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Cultivating resilient economies through responsible mineral resource trade: Does eco-resourcing rebate matter?

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ABSTRACT

The pursuit of sustainable development in the face of global environmental challenges has underscored the need to integrate economic growth with environmental conservation. This study investigates the intricate relationship between resource trade and green economic recovery from 1973 to 2019 for 43 African countries. This relationship is not merely transactional; it is intricately shaped by the moderating role of technological innovation and the eco-resourcing rebate policies. Technological innovation serves as a conduit through which resource trade channels its effects on green economic recovery. Eco-resourcing rebates, as financial incentives, amplify the positive influence of resource trade and ultimately drive the attainment of green economic recovery objectives. This study contributes to the growing body of literature on the interplay between economic activities and environmental stewardship. The findings highlight the significance of mediating resource trade with technological innovation, and eco-resourcing rebates to foster a resilient green economic recovery.

1. Introduction

In an era characterized by unprecedented global difficulties, the endeavor to achieve economic growth while ensuring environmental sustainability has become an indispensable obligation. The paradigm shift in societal recovery has been prompted by the consequences of events like the COVID-19 pandemic, as well as growing apprehensions regarding climate change, biodiversity decline, and resource exhaustion (ESCAP, 2022; Hartley and Kuecker, 2022). The concept of a "green economic recovery" has garnered substantial attention, embodying the belief that economic resurgence can be achieved alongside fostering ecological restoration (Stern and Xie, 2023).

At the core of this nascent paradigm lies the relationship interplay between the trade of natural resources and the pursuit of a sustainable economic recovery. The utilization of natural resources, such as minerals, energy sources, agricultural goods, and forests, has historically been of fundamental significance in every economy (Auty, 2001; Peras et al., 2021). However, the exploitation and trading of these resources often resulted in environmental degradation and societal injustices. Recognizing the intricate nature of these factors, the current study places significant emphasis on the capacity of resource trade to serve as a driving force for both economic revitalization and the promotion of sustainable development.

The integration of natural resource trade and green economic recovery is driven quest for environmental and economic objectives (Hou and Fang, 2023). Interestingly, the usage of natural resources, comes with global trade networks, stimulates economic diversity, fosters innovation, and generates employment opportunities. By strategically directing resource-based industries towards the adoption of sustainable practices, nations offer the capacity to effectively address and reduce the adverse environmental consequences associated with these industries. This, in turn, can contribute to the development of a more resilient and ecologically balanced future (Khan et al., 2021; Schroeder et al., 2019).

The implementation of a green economic recovery model signifies a deviation from conventional growth paradigms. This highlights the importance of incorporating environmental externalities into decision-making processes, advocating for circular economy concepts, and leveraging technology to establish a mutually beneficial connection between economic advancement and ecological welfare. Within this particular scenario, it becomes crucial to examine the correlation

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between the trade of natural resources and the adherence to the principles of green economic recovery.

The primary objective of this study is to examine and evaluate the complex relationship between the eco-resourcing rebate and responsible resource trade and the efforts to achieve a sustainable and environmentally friendly economic recovery. This study seeks to examine empirical data in order to reveal the fundamental dynamics that dictate the viability and efficacy of utilizing resource trading as a means to promote a sustainable and resilient economic trajectory. As anticipated, our estimation results a positive relationship between resource trade and green economic recovery are mediates by technological innovation and rebate on eco-resourcing. These findings implies that resource trading is associated with increasing environmentally sustainable economic recovery. This occur if resource exploration is sustained through technology and eco-resource rebates. To capitalize on this opportunity and foster sustainable economic growth, policymakers should consider promoting technology adaptation, incentivize eco-resourcing, regulatory support, public awareness campaigns and research and development. By implementing these policies, government can harness the potential of resource trading to drive green economic recovery as well as create jobs, and mitigate environmental impact, fostering a more sustainable future for society.

This study makes incremental contribution, first, it provides innovative approaches to achieving green economic recovery. By emphasizing the role of technology and incentives in resource trading, it provides practical insights for policymakers and researchers interested in sustainable economic development strategies. Second, offers specific policy implications grounded in empirical evidence. This contribution is crucial for the field of environmental economics, providing policymakers with evidence-based recommendations for designing effective policies that promote eco-friendly practices and stimulate economic growth simultaneously. Third, the study provides empirical validation of the effectiveness of eco-resourcing rebates and technology-enabled resource trading. This empirical support strengthens the theoretical foundations of green initiatives and provides real-world examples that can be referenced by scholars and policymakers working on related topics.

The subsequent sections of this study are as follows: Section two comprises a comprehensive literature review, section three presents the data and methods employed, section four presents the results and subsequent discussion, and the final portion encompasses the conclusion and policy implications.

2. Literature review

The relationship between the natural resources trade and the pursuit of a green economic recovery has garnered growing interest among scholars and policymakers. Scholars and researchers have extensively investigated different aspects of this interconnection, analyzing the ways in which the prudent administration of natural resources and their trade might foster economic revitalization while promoting environmental sustainability.

Economies endowed with abundant natural resources often have difficulties arising from their substantial dependence on a restricted array of commodities. The existing body of literature recognizes that the trade of natural resources has the potential to either exacerbate or alleviate these difficulties. Some research studies propose an alternative perspective to the "resource curse" idea, asserting that strategic resource trade has the potential to foster economic diversity and mitigate susceptibility to price changes. According to Stijns (2005), the exchange of resources has the potential to stimulate the expansion of sectors unrelated to resources by promoting increased productivity and the diffusion of technology. This implies that the implementation of responsible resource trading practices has the potential to support a green economic recovery by fostering a more equitable and robust economy.

There are extensive existing literatures regarding the environmental consequences associated with the extraction and exchange of natural resources. The correlation between economies reliant on natural resources and heightened environmental degradation has been underscored by studies such as Liu et al. (2022). However, existing study also highlight the possibility of trade playing a crucial role in promoting ecologically sustainable practices. For instance, Less and McMillan (2005) assert that trade plays a crucial role in promoting the transfer of ecologically sustainable technologies and practices across national boundaries. This finding is consistent with the principles of the green recovery agenda, suggesting that trade can serve as a catalyst for encouraging the adoption of environmentally friendly industrial techniques and resource-efficient technologies.

The concept of a circular economy, which prioritizes waste reduction and resource efficiency, has garnered attention as a fundamental aspect of environmentally sustainable and economic revitalization. The study conducted by Heshmati (2017) highlights the significance of resource trade in promoting the concepts of a circular economy. By means of recycling and reusing resources within global supply chains, international trade has the potential to mitigate the environmental consequences associated with resource extraction, while simultaneously promoting economic development. This implies that the incorporation of circular economy ideas into trade frameworks has the potential to be achieve the goals of promoting environmentally sustainable economic recovery.

The influence of international collaboration and trade agreements is significant in determining the environmental consequences of resource trading. The literature emphasizes the importance of policy frameworks that facilitate the adoption of sustainable trade practices. The United Nations Sustainable Development Goals (SDGs) and international accords, such as the Paris Agreement, provide as frameworks for effectively addressing the environmental consequences associated with trade. Alhassan et al. (2020), highlight the significance of international governance in facilitating the alignment of trade with economic and environmental goals. They stress the crucial role of multilateral cooperation in attaining a green economic recovery.

Ensuring the fair allocation of advantages resulting from the trade of resources is a pivotal factor to be taken into account in the context of promoting a sustainable and environmentally friendly economic recovery. Studies such as Schaffartzik et al. (2019) have conducted investigate into the potential of resource trade to amplify social disparities, frequently resulting in conflicts and instability. Nevertheless, the study also highlights instances in which trade proceeds have been directed towards social and environmental projects, hence fostering inclusive economic growth. The crucial aspect of achieving a genuinely sustainable recovery lies in guaranteeing that the exchange of resources leads to socioeconomic progress across all sectors of society.

The concept of green recovery entails the reconstruction of economies in a manner that fosters the safeguarding of the environment, enhances resilience, and facilitates the shift towards a more sustainable and low-carbon trajectory. The correlation between green recovery and resource utilization is essential in attaining these objectives. The concept of a green recovery places significant emphasis on the principles of resource efficiency and conservation. This entails the optimization of natural resource utilization, waste reduction, and the minimization of environmental consequences (Zhao and Rasoulinezhad, 2023). Sustainable infrastructural investment also serves as a strategic tool to enhance resource utilization by advocating for the adoption of clean and renewable energy sources, implementing energy-efficient buildings to minimize energy waste, and establishing transportation systems that minimize resource-intensive activities (Ruddock, 2022).

In a nutshell, the literature examined in this study highlights the intricate nature of the correlation between trade in natural resources and the pursuit of a sustainable economic recovery. While recognizing the possible difficulties, literature also emphasizes the significant impact that strategic resource trading may have in promoting both economic recovery and environmental sustainability. This study endeavours to enhance our comprehension of how resource trade might significantly influence the development of a resilient and ecologically sustainable approach to economic recovery in Africa by incorporating insights from a range of perspectives such as technology and fiscal policy of government.

3. Data, theoretical models, and methodology

3.1. Data

This study use secondary data source includes green economic recovery, resource commodity exchange, import, and export, as well as technological innovation and eco-resourcing rebates. The study covers the period from 1973 to 2019 for 43 African countries.[1] Except for technological innovation and eco-resourcing taxes and incentives, all other variables in this study come from the world bank's world development index (WDI) and the environmental live/global material flows database. The selection of these datasets was based on their relevance to the research question and their comprehensive coverage of the variables of interest. Table 1 provides a description of the data measurements and sources.

3.2. Theoretical models and methodology

In the realm of environmental and welfare economics, the presence of externalities poses a significant challenge to the efficient functioning of markets (Papandreou, 1998). Externalities, whether positive or negative, result from economic activities and impact parties not directly involved in the transaction. Market failures arising from externalities necessitate innovative economic instruments to realign private incentives with broader social goals (Gillingham and Sweeney, 2010). One such set of instruments, grounded in the seminal work of Arthur Pigou, involves the use of Pigouvian taxes and subsidies to internalize external costs and benefits, respectively.

Externalities disrupt the traditional functioning of markets by causing divergence between private and social costs or benefits. Negative externalities, such as pollution from industrial production, lead to an underestimation of the true societal cost of the activity (Van Woensel et al., 2001). Conversely, positive externalities, such as the educational spillover effects of an informed populace, result in an underappreciation of the broader societal benefits (O'carroll et al., 2006). Pigouvian taxes serve as a powerful tool to address the market failures associated with negative externalities. By imposing levies on producers or consumers engaged in activities that generate adverse spillover effects, Pigouvian taxes seek to internalize the external cost (Shughart, 1997). The taxation mechanism increases the overall cost of the activity, prompting market participants to reduce their engagement in the activity, thereby mitigating the negative externality.

Conversely, Pigouvian subsidies are instrumental in incentivizing activities with positive externalities. By providing financial incentives to producers or consumers engaged in socially beneficial activities, these subsidies aim to internalize the external benefits (Roberts, 2020). The reduction of costs associated with the activity makes it more attractive, leading to increased engagement and a higher quantity of the socially beneficial good or service. The core objective of Pigouvian taxes and subsidies is to enhance the efficiency of resource allocation in the economy and elevate overall social welfare. Through these instruments, the divergence between private and social costs or benefits is narrowed,

Table 1
Variable description and sources.

Variable	Descriptions	Sources
Green economic recovery (GER)	Adjusted net savings, including particulate emission damage (% of GNI)	WDI (2023)
Resources commodities exchange (RCE)	The amount of biomass, excavated earthen materials (including soil), fossil fuels, metal ores, mixed and complex products, non-metallic minerals, products from biomass, products from fossil fuels, products from metals, products from non-metallic minerals, and waste for final treatment and disposal exchanged with countries across the world (Tonnes).	Environment Live/ Global Material Flows Database (2023)
Resources commodities export (RCEP)	The amount of biomass, excavated earthen materials (including soil), fossil fuels, metal ores, mixed and complex products, non-metallic minerals, products from biomass, products from fossil fuels, products from metals, products from non-metallic minerals, and waste for final treatment and disposal exported to the rest of the world (Tonnes).	Environment Live/ Global Material Flows Database (2023)
Resources commodities import (RCIP)	The amount of biomass, excavated earthen materials (including soil), fossil fuels, metal ores, mixed and complex products, non-metallic minerals, products from biomass, products from fossil fuels, products from metals, products from non-metallic minerals, and waste for final treatment and disposal imported (Tonnes)	Environment Live/ Global Material Flows Database (2023)
Eco-resourcing rebate (CIT)	A dummy variable is 1 for countries that initiated incentive mining and 0 otherwise.	Albertin et al. (20233)
Technological innovation (TECH)	Patent, residential and non-residential	WDI (2023)

creating a more accurate reflection of the true societal impact of economic activities. The result is a market that internalizes externalities, aligning individual choices with societal well-being and promoting a more optimal allocation of resources. Given the above assumption, we apply Pigouvian tax and incentives to drive our benchmark equation:

$$RCE_{it} = \beta_0 + \beta_1 TECH_{it} + \beta_2 CIT_{it} + \varepsilon_{it} \tag{1}$$

Where *RCE* represent the vector of resources trade including export and import of resource commodities, *TECH* refer to the technological innovation and *CIT* is the eco-resourcing rebate (i.e., representing Pigouvian incentives) and the *i* and *t* are country and time, while ε refer to the error terms.

In addition, we interact technological innovation and fiscal policy (i.e., eco-resourcing rebates) on resource trade to examine the moderating impact on green economic recovery. Engaging in resource trade may expose the country to advanced technologies and managerial practices as well taxes and subsidies from trading partners. This technology transfer can improve efficiency and productivity across various sectors (Enzmann and Moesli, 2022).

$$GER_{it} = \beta_0 + \beta_1 RCE * TECH_{it} + \beta_2 RCE * CIT_{it} + \varepsilon_{it} \tag{1}$$

[1] Algeria, Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Comoros, Cote d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia, and Zimbabwe.

Where $RCE * TECH$ and $RCE * CIT$ represent the resource exchange*-technological advancement, resource exchange*fiscal policy and the other variables remain the same as in equation (1).

Given that panel data often reveal unobserved individual differences that can influence the dependent variable. We use two-way fixed effects of panel spatial correlation consistent model to account for these unobserved individual-specific characteristics, such as natural endowment or cultural factors, that may influence the investigated relationships (Brüderl and Ludwig, 2015). As is typical in panel data, the dependent variable may influence one of the independent variables, which can result in endogeneity. In the presence of endogeneity, results may be biased and present inconsistent parameter estimates, undermining the reliability of the results (Clougherty et al., 2016). However, we included the lag of the dependent variable in the model. This has been the standard approach for controlling endogeneity in models (Bollen and Brand, 2010).

4. Results and discussion

4.1. Pre-regression analysis

Table 2 presents the descriptive statistics, which reveal that the green economic recovery variable (-$5.594 million) exhibits a negative value. This negative value suggests a decrease or contraction in economic indicators related to environmental sustainability or the endeavor to shift towards an ecologically friendly economy. The states are actively engaged in the exportation of resources, while the selected nations are seeing a decline in resource imports with an approximate value of $0.040 million and -$0.010 million, respectively.

4.2. Main results

The main findings are presented in Table 3, which provide evidence that technological progress exhibits a statistically significant positive effect (0.001***) at the 1% significance level. This suggests that technological progress might promote resource trade. From a logical standpoint, this assertion is reasonable considering that a significant number of African countries had embraced technology such as advanced mining equipment and geological survey techniques, can lead to more efficient extraction of mineral and natural resources. This can enhance productivity, reduce waste, and lower extraction costs, making African resources more competitive in the global market. In addition, technological advancements in transportation, including better road infrastructure, port facilities, and digital logistics solutions, can reduce trade barriers and the costs associated with moving resources to international markets. Efficient logistics can make resource exports more competitive. This finding is partly consistent with Márquez-Ramos and Martínez-Zarzoso (2010), who posit that the presence of technology could enhance international goods and service exchange.

The coefficient for eco-resourcing rebate (0.002***) exhibits a positive and statistically significant relationship at the 1% level. This implies that the fiscal policy (i.e., eco-resourcing rebates) is associated with a increasing responsible resource exchange. This finding aligns with intuitive, if governments provide subsidies to companies that adopt responsible and sustainable practices in resource extraction, processing, and trading. These practices is likely to lead to the use of eco-friendly technologies, adhering to environmental standards, and engaging in community development. Therefore, foster environmental quality and sustainability. This is partly consistent with Kollmann (1998), who posit that fiscal policy in US resulted in export fluctuations. Regrading resource export, the coefficient of technological innovation (0.002***) and eco-resourcing rebate (0.009***) has not shown any quantitative difference with the resource trade or exchange. This suggests that technological innovation and fiscal policy (i.e., eco-resourcing rebates) are associated with increasing responsible resource exchange. This consistent with eco-technology hypothesis as technology progresses and incentive are given in the extraction industries, the probability translating to responsible resources recovery and trading increases.

Table 2
Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
GRE	2021	−5.594	11.333	−34.333	7.672
RCE	2021	0.030	1.274	−1.211	2.869
RCEP	2021	0.040	0.439	−0.443	1.060
RCIP	2021	−0.010	0.838	−0.841	1.836
TECH	2021	698.153	198.184	302.643	1125.429
CIT	2021	0.581	0.493	0	1

Table 3
PSCC results (Dpv: RCE, RCEP & RCIP).

	(1)	(2)	(3)
Variable	RCE	RCEP	RCIP
TECH	0.001***	0.002***	0.001***
	(0.002)	(0.006)	(0.001)
CIT	0.002***	0.009***	−0.010***
	(0.005)	(0.003)	(0.003)
Constant	−1.020***	−0.460***	−1.480***
	(0.001)	(0.005)	(0.002)
Country fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Observations	2021	2021	2021
R-squared	0.555	0.566	0.587
Number of groups	43	43	43

Standard errors in parentheses.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

In the case of resource import, the coefficient of technological progress (0.001***) is positive and statistically significant at a 1% level, suggesting that technological innovation is associated with promoting resource import. This is consistent with our expectation that technological advancements in transportation, including better road infrastructure, port facilities, and digital logistics solutions, can reduce trade barriers and the costs associated with moving resources to international markets. However, the coefficient of eco-resourcing rebate (−0.010***) is negative and statistically significant at a1% level, suggesting that fiscal policy (i.e., eco-resourcing rebates) is associated with reducing resource importation. This is expected given that natural endowment in the Africa, it will be the interest of the states to export their resources in exchange of goods and services that are of no comparative advantage, rather than importing resources in which it has comparative advantages. This is partly consistent with Ramakrishna et al. (2023), who find that import tariff reduction has negative impact on macroeconomic variables.

4.3. Mediating impact of technological innovation and eco-resourcing rebates

According to the findings in column 1 presented in Table 4, there is significant positive association between resource trade and green economic recovery. The coefficient for resource trade is (12.42***), showing that an increase in resource trade is linked to an increase in green economic recovery. This relationship is significant at the 1% level. Similarly, technological innovation (0.031***) is positive and statistically significant at a 1% level. In addition, the coefficient of the variable representing the relationship between resource trade and technological innovation (0.009***) exhibits a positive and statistically significant association at a significance level of 1%. This suggests that technological innovation plays a crucial role in enhancing resource trade and promoting a green economic recovery. The connection between technological advances and enhanced resource utilization, waste reduction, and environmental effect mitigation is in accordance with intuitive. This

Table 4
PSCC results of the moderating effects with technological innovation (Dpv: GRE).

	(1)	(2)	(3)
Variable	GRE	GRE	GRE
RCE	12.42***		
	(0.004)		
TECH	0.031***	0.046***	0.0283***
	(0.007)	(0.001)	(0.006)
RCEP*TECH	0.009***		
	(0.005)		
RCEP		0.001**	
		(0.001)	
RCEP*TECH		0.016***	
		(0.001)	
RCIP			17.16***
			(0.005)
RCIP*TECH			0.011***
			(0.006)
Constant	−31.86***	−46.46***	−31.22***
	(0.006)	(0.001)	(0.005)
Country fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Observations	2021	2021	2021
R-squared	0.605	0.765	0.645
Number of groups	43	43	43

Standard errors in parentheses.
***p < 0.01, **p < 0.05, *p < 0.1.

has the potential to facilitate a more environmentally sustainable economic recovery by maximizing the value derived from traded resources while simultaneously avoiding their adverse environmental consequences.

The implementation of innovative production technologies that prioritize health and well-being can significantly improve the environmental performance of companies that heavily rely on natural resources. The reduction of carbon footprint associated with traded resources can be achieved through the implementation of environmentally friendly production methods, the utilization of renewable energy sources, and the establishment of sustainable waste management techniques. Technological advancements, such as blockchain, Internet of Things (IoT), and data analytics, have the potential to enhance the transparency and provenance of supply chains. This technique contributes to the promotion of responsible and sustainable sourcing of resources, thereby reducing the probability of engaging in ecologically harmful actions. Furthermore, the integration of technical breakthroughs can play a pivotal role in expediting the shift towards a circular economy by enabling the efficient utilization of resources through processes such as resource reuse, remanufacturing, and recycling. This practice mitigates the necessity for ongoing resource extraction and effectively eliminates waste generation. The aforementioned finding aligns with the study conducted by Vu et al. (2023), which demonstrated that the presence of innovation has an impact on the role played by natural resources in the process of economic recuperation.

In the second column, the coefficient of resource export (0.001**) exhibits a positive sign and demonstrates statistical significance at the 5% level. This suggests a significant association between resource export and a increase in green economic recovery. In addition, the statistical analysis reveals that the coefficient associated with the technological innovation and moderating variables of resource export and innovation in technology. This suggests that technological innovation plays a crucial role in promoting the export of resources and facilitating the advancement of green economic recovery. The correlation between technical innovation and the influence of resource exports on the shift towards a greener and more sustainable economy aligns with common intuition.

The coefficient of resource import (17.16***) exhibits statistical significance at the 1% level and demonstrates a positive relationship in the third column. In a similar vein, the coefficient of the technological innovation and moderating variable representing resource import and innovation in technology exhibits a positive and highly significant relationship at the 1% level. This suggests that technological innovation has a discernible impact on the influence of resource import in Africa's pursuit of green economic recovery. This aligns with intuitive since advancements in technology have the potential to improve the ability to track and disclose information about supply chains. This, in turn, can help guarantee that imported resources are obtained in a manner that is both sustainable and ethical, while also considering environmental concerns. The obtained results align with the intuitive expectations pertaining to control variables. The coefficients pertaining to capital and labor exhibit positive and statistically significant values, suggesting a significant association between capital and labor and the enhancement of green economic recovery.

In Table 5, we examine the moderating role of eco-resourcing rebate, and interestingly, the coefficient of resource trade (9.884***) is positive and significant at a 1% level, suggesting that resource trade is associated with promoting green economic recovery. In the same vein, the coefficient of eco-resourcing rebate and moderating variables representing resource trade and rebate in eco-resourcing are positive and statistically significant. These suggests that rebate in eco-resourcing have significant impact on how resource trade promoting green economic recovery. By encouraging sustainable practices, the eco-resourcing rebate contributes to a green economic recovery by promoting industries that prioritize environmental sustainability and contribute to a more resilient and environmentally friendly economy. This is partly consistent with Zhang and Song (2022), who posits that tax rebate has benefit in promoting economy and environment.

In column 2 and 3, the coefficient of resource export and import are positive and statistically significant, suggesting that resource export and import are associated with promoting green economic recovery. In the same vein, the coefficient of eco-resourcing rebate is positive and statistically significant, an indication that eco-resourcing rebate is promoting green economic recovery. While the coefficient of the moderating variable of resource export and import, and eco-resourcing rebate are positive and statistically significant, suggesting that mediating effect of eco-resourcing rebate on resource export and import is significantly impacting on green economic recovery. This is not quantitatively difference from the finding in column 1.

Table 5
PSCC results of the moderating effects with eco-resourcing rebate (Dpv: GRE).

	(1)	(2)	(3)
Variable	GRE	GRE	GRE
RCE	9.884***		
	(0.002)		
CIT	0.005***	0.004***	0.007***
	(0.002)	(0.001)	(0.002)
RCE*CIT	0.003**		
	(0.002)		
RCEP		27.12***	
		(0.007)	
RCEP*CIT		0.007*	
		(0.006)	
RCIP			15.69***
			(0.002)
RCIP*CIT			0.001*
			(0.002)
Constant	−22.37***	−24.31***	−21.14***
	(0.006)	(0.007)	(0.03)
Country fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Observations	2021	2021	2021
R-squared	0.563	0.763	0.524
Number of groups	43	43	43

Standard errors in parentheses.
***p < 0.01, **p < 0.05, *p < 0.1.

4.4. Endogeneity check

Given that our study examine relationship between resource trading and green economic recovery among the selected African countries, the probability of encountering reverse relationship is heightened. This can lead to biased outcomes, if fails to address this concern. In order to address the issue of endogeneity, we employ the conventional method by incorporating a lagged dependent variable into our model. The findings of the endogeneity test are presented in Table 6, revealing that the coefficients for technological innovation and eco-resourcing rebate exhibit a positive and statistically significant relationship with resource trade (including sub-resource export and import). This suggests that there is an association between technological innovation, eco-resourcing rebate and resource trade. The findings obtained is consistent with our main findings in Table 3, indicating that our model is unaffected by endogeneity.

5. Conclusion and policy implications

5.1. Conclusion

This study examines the complex correlation between technological innovation, eco-resourcing rebate and responsible resource trade. Through the utilization of an extensive dataset, an empirical analysis has been conducted to uncover the various obstacles and prospects that emerge at the convergence of technological innovation, eco-resourcing rebate and responsible resource trade. The outcomes of this research provide valuable insights into significant patterns and trends that necessitate thoughtful deliberation among policymakers, economists, and environmental proponents.

The analysis conducted revealed the intricate dynamics between economies that technological innovation and eco-resourcing rebate, underscoring the importance of adopting a sophisticated approach to guarantee that resource trade effectively contributes to a sustainable economic recovery. The empirical findings highlight the capacity of countries abundant in natural resources to leverage their competitive advantage and shift their export focus towards environmentally friendly technologies and sustainable enterprises. Furthermore, our research has uncovered compelling evidence suggesting that countries reliant on resource imports possess the ability to utilize their need for resources as a means to incentivize exporting nations to embrace and implement production strategies that are more environmentally sustainable.

Table 6

PSCC results with a lag of GRE (Dpv: GRE).

	(1)	(2)	(3)
Variable	RCE	RCEP	RCIP
L.RCE	1.007***		
	(0.002)		
TECH	0.002***	0.001***	−0.007***
	(0.002)	(0.001)	(0.005)
CIT	0.003***	−0.006***	−0.007***
	(0.001)	(0.002)	(0.005)
L.RCEP		0.984***	
		(0.004)	
L.RCIP			0.972***
			(0.007)
Constant	0.131***	0.006***	0.078***
	(0.002)	(0.009)	(0.004)
Country fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Observations	1978	1978	1978
R-squared	0.989	0.989	0.989
Number of groups	43	43	43

Standard errors in parentheses.

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

5.2. Policy implications

The findings of our study have significant significance for policy-makers who are responsible for guiding economies towards sustainable and environmentally friendly paths of economic recovery. Based on the findings of our study, we propose the following policy recommendations. Firstly, there is need for African states to strengthen international collaboration on green technology transfer. Implement mechanisms that facilitate the exchange of knowledge and resources to support the integration of sustainable practices in emerging African economies. By fostering international partnerships and technology transfer, African states can leverage the expertise of developed countries to accelerate the adoption of green technologies. This can be particularly impactful in sectors such as renewable energy, where advanced technologies can contribute to both environmental sustainability and economic growth.

Second, African states should integrate clauses in resource trade agreements that incentivize and reward innovation in environmentally friendly practices and technologies. Provide tariff reductions or preferential treatment for products and services that adhere to stringent sustainability standards. By embedding incentives within trade agreements encourages businesses to adopt and invest in green technologies. This approach aligns economic interests with environmental goals, creating a mutually beneficial framework for sustainable resource trade. Third, African states should establish a regional green technology fund. By creating a regional fund dedicated to financing research, development, and implementation of green technologies. This fund could be supported by contributions from governments, international organizations, and private sector stakeholders. Through regional collaboration states can pool resources and expertise to address common environmental challenges. A dedicated fund will stimulate innovation by providing financial support to promising green technology projects, fostering a culture of sustainability across industries.

Fourth, African states should develop policies that encourage circular economy practices in resource trade, emphasizing the reduction of waste and the promotion of recycling and reuse. Provide incentives for businesses adopting circular business models and implement regulations that discourage the disposal of hazardous materials. Circular economy principles can significantly reduce the environmental impact of resource trade. By promoting sustainable production and consumption patterns, states can contribute to both economic prosperity and environmental conservation. Fifth, there is need to expand existing eco-resource rebate programs and tailor them to the specific needs and challenges of individual African countries. Ensure that these programs target key sectors contributing to environmental degradation and focus on incentivizing sustainable practices. The success of eco-resource rebates in promoting green economic recovery is contingent on their alignment with the unique socio-economic and environmental contexts of African nations. Tailoring rebate programs ensures relevance and effectiveness in diverse regional settings.

While our research has established the positive association between resource trade, technological innovation, and green recovery, future studies should delve deeper into assessing the long-term impact of green technology transfer. Investigating how transferred technologies through bilateral evolve and contribute to sustained environmental improvements will provide valuable insights for policymakers.

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Declaration of competing interest

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

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