental Governance and Green Investment in China: Exploring the Intrinsic Mechanisms Under the Framework of COP26. *Technological Forecasting and Social Change* 194: 122708. [\[CrossRef\]](#)
- Li, Zongyun, Syed Kumail Abbas Rizvi, Ghulame Rubbaniy, and Muhammad Umar. 2021. Understanding the Dynamics of Resource Curse in G7 Countries: The Role of Natural Resource Rents and the Three Facets of Financial Development. *Resources Policy* 73: 102141. [\[CrossRef\]](#)
- Liang, Yunbao, Hongxia Zhou, Jun Zeng, and Chuanbin Wang. 2024. Do Natural Resources Rent Increase Green Finance in Developing Countries? The Role of Education. *Resources Policy* 91: 104838. [\[CrossRef\]](#)
- Liu, Kaiyuan, Ayesha Afzal, Yifan Zhong, Amir Hasnaoui, and Xiao-Guang Yue. 2023. Investigating the Resource Curse: Evidence from MENA and N-11 Countries. *Resources Policy* 80: 103215. [\[CrossRef\]](#)
- Liu, Nan, and Cencen Hong. 2024. How Export and Import Concentration Influence Natural Resources and Green Growth Nexus in OECD Countries. *Resources Policy* 91: 104932. [\[CrossRef\]](#)
- Meng, Fanting. 2024. Driving Sustainable Development: Fiscal Policy and the Promotion of Natural Resource Efficiency. *Resources Policy* 90: 104687. [\[CrossRef\]](#)
- Miao, Nana, Arshian Sharif, Ilhan Ozturk, and Asif Razzaq. 2023. How Do the Exploitation of Natural Resources and Fiscal Policy Affect Green Growth? Moderating Role of Ecological Governance in G7 Countries. *Resources Policy* 85: 103911. [\[CrossRef\]](#)
- Oberle, Bruno, Stefan Bringezu, Steve Hatfield-Dodds, Stefanie Hellweg, Heinz Schandl, and Jessica Clement. 2019. *Global Resources Outlook 2019: Natural Resources for the Future We Want*. Nairobi: United Nations Environment Programme.
- Okombi, Idrys Fransmel, and Van Breg-Dony Ndoum Babouama. 2024. Environmental Taxation and Inclusive Green Growth in Developing Countries: Does the Quality of Institutions Matter? *Environmental Science and Pollution Research* 31: 30633–62. [\[CrossRef\]](#) [\[PubMed\]](#)
- Organization for Economic Co-Operation and Development (OECD). 2018. *What Is Green Growth and How Can It Help Deliver Sustainable Development?* Paris: OECD Publishing.
- Ozyilmaz, Ayfer, Yuksel Bayraktar, and Mehmet Firat Olgun. 2023. Effects of Public Expenditures on Environmental Pollution: Evidence from G-7 Countries. *Environmental Science and Pollution Research* 30: 75183–94. [\[CrossRef\]](#) [\[PubMed\]](#)
- Pesaran, M. Hashem. 2004. *General Diagnostic Tests for Cross Section Dependence in Panels*. Cambridge Working Papers in Economics No. 0435. Cambridge: Faculty of Economics, University of Cambridge.
- Pesaran, M. Hashem. 2007. A Simple Panel Unit Root Test in the Presence of Cross-Section Dependence. *Journal of Applied Econometrics* 22: 265–312. [\[CrossRef\]](#)
- Pesaran, M. Hashem. 2015. Testing Weak Cross-Sectional Dependence in Large Panels. *Econometric Reviews* 34: 1089–117.
- Pesaran, M. Hashem, and Takashi Yamagata. 2008. Testing Slope Homogeneity in Large Panels. *Journal of Econometrics* 142: 50–93. [\[CrossRef\]](#)
- Petrović, Predrag, and Mikhail M. Lobanov. 2020. The Impact of R&D Expenditures on CO₂ Emissions: Evidence from Sixteen OECD Countries. *Journal of Cleaner Production* 248: 119187. [\[CrossRef\]](#)
- Qiang, Qiu, and Chen Jian. 2020. Natural Resource Endowment, Institutional Quality and China's Regional Economic Growth. *Resources Policy* 66: 101644. [\[CrossRef\]](#)
- Razzaq, Asif, Tahseen Ajaz, Jing Claire Li, Muhammad Irfan, and Wanich Suksatan. 2021. Investigating the Asymmetric Linkages Between Infrastructure Development, Green Innovation, and Consumption-Based Material Footprint: Novel Empirical Estimations from Highly Resource-Consuming Economies. *Resources Policy* 74: 102302. [\[CrossRef\]](#)
- Rennings, Klaus. 2000. Redefining Innovation—Eco-innovation Research and the Contribution from Ecological Economics. *Ecological Economics* 32: 319–32. [\[CrossRef\]](#)
- Rennings, Klaus, Andreas Ziegler, and Thomas Zwick. 2004. The Effect of Environmental Innovations on Employment Changes: An Econometric Analysis. *Business Strategy and the Environment* 13: 374–87. [\[CrossRef\]](#)
- Ross, Michael L. 2001. Does Oil Hinder Democracy? *World Politics* 53: 325–61. [\[CrossRef\]](#)
- Sachs, Jeffrey D., and Andrew M. Warner. 1995. *Natural Resource Abundance and Economic Growth*. NBER Working Paper No. 5398. Cambridge: National Bureau of Economic Research.

- Teklie, Derese Kebede, and Mete Han Yağmur. 2024. The Role of Green Innovation, Renewable Energy, and Institutional Quality in Promoting Green Growth: Evidence from African Countries. *Sustainability* 16: 6166. [\[CrossRef\]](#)
- Van der Ploeg, Frederick. 2011. Natural resources: Curse or blessing? *Journal of Economic Literature* 49: 366–420. [\[CrossRef\]](#)
- Van der Ploeg, Frederick, and Anthony J. Venables. 2013. Absorbing a Windfall of Foreign Exchange: Dutch Disease Dynamics. *Journal of Development Economics* 103: 229–43. [\[CrossRef\]](#)
- Wang, Xiaolei, Yanhua Wang, and Chunxin Wei. 2023. The Impact of Natural Resource Abundance on Green Economic Growth in the Belt and Road Countries: The Role of Institutional Quality. *Environmental Impact Assessment Review* 98: 106977. [\[CrossRef\]](#)
- Wei, Hua, Syed Kumail Abbas Rizvi, Ferhana Ahmad, and Yuchen Zhang. 2020. Resource Cursed or Resource Blessed? The Role of Investment and Energy Prices in G7 Countries. *Resources Policy* 67: 101663. [\[CrossRef\]](#)
- Westerlund, Joakim. 2007. Testing for Error Correction in Panel Data. *Oxford Bulletin of Economics and Statistics* 69: 709–48. [\[CrossRef\]](#) [\[PubMed\]](#)
- Xuan, Di, Xiaoyan Jiang, and Yan Fang. 2023. Can Globalization and the Green Economy Hedge Natural Resources? Functions of Population Growth and Financial Development in BRICS Countries. *Resources Policy* 82: 103414. [\[CrossRef\]](#)
- Yu, Siming, Kang Wan, Cheng Cai, Lingli Xu, and Tuanjie Zhao. 2023. Resource Curse and Green Growth in China: Role of Energy Transitions Under COP26 Declarations. *Resources Policy* 85: 103768. [\[CrossRef\]](#)
- Zhao, Zhenyu, and Hanting Xu. 2024. Exploring Configurational Effects of National Environmental, Social, and Governance Performance on Energy Efficiency: A Dynamic Qualitative Comparative Analysis. *Environment, Development and Sustainability* 28: 14627–70. [\[CrossRef\]](#)

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