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Research article

Financial development, resource richness, eco-innovation, and sustainable development: Does geopolitical risk matter?

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A R T I C L E I N F O

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A B S T R A C T

Financial development and geopolitical risks can significantly affect sustainable development. However, the roles of these factors in sustainable development are rarely investigated. Thus, this study takes into account the role of geopolitical risk while exploring the effects of financial development, natural resource rents, and eco-innovation on sustainable development in the Organization for Economic Co-operation and Development (OECD) countries. To this end, yearly data from 1990 to 2019 is analyzed using advanced econometric tests. The Common Correlated Effects Mean Group (CCEMG) results indicate that financial development and eco-innovation are significantly and positively related to sustainable development. Natural resource rents have a detrimental impact on sustainable development which confirms the presence of the resource curse hypothesis in OECD countries. Furthermore, the results revealed that controlling geopolitical risk is useful in fostering sustainable development. Lastly, the panel Granger causality test unveiled one-way causality from financial development, eco-innovation, natural resource rents, and geopolitical risk to sustainable development. Moreover, causalities are found from geopolitical risk to financial development, eco-innovation and natural resources. These findings suggest that OECD countries should prioritize financial development and eco-innovation policies for sustainable development while mitigating the negative effects of natural resource rents. The geopolitical risk can harm sustainable development, so policymakers should promote international cooperation and risk-sharing.

1. Introduction

Sustainable development has received a lot of attention in recent years due to growing awareness about the importance of balancing economic progress with environmental conservation and social well-being. The term "sustainable development" was introduced initially in the Brundtland Commission report in 1987, and it has since become a central objective of national and international policies. According to that report, "*Sustainable development aims to meet the needs of the present generation without compromising the ability of future generations to meet their own needs*" (United Nations, 1987). Sustainable development necessitates a comprehensive strategy that could incorporate social, environmental, and economic aspects into the decision-making process. In 2015, the United Nations established a worldwide structure for sustainable development known as the Sustainable Development Goals (SDGs). This framework offers a road map for reaching a better and more sustainable future (United Nations, 2015).

Financial development and sustainable development are two interconnected concepts that have received considerable interest in academic literature and policy discourse. Financial development refers to the improvement of financial systems and institutions, which enables greater access to financial services, better allocation of resources, and

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increased financial stability (Umar et al., 2020). Levine (2005) argues that the financial sector mainly contributes to economic development by affecting investment decisions, savings rates, and the pace of technological innovation. Thriving studies on the finance-growth nexus show that the financial sector is critical to economic development, despite a few opposing arguments (Boikos et al., 2022; Hung, 2023; Hunjra et al., 2021; Mtar and Belazreg, 2023). However, the research examining the relationship between financial development and sustainable development is limited. The contemporary world is confronted with formidable environmental, social, and economic predicaments. The sustainability risks are compounded by external conflicts among countries, exemplified by the ongoing Russia-Ukraine conflict and the persistent shortage of sustained financial policies, which continue to present critical challenges.

Geopolitical risk refers to the political risks that emerge due to the active engagement of nations in international affairs. Geopolitical risks encompass a range of factors, including political instability, social unrest, military conflicts, and economic challenges, among others (Caldara and Iacoviello, 2022). The multifaceted nature of geopolitical risk can impact sustainable development in several ways. Firstly, political instability and conflicts arising from geopolitical tensions can impede economic activities, infrastructure development, and foreign direct investment (Khan et al., 2023; Nguyen et al., 2022, 2023). In addition, economic unrest due to political instability can disrupt financial markets and fundamental services like healthcare, education, and green investment projects. Secondly, geopolitical risk can intensify environmental degradation and impede the effective implementation of sustainable resource management practices (Ma et al., 2023; Zhang et al., 2023). In areas that experience conflicts or political instability, there is a tendency for natural resources to be exploited in an unsustainable manner (Wang et al., 2023). Moreover, Gupta et al. (2019) argue that geopolitical risk can result in a decline in international trade which can disrupt the supply chain of goods. This, in turn, can have adverse consequences for countries that heavily rely on exports as a primary driver of their economic development. In addition, geopolitical risk can impede the flow of technology transfer, knowledge, and resources essential for eco-innovation (Lee et al., 2023). Moreover, the presence of geopolitical conflicts can shift attention and allocate resources away from cooperative international endeavors towards internal concerns, which might potentially impede the progress of eco-innovations necessary to confront urgent environmental issues. Therefore, policymakers must mitigate geopolitical risk and prioritize sustainable development. By managing geopolitical risk effectively and promoting sustainable development, countries can create more resilient and stable economies that are better equipped to navigate future challenges (Zhang et al., 2023).

Nations endowed with abundant natural resources are expected to enjoy greater prosperity and a more accelerated development trajectory than those without such valuable natural capital. Nevertheless, this inference holds true only for a few countries with abundant natural resources (Ben-Salha et al., 2021; Jović et al., 2016). Natural resources have often been viewed as a curse rather than a blessing for many nations. A substantial body of research provides evidence for the proposition that countries with limited natural resources often demonstrate higher levels of economic growth in comparison to those nations endowed with abundant resources (Hordofa et al., 2022; Shahbaz et al., 2019; Yasmeen et al., 2021). The hypothesis of the "natural resource curse," alternatively referred to as the paradox of plenty, elucidates the detrimental consequences of natural resources on economic development. Within this particular context, it is worth noting that natural resource rents can present notable obstacles to achieving sustainable development. Natural resource revenues are a financial resource for governments to allocate towards developmental initiatives. However, it is crucial to acknowledge that inadequate management of these rents can give rise to issues such as corruption, inequality, and environmental deterioration (Ahmad et al., 2020). The achievement of sustainable development necessitates the meticulous administration of natural resource rents to guarantee their utilization in manners that yield advantages for both present and future generations. This entails the implementation of measures to prevent environmental degradation and mitigate the negative impacts on the socio-economic well-being of indigenous communities caused by resource extraction activities.

Technological innovation is critical for productivity growth, but its role in resource income growth was neglected prior to the advent of the industrial revolution. Traditional growth theories treated technology as exogenous (Solow, 1956), but endogenous growth theories recognized it as an important factor in shaping growth (Romer, 1990). The Fourth Industrial Revolution, characterized by advanced technologies, emphasizes the significance of technology in driving economic growth. However, even though technologically advanced initiatives have significantly increased global output, they have also contributed to the destruction of the natural environment, negatively impacting SDGs. The term "eco-innovation" was first introduced by Fussler and Peter (1996) as a means to address the challenge of sustainable development. Subsequently, numerous researchers and policymakers have recognized eco-innovation as a critical enabler of sustainable development. Eco-innovations can generate economic advantages, such as reduced costs, enhanced competitiveness, and efficient utilization of natural resources while fostering environmentally friendly development (Ahmad and Wu, 2022; Hao et al., 2023).

The study diligently focused on OECD countries, which consist of economically significant nations known for their well-established financial systems, strong environmental standards, and substantial impact on the world's economic policies. Although the G20, G7, and BRICS groups hold undeniable importance in the realm of international economic issues, our selection of OECD countries is primarily motivated by our study objectives. OECD countries play a pivotal role in the adoption and implementation of policies pertaining to sustainable development. By incorporating sustainability principles into their respective policies and sectors, these countries establish standards that can serve as models for others to emulate. In addition, OECD countries make significant contributions to the advancement of sustainable development globally by means of providing aid, making investments, and establishing partnerships with developing nations. These efforts facilitate economic growth that is in harmony with environmental preservation and social well-being. This study provides valuable insights into the complex relationships between financial development, resource richness, eco-innovation, sustainable development, and the influence of geopolitical risk.

Against these arguments, the aim of the study is to probe the impact of financial development (FD), natural resource rents (NRR), and eco-innovation on sustainable development in OECD nations while considering the influence of geopolitical risk. In doing so, this study adds to the literature in a number of ways. Firstly, the study explores the effect of financial development on sustainable development. Financial development has mostly been analyzed in relation to environmental quality and GDP (Cheng et al., 2021; Lv and Li, 2021; Mtar and Belazreg, 2023), but the literature on its effects on sustainable development is scarce and contradictory. Secondly, the study investigates the influence of geopolitical risk on sustainable development. Notably, the effect of geopolitical risk on sustainable development is rarely investigated and unidentified in the context of OECD countries. Thirdly, this study assesses the effect of NRR on sustainable development. Although research on the association between NRR and sustainable development exists, earlier studies have mainly concentrated on developing and emerging countries and yielded mixed results (Ahmad et al., 2023b; Koirala and Pradhan, 2020; Lee and He, 2022). Therefore, this study endeavors to analyze this relationship in OECD countries, which are considered to be more advanced and developed. The objective is to determine whether the abundance of natural resources is a blessing or curse for these countries. Fourthly, this work explores the linkage between eco-innovation and sustainable development. Lastly, this study uses advanced econometric estimation methods robust to slope heterogeneity, cross-sectional dependence, and endogeneity.

The study is organized as follows: Section 2 presents the theoretical framework and literature review, while Section 3 details the materials and methods employed. Section 4 focuses on the presentation of results and subsequent discussion. Finally, Section 5 summarizes the study's conclusion and outlines its policy implications.

2. Literature review

2.1. Financial development and sustainable development

Financial development (FD) and sustainable development are two interconnected concepts that are crucial for the growth and prosperity of any economy. Asteriou and Spanos (2019) stressed that FD is critical for sustainable development as it provides the necessary tools to mobilize resources, manage risks, and promote inclusive growth, ultimately contributing to a more sustainable and equitable economic system. Jalilian and Kirkpatrick (2005) found that FD can enhance economic growth and reduce poverty, which is essential to sustainable development. They assert that a proficient financial system can gather and deploy savings efficiently, ultimately resulting in increased levels of economic growth and investment. Cao et al. (2021) found that FD significantly boosts green growth by funding green projects and incentivizing the adoption of green technologies. They underlined that long-term sustainable development can be achieved by a variety of strategies, including limiting the extent of financial institution expansion while confiscating governmental privileges, encouraging capital market growth, and boosting the integration of FD with technology progress. However, in another study, Cao et al. (2022) used the spatial Durbin model in China. They concluded that the development level of a financial institution in a specific province exerts a negative influence on the green growth of that province. Conversely, it has a notably positive influence on the green growth of neighboring provinces. Moreover, the size of the stock market has a significant favorable effect on green growth in various provinces.

Ahmed et al. (2022) analyzed South Asian countries' data from 2000 to 2018 and discovered that FD had a positive impact on sustainable development. Ngo et al. (2022) found a bidirectional linkage between FD and green growth in 36 countries. They further emphasized that financing strategies for sustainable infrastructure can be crucial in accomplishing SDGs within the UN 2030 agenda for sustainable development. Deng et al. (2023) probed the effect of FD on green growth in the top polluted nations, i.e., India, Russia, Japan, China, and the USA. Their outcomes indicate that the financial market's efficiency positively promotes green growth in China and Russia while it impedes green growth in USA, Japan, and India. However, the efficiency of financial institutions significantly and positively impacts green development in Japan, China, and the USA, while negatively affecting green growth in Russia and India. Yang and Ni (2022) disclosed that FD has an adverse impact on green development in Belt and Road nations.

2.2. Natural resource rents and sustainable development

The effect of NRR on sustainable development has been subject to extensive examination in both theoretical and empirical literature. Nevertheless, whether resource abundance stimulates or impedes economic growth is debatable and literature is divided on this issue. For instance, Brunnschweiler (2008) found that countries with high NRR tend to have higher growth rates in the long term. Likewise, Raheem et al. (2018) suggest that NRR contributes to lessening poverty and enhances economic development in sub-Saharan African economies. Their study argues that NRR can finance investments in human capital, infrastructure, and social services, promoting sustainable development. Huang and Zhao (2022) claim that the efficient usage and accurate management of natural resources can promote green development. However, Yu (2023) demonstrates that the overall NRR has a detrimental effect on economic development in Afghanistan, Nepal, and Sri Lanka, adding credence to the resource curse phenomena in three nations.

Ampofo et al. (2023) gauged the effect of NRR on economic growth in the top 8 resource abundant SSA countries. Their result suggests that an expansion in NRR in the Republic of the Congo has been found to impede economic growth, providing further evidence for the resource curse phenomenon. At the same time, they fail to find a significant correlation between NRR and economic growth in the other seven countries. Fu and Liu (2023) argue that natural resource rents pose an asymmetric effect on sustainable development. They found that natural gas and mineral rents positively impact sustainable development, while forest rents impede sustainable development.

2.3. Geopolitical risk and sustainable development

Geopolitical risk has emerged as a crucial factor affecting sustainable development in recent years. Yet, few studies have delved into the association between geopolitical risk and sustainable development. Earlier studies mainly explored the linkage between geopolitical risk and sustainable development, with a focus on how geopolitical risk affects GDP and environmental sustainability. For instance, Cheng et al. (2018) found that international geopolitical risk shocks had a significant negative impact on the GDP of 38 developing economies. Akadiri et al. (2020) identified a one-way causality from geopolitical risk to economic development in Turkey. They emphasized that geopolitical risk is an essential factor that policymakers need to consider when designing strategies to foster sustainable economic growth in Turkey. However, Sweidan and Elbargathi (2022) unveiled that there is no correlation exists between economic development and geopolitical risk in the context of Saudi Arabia. However, the joint effect of oil rents and geopolitical risk on economic progress is negative in the short run and insignificant in the long term.

2.4. Eco-innovation and sustainable development

Innovative technologies are necessary to meet the increasing needs of a growing population. Mensah et al. (2019) highlighted the significance of technological advancement in ensuring the long-term sustainability of economic development. However, with the emergence of environmental and resource-related concerns, research emphasis has progressively shifted towards achieving green and sustainable development in an environmentally conscientious manner. In this context, eco-innovation has emerged as a critical driver of sustainable development. In this context, Chen et al. (2023) studied the influence of eco-innovation on green growth in the BRICS countries during 1993–2019. Their results indicate that eco-innovations and green patents positively stimulate green growth in BRICS nations. They emphasize the need for countries to promote R&D activities to facilitate the promotion of green innovation, which can aid in achieving green growth. Likewise, from the perspective of ASEAN nations, Suki et al. (2022) discovered that eco-innovation assists in reducing carbon emissions and optimizing resource utilization, implying that eco-innovation positively impacts green growth.

Mahmood et al. (2022) evaluated the effect of eco-innovation on green growth. Their outcomes revealed that eco-innovations positively contribute to green growth because green innovation contributes to the promotion of affordable and eco-friendly technologies that not only decrease environmental pollution but also provide access to modern technologies, thereby fostering sustainable economic growth. Koseoglu et al. (2022) suggested that countries' transition towards green innovation is vital for attaining sustainable development because green innovation is the only feasible way to accomplish sustainable development while preserving the environment. In addition, green innovation can also improve resource efficiency, which is a critical aspect of green growth. According to a study by Sun et al. (2023), green innovation can increase resource efficiency by improving product design and production processes, reducing waste, and promoting the circular economy, which in turn, reduces the pressure on natural resources and helps to promote sustainable growth.

2.5. Geo-political risk, financial development, natural resources, and eco-innovation

The influence of geopolitical risk on global economic dynamics has emerged as a crucial issue, carrying significant consequences for financial markets, natural resource management, and the advancement of eco-innovation. The impact of war, conflicts, and political tensions among nations has had a deleterious influence on financial institutions and markets. For instance, Zhang and Shi (2023) found that geopolitical risk negatively affects financial development in BRICS countries. Likewise, the study of Shi and Li (2023) reveals that geopolitical risks impede financial development in China. Phan et al. (2022) posit that an escalation in geopolitical risk significantly undermines the stability of banks in the United States. Khraiche et al. (2023) concluded that geopolitical risk posed a negative impact on the stock market development in 37 countries.

Geopolitical risk profoundly influences the utilization, trade, extraction, and management of natural resources. The literature on the nexus between geopolitical risk and NRR can be categorized into three strands. The first strand of the literature suggests a negative impact of geopolitical risk on NRR (Aloui et al., 2023; Dogan et al., 2021; Li et al., 2022). Aloui et al. (2023) studied the linkage between geopolitical risk and natural resources such as coal, oil, zinc, and copper. Their findings indicate that the ongoing Russian and Ukraine conflict has a significant impact on energy markets. Dogan et al. (2021) posits that geopolitical risk decreases NRR in the developing countries. Olanipekun and Alola (2020) used the non-linear autoregressive distributed lag model (NARDL) to investigate the relationship between oil output and geopolitical risk in the Persian Gulf. Their findings indicate that upsurges in geopolitical risk are associated with a decline in oil production. The second strand of the literature posits a favorable influence of geopolitical risks on NRR. For instance, Bouoiyour et al. (2019) contend that geopolitical risk has a positive impact on resource rent. Omar et al. (2017) found that the oil market exhibits positive returns during international crises and conflicts. This finding implies that oil functions as a safe haven in periods of geopolitical instability. The favorable impact of geopolitical unpredictability on oil prices is ascribed to heightened demand for oil due to increased military, speculative, and precautionary consumption. The third strand of the literature uncovered insignificant effects of geopolitical risk on NRR (Joëts et al., 2017; Sweidan and Elbargathi, 2022).

The existing body of work examining the effects of geopolitical risk on green innovation highlights a multifaceted and intricate linkage that is shaped by a range of contextual elements. For instance, Lee et al. (2023) geopolitical risk exerts a deleterious impact on the green innovation endeavors of enterprises, primarily by magnifying the costs associated with external funding and diminishing firms' proclivity to secure capital. On the contrary, Jia et al. (2022) posit that geopolitical risk exerts a positive influence on corporate green innovation. Furthermore, the magnitude of this impact is more pronounced for state-owned enterprises, entities receiving higher government subsidies, and those engaged in overseas operations. Yang et al. (2022) propose that diminished political risk ensures consistent policy support and financial assistance for green innovation initiatives, thereby fostering sustainable development.

2.6. Literature gap

In summary, the literature review has revealed a lack of conclusive evidence concerning the impact of FD and NRR on sustainable development and limited research devoted to gauging the effects of eco-innovation on sustainable development. Furthermore, previous studies in environmental economics have overlooked the potential impact of geopolitical risk when exploring the impact of financial development, eco-innovation, and NRR on sustainable development. In addition, many earlier studies have not effectively tackled slope heterogeneity and interdependence in panel data; thus, their findings can be biased.

3. Theoretical framework, data, and empirical methods

3.1. Theoretical framework and model construction

This study section elucidates the theoretical framework on how financial development, geopolitical risk, eco-innovation, and NRR impact sustainable development. Sustainable finance theory posits that advancing sustainable investments and financial practices can effectively leverage financial development to bolster achieving sustainable development goals. The mobilization of financial resources through financial development facilitates the availability of funding for sustainable development projects, including renewable energy generation, sustainable agriculture, and green infrastructure. Financial development can facilitate innovation by supporting research and development activities, entrepreneurial actions, and the transfer of technology (Yu et al., 2023; Zhou and Du, 2021). Financial development plays a crucial role in fostering innovation, which in turn can contribute to addressing pressing environmental issues, such as resource depletion and climate challenges. In addition, financial development can also encourage the adoption of sustainable production and consumption patterns, thereby promoting sustainable development (Elahi et al., 2022).

Geopolitical risks can tentatively hinder sustainable development by causing various detrimental effects, as posited by the theory of political economy. Geopolitical risks are predominantly associated with political elements, including regional conflicts, economic sanctions, political instability, and trade wars. These factors can substantially impact business operations through international restrictions and risk factors. One of the primary impacts of geopolitical risks on sustainable development is the decline in investment inflows, encompassing domestic and foreign investments (Esfahani, 2006). This phenomenon may arise when investors adopt a more prudent and risk-averse approach, especially in response to a perceived escalation in the likelihood of political instability or conflict within a given geographical area. Consequently, enterprises may hesitate to allocate resources towards novel initiatives or extend their activities within these circumstances, potentially impeding the progress and advancement of the economy. Geopolitical risks can restrict trade and business activities, especially due to economic sanctions or trade barriers (Nguyen et al., 2022). These limitations can potentially restrict entry into markets and access to resources, resulting in a decline in economic activity and a decrease in overall economic growth. This can ultimately undermine the accomplishment of SDGs, particularly those related to economic growth and poverty reduction (Unger and Waarden, 1999).

The ecological modernization theory supports the association between eco-innovation and sustainable development by advocating that innovation in environmental technologies can be a powerful tool for achieving sustainable development goals. This theory posits that sustainable development can be accomplished by promoting the creation and implementation of new environmentally friendly and resource-efficient technologies and processes through eco-innovation. This can help reduce environmental impacts and increase economic competitiveness, promoting social equity and improving quality of life. Additionally, Eco-innovation can help to conserve biodiversity by promoting the development of sustainable land use practices and lowering the impact of human actions on natural ecosystems.

The resource curse theory suggests that nations rich in resources (i.e., oil, gas, and minerals) have slower economic growth and development than resource-poor nations (Ross, 1999). This is because the concentration of wealth and power associated with NRR can lead to increased corruption, unequal distribution of resources, and a lack of diversification in the economy which in turn can hinder sustainable development (Pendergast et al., 2011).

The Dutch disease is a notable consequence of NRR that significantly affects the country's effort toward sustainable development. This phenomenon arises when a nation's economy becomes excessively reliant on a specific natural resource, such as oil, gas, or minerals; it may result in the inadvertent disregard of alternative sectors, such as manufacturing or agriculture. Excessive dependence on a single sector can potentially lead to a decrease in the competitiveness of alternative industries, ultimately resulting in their contraction or potential collapse (Ben-Salha et al., 2021). An alternative viewpoint posits that the effective management of natural resource rents has the potential to foster sustainable development. According to Brunnschweiler (2008), the presence of natural resource rents in abundant resource-rich countries can facilitate the transfer of technology and foster innovation. This, in turn, can contribute to developing appropriate approaches to address environmental issues and promote sustainable production and consumption patterns. Additionally, natural resource rents can be used to finance investments in education, infrastructure, and social services, which can lead to sustainable development (Hussain et al., 2021).

In light of the theoretical underpinnings and work of Koirala and Pradhan (2020) and Hunjra et al. (2022), this study specifies the following functional form in equation (1).

$$SD_{it} = f(FD_{it}, GPR_{it}, EI_{it}, NRR_{it}, GDP_{it}) \tag{1}$$

In equation (1), sustainable development (SD) is the function of financial development (FD), geopolitical risk (GPR), eco-innovation (EI), natural resource rents (NRR), and economic growth (GDP), respectively. The equation is formulated as expressed in equation (2) for empirical examination.

$$SD_{it} = \alpha_0 + \beta_1 FD_{it} + \beta_2 GPR_{it} + \beta_3 EI_{it} + \beta_4 NRR_{it} + \beta_5 GDP_{it} + \varepsilon_{it} \tag{2}$$

In equation (2), α_0 denotes the constant term while "t," and "i" refer to the time dimension and cross-sections, respectively. ε_{it} shows the error term while $\beta_1, \beta_2, \beta_3, \beta_4$, and β_5 represent the coefficients of FD, GPR, EI, NRR, and GDP, respectively.

3.2. Data

This study covers the yearly panel time series dataset for OECD countries from 26 OECD countries "Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Japan, South Korea, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States" from 1990 to 2019. The duration of the study is determined due to the availability of data. The starting year of 1990 is aligned with the availability of sustainable development data. Similarly, the selection of the end year of 2019 is based on the data availability for eco-innovation.

The dependent variable (sustainable development) is quantified as adjusted net savings as a percentage of gross net income (GNI) "Adjusted net savings are equal to net national savings plus education expenditure minus energy depletion, mineral depletion, net forest depletion, and carbon dioxide and particulate emissions damage". Adjusted net savings is a commonly employed proxy to assess sustainable development in contemporary academic literature (Azam et al., 2022; Hunjra et al., 2022; Islam et al., 2022; Koirala and Pradhan, 2020). The World Bank defines adjusted net savings as "gross national savings adjusted for the annual changes in the volume of all forms of capital". As stated by Atkinson and Hamilton (2007), the evaluation of a nation's wealth encompasses the assessment of the social value of its entire capital, encompassing various forms of assets (financial, social, natural, and human). The measurement of net investment over a specific time frame serves as a means to ascertain the progression of wealth. Asset investment is also employed to assess the evolution of social welfare over a specified period. Net investment refers to the collective investment within an economy, excluding the impacts of capital stock depletion or depreciation. The measure of adjusted net savings incorporates net investment as a means of evaluating the economic sustainability within a given society, and it is particularly useful because it also covers social welfare (Hunjra et al., 2023). The data on adjusted net savings is collected from WDI (2022).

The data on the financial development index is obtained from the IMF (2022). The financial development index quantifies the depth, access, and efficiency of a country's financial institutions and financial markets, which reflect the size and scope of financial institutions, access to financial services, and the effectiveness of financial intermediation and market operations, respectively (Tao et al., 2023; Ullah et al., 2023). The geopolitical risk rating index is attained from the ICRG (2022) database. The political risk rating index stipulates a way of gauging the political stability of nations taking into account factors such as bureaucratic quality, external conflicts, internal conflicts, demographic accountability, socio-economic conditions, ethnic tensions, law & order, investment profile, religious tension, government stability, corruption, and military interference in politics. A country with a lower geopolitical risk rating indicates a higher geopolitical risk. On the other hand, if a country has a higher rating, it denotes a lower risk. The geopolitical risk rating index is commonly employed in various studies as a tool to assess and evaluate geopolitical risk ratings (Ahmad et al., 2023a; Wang et al., 2023). The data on natural resource rents (% of GDP), and economic growth (Constant, 2015$) are collected from WDI (2022), while the data on eco-innovation (innovation in environment-related technologies) is obtained from OECD (2022). The variables' measurement, abbreviation used, and data source are provided in Table 1.

3.3. Estimation methods

3.3.1. Cross-sectional dependency test

When analyzing panel data, it is often assumed that the observations are independent and identically distributed across individuals. This assumption may not hold if there is cross-sectional dependence (CSD), which occurs when the observations of one individual in the dataset are correlated with those of another individual. The prevalence of CSD can lead to biased estimates and incorrect inferences in data analysis. Hence, conducting CSD testing before employing other panel data methodologies is imperative. For this purpose, the study used Pesaran's (2004) CSD test. The CD test is specified in equation (3).

$$CSD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\widehat{\rho}_{ij}\right) \tag{3}$$

where the pairwise correlation is indicated by " $\widehat{\rho}_{ij}$, N is for cross-sectional units, and T denotes the study duration.

Table 1
Variables measurement.

Variable	Abb.	Measurement	Data source
Sustainable development	SD	Adjusted net savings (% of GNI)	WDI (2022)
Financial development	FD	This index assesses the level of accessibility, efficiency, and depth of financial institutes and markets.	IMF (2022)
Geopolitical risk	GPR	Political risk rating index	ICRG (2022)
Eco-innovation	EI	Patents on environmental technologies (% of total)	OECD (2022)
Natural resource rents	NRR	Natural resource rents (% of GDP)	WDI (2022)
Economic growth	GDP	GDP per capita (constant 2010 USD)	WDI (2022)

3.3.2. Slope homogeneity test

This study utilized Pesaran and Yamagata (2008) to assess whether the slope is homogenous or heterogenous. The examination of heterogeneity is of utmost importance as it pertains to the identification of potential variations in slope parameters among OECD countries. These variations, stemming from differences in demographic and economic structures, have the potential to impact the consistency of panel estimators. The test equations are provided in equations (4) and (5).

$$\widetilde{\Delta}_{SH} = (N)^{\frac{1}{2}}(2K)^{-\frac{1}{2}}\left(\frac{1}{N}\widetilde{S} - k\right) \tag{4}$$

$$\widetilde{\Delta}_{ASH} = (N)^{\frac{1}{2}}\left(\frac{2k(T-k-1)}{T+1}\right)^{-\frac{1}{2}}\left(\frac{1}{N}\widetilde{S} - k\right) \tag{5}$$

3.3.3. Unit root tests

CIPS and CADF are popular unit root tests used in panel data analysis. Notably, a unit root test is used to determine whether a time series is stationary or not, which is important for conducting appropriate statistical inferences. The CADF and CIPS tests proposed by Pesaran (2007) are useful for unit root analysis, as they account for CSD among the individual time series in the data. Taking into account the CSD enables the tests to offer more precise approximations of the parameters that can enhance the dependability and authenticity of the findings. The CADF test is given in equation (6).

$$\Delta CA_{i,t} = \lambda_i + \varphi_i Z_{i,t-1} + \varphi_i \overline{Z}_{t-1} + \sum_{l=0}^{p} \varphi_{il}\Delta\overline{CA_{t-1}} + \sum_{l=0}^{p} \varphi_{il}\Delta CA_{i,t-1} + \mu_{it} \tag{6}$$

where in equation (6), the cross-section averages are represented by $\overline{CA}_{t-1}$ and $\Delta\overline{CA_{t-1}}$. The expression for the CIPS test is given in equation (7):

$$\widehat{CIPS} = \frac{1}{N}\sum_{i=1}^{n} CDF_i \tag{7}$$

In equation (7), the cross-sectional augmented Dickey-Fuller is denoted by CDF.

3.3.4. Panel cointegration test

The panel cointegration test is important in econometric analysis because it can help identify the underlying relationships among variables that may not be apparent in simple cross-sectional or time-series analyses. Westerlund (2007) proposed a panel cointegration test that has gained popularity in the field of econometrics. The test is centered on the bootstrap procedure and is robust to CSD, heterogeneity, and non-stationarity of the variables, which are common issues in panel data analysis. The cointegration equation is given in equation (8):

$$\alpha_i(L)\Delta y_{it} = \delta_{1i} + \delta_{2i}t + \alpha_i\left(y_{it-1} - \beta_i^{'}x_{it-1} + \lambda_i(L)^{'}v_{it} + e_{it}\right. \tag{8}$$

In equation (8), β_i represents the vector of the cointegrating relationship between the interrelated variables y and x.

3.3.5. Long-run analysis and robustness test

After identifying the cointegration relationship, the next recommended step is to investigate the long-term cointegration coefficients of the selected variables. The Common Correlated Effects Mean Group (CCEMG) method, as proposed by Pesaran (2006), is a widely employed approach in panel data analysis for evaluating the long-term association among the variables as it effectively addresses panel data issues, such as slope heterogeneity and cross-sectional dependence (Zeqiraj et al., 2020). The test can be written as follows:

$$y_{it} = \beta_i x_{it} + \eta_i \overline{y}_{it} + \theta_i \overline{x}_{it} + \alpha_i + \gamma_i f_t + u_{it} \tag{9}$$

In equation (9), the symbols $\overline{x}_{it}$ and $\overline{y}_{it}$ represent the means of the independent and dependent variables across different cross-sectional units, respectively. The symbol β_i represents the coefficient of the unit slope in the given context. Meanwhile, f_t, and u_{it} represent the latent common factors and the stochastic error term. Similar to the mean group (MG) technique, each panel regression is evaluated using ordinary least squares (OLS), and the MG estimators are obtained by averaging the observations within each panel unit. This test is articulated in equation (10).

$$CCEMG = \frac{1}{N}\sum_{i=1}^{N}\widehat{\beta}_i \tag{10}$$

In order to validate the findings derived from the CCEMG analysis, this study employs the CuP-FM and CuP-BC methodologies established by Bai et al. (2009). These methodologies provide numerous benefits, including the ability to tackle endogeneity, serial correlation, cross-sectional dependence, and heteroscedasticity. This method is expressed in equation (11):

$$\widehat{\beta}cup, \widehat{F}cup = \text{armin}\frac{1}{nT^2}\sum\nolimits_{i=1}^{n}(y_i - x_i\beta)^{'}M_F(y_i - x_i\beta) \tag{11}$$

3.3.6. Panel granger causality test

Although the results from the CCEMG provide valuable inferences, estimating the causal flow among the variables is equally imperative for sustainable growth policies. The causal directions can give policymakers and researchers valuable insights into the underlying mechanisms that drive changes in the dependent variable, allowing them to develop impactful policies and interventions. In this study, we employ the Granger causality method proposed by Dumitrescu and Hurlin (2012) to probe the causal relationships among the variables. The causality test is articulated in equation (12):

$$\delta_{i,t} = \eta_i + \sum_{k=1}^{N}\gamma_i^{(k)}\delta_{i,t-k} + \sum_{k=1}^{N}\varphi_i^{(j)}\delta_{i,t-j} + \kappa_{i,t} \tag{12}$$

Where in equation (12) η_i is the intercept term and is the lag order ($1K \sim K$). In addition, γ and φ show the autoregressive coefficients.

4. Results and discussions

Table 2 displays the Pesaran's (2004) CSD test results for the variables under investigation. The test statistics for all variables exhibit statistical significance at the 1% level, suggesting the presence of CSD among the variables. The study includes each variable's mean absolute values of pairwise correlations (ρ). These correlations range from 0.350 for SD to 0.930 for GDP, with a median value of 0.517 for EI. In general, the findings indicate that the variables within the dataset exhibit a lack of independence and demonstrate a notable level of interdependence. Consequently, it is crucial to consider and address this CSD in subsequent analyses in order to prevent biased and inefficient estimates.

Table 3 demonstrates the finding of Pesaran and Yamagata's (2008) slope heterogeneity test. The significant test values for $\widetilde{\Delta}$ and $\widetilde{\Delta}_{adjusted}$ demonstrate the existence of slope heterogeneity against the null hypothesis of homogeneity of slopes. These findings suggest heterogeneity

Table 2
CSD test results.

Variable	Value	P-value	Mean abs(ρ)
SD	14.621*	0.000	0.350
FD	9.453*	0.000	0.805
GPR	35.626*	0.000	0.392
EI	49.546*	0.000	0.517
NRR	31.361*	0.000	0.373
GDP	88.274*	0.000	0.930

Note. The symbol * denotes a level of significance at 1%.

Table 3
Slope heterogeneity test results.

Test	Value	Prob.
$\tilde{\Delta}$	17.597*	0.000
$\tilde{\Delta}_{adjusted}$	20.097*	0.000

Note. The symbol * denotes a level of significance at 1%.

in the slope parameters, and it is necessary to account for this slope heterogeneity in subsequent analyses to ensure robust and accurate outcomes.

Pesaran (2007) CADF and CIPS tests were utilized to determine the variables' stationarity under investigation, and the findings are given in Table 4. The results specify that the SD and GDP indicate a unit root issue at the level (I (0)) in the CIPS test. The findings of the CADF reveal that the SD, NRR, and GDP variables show signs of nonstationarity at the level (I (0)). Overall, the unit root test indicates that the variables' sequence of integration is inconsistent. After the first differentiation, however, all variables become stationary.

As illustrated in Table 5, the outcomes of the panel cointegration test performed by Westerlund (2007) specify the presence of cointegration among the underlying variables. The group and panel values are statistically significant at the 1% level, indicating that SD, FD, GPR, EI, NRR, and GDP move in tandem. Given that the panel dataset of OECD countries exhibits cointegration, it is suitable to obtain the long-term coefficients.

The long-run results using the CCEMG approach in Table 6 indicate that FD has a positive and statistically significant influence on sustainable development. Specifically, the coefficient of FD in the regression model is 0.551, which means that a 1% upsurge in FD is linked with a 0.551% increase in sustainable development, holding all other factors constant. This suggests that FD can play an imperative role in promoting sustainable economic growth in OECD countries. One way in which FD promotes sustainable economic growth is by increasing access to credit and financing. This allows businesses and individuals to invest in new technologies and innovations that promote sustainability and reduce the undesirable impact of economic activities on the natural environment. For instance, FD may provide loans to firms that invest in renewable energy sources like solar or wind power, reducing their dependency on fossil fuels and contributing to sustainable economic growth. The availability of credit and other financial services can help individuals and businesses invest in education, health care, and other basic needs, leading to higher incomes, improved living standards, and sustainable development. Financial development can facilitate international investment in sustainable projects and initiatives. OECD countries have the advantage of having developed financial markets and institutions, which can attract foreign investments in sustainable projects and promote sustainable development. These findings are similar to the study of Jalilian and Kirkpatrick (2005), Asteriou and Spanos (2019), and Cao et al. (2021), who also found a favorable impact of FD on sustainable development.

The geopolitical risk rating index (GPR) significantly and positively impacts sustainable development in OCED countries. As discussed before, a country with a higher rating implies a lower geopolitical risk, whereas a lower geopolitical risk rating index indicates a high risk. Thus, statistically, a 5% improvement in the GPR can increase sustainable development by 0.013%. These results are reasonable because OECD countries are advanced economies with stable political systems compared to non-OECD countries. In addition, OECD countries have access to more resources and expertise to help them manage geopolitical risks. OECD can also benefit from diplomatic channels and international organizations like the United Nations to reduce geopolitical risks. Thus, stable political systems generally give them a greater ability to manage these risks and continue to pursue sustainable development. Geopolitical risk mitigation positively impacts sustainable development within OECD countries through various mechanisms. Firstly, reduced geopolitical tensions and conflicts significantly foster a stable and foreseeable atmosphere conducive to economic endeavors (Cao et al., 2023). The stable political and economic environment serves as a catalyst for investments, trade activities, and the expansion of businesses, thereby facilitating the process of sustainable development. Countries that experience long-term economic growth are in a more advantageous position to allocate resources toward initiatives that promote sustainable development. These initiatives may include projects focused on renewable energy, conservation of the environment, and improving social welfare.

Additionally, a reduction in geopolitical risk facilitates international cooperation and collaboration. Nations can collaborate in mutual actions to tackle worldwide issues, such as climate change, pollution, and resource depletion. Through collaboration, OECD countries can combine their resources, exchange expertise, and adopt efficient policies and strategies to attain sustainable development objectives successfully. Additionally, the mitigation of geopolitical risk has the potential to bolster stability within supply chains and improve the availability of resources. The occurrence of political instability and conflicts in specific regions has the potential to cause disruptions in supply chains, thereby resulting in economic disturbances and subsequent price escalations. By implementing strategies aimed at reducing geopolitical risks, countries can effectively guarantee consistent and dependable access to vital resources and commodities required to promote sustainable development. Finally, a decrease in geopolitical risk can positively impact investor confidence and serve as a catalyst for attracting foreign direct investment (FDI) (Nguyen et al., 2022). International investors are inclined towards long-term investments due to the appeal of political stability and diminished risk. The augmentation of FDI can infuse financial resources, specialized knowledge, and advanced technology into

Table 4
Panel unit root test.

	CIPS		CADF	
	I(0)	I(1)	I(0)	I(1)
SD	−1.991	−5.058*	−1.960	−4.224*
FD	−2.682*	−5.389*	−2.361*	−4.071*
GPR	−2.914*	−5.316*	−2.904*	−4.455*
EI	−3.683*	−5.617*	−3.102*	−4.663*
NRR	−2.273*	−5.552*	−1.873	−4.222*
GDP	−1.857	−4.182*	−1.882	−3.086*

Note. The symbol * denotes a level of significance at 1%.

Table 5
Panel cointegration test results.

Statistic	Value	Z-value	P-value	Robust P-value
G_t	−3.068*	−4.357	0.000	0.000
G_a	−9.583**	1.422	0.923	0.028
P_t	−13.212**	−2.961	0.002	0.042
P_a	−8.374	−0.219	0.413	0.113

Note: The symbols * and ** denote significance levels of 1% and 5%, respectively. Bootstrapping at 600.

Table 6
Long-run results (CCEMG).

	Coefficient	Std error	Z-stat.	Prob.
FD	0.551**	0.267	2.060	0.039
GPR	0.013**	0.005	2.440	0.015
EI	0.027**	0.012	2.320	0.020
NRR	−0.161**	0.073	−2.220	0.026
GDP	1.047*	0.399	2.620	0.009
Constant	4.304*	1.439	2.990	0.003

Note: The symbols * and ** denote significance levels of 1% and 5%, respectively.

initiatives aimed at sustainable development. These factors jointly contribute to pursuing sustainable development goals and creating a more sustainable future. These results are similar to the findings of Cheng et al. (2018) and Akadiri et al. (2020) but oppose the outcomes of Sweidan and Elbargathi (2022), who did not find a significant association between geopolitical risk and economic development.

The findings further revealed a positive association between eco-innovation (EI) and sustainable development (SD). The positive coefficient suggests that for every 1% increase in eco-innovation, sustainable development increases by 0.027% in the long term. The result indicates that promoting eco-innovation is a useful strategy for attaining sustainable progress in OECD countries. One of the vital aspects of this favorable association lies in eco-innovations capacity to encounter various environmental challenges, including but not limited to climate change, pollution, and the exhaustion of natural resources. Eco-innovation addresses these challenges through the development of cleaner and more efficient technologies, the utilization of renewable energy sources, and the implementation of sustainable production methods. Countries can facilitate the emergence and growth of green industries and sectors associated with renewable energy, waste management, and environmentally conscious products and services by allocating resources toward developing and implementing environmentally sustainable technologies and practices. The emergence of these sectors not only generates employment opportunities and fosters economic development but also serves to advance sustainable practices. The implementation of eco-innovation has the potential to enhance the overall quality of life through the provision of improved air and water quality, as well as the creation of more favorable surroundings. Moreover, eco-innovation facilitates the mitigation of social disparities and the enhancement of accessibility to sustainable solutions, assuring the equitable distribution of sustainable development advantages across diverse societal groups (Beretta, 2018). These results are consistent with Chen et al. (2023) for BRICS and Suki et al. (2022) for ASEAN countries.

The results further suggest an unfavorable impact of NRR on sustainable development in OECD nations. The coefficient for NRR is −0.161, which is statistically significant at the 5% level. This suggests that a 1% rise in NRR is associated with a 0.161% decrease in sustainable development in OECD countries. The observed negative association can be attributed to the phenomenon known as the "resource curse," which posits that countries endowed with abundant natural resources often experience lower levels of sustainable development. This implies that nations heavily dependent on revenue generated from natural resources may encounter obstacles in attaining sustainable development in the long run. Policymakers ought to take into account the importance of investing in alternative sectors, such as renewable energy, green technologies, and services, as a means to diversify the economy and diminish reliance on revenue derived from natural resources. This may help to promote sustainable development over the long term while mitigating the negative environmental and social impacts of natural resource extraction. The results of the study support the findings of Ampofo et al. (2023) but contradict the results of Brunnschweiler (2008), Raheem et al. (2018), and Huang and Zhao (2022), who argued that NRR positively contribute to sustainable development. Furthermore, the findings revealed a favorable relationship between income per capita and sustainable development in OECD nations. Specifically, the per capita income demonstrates a positive association with adjusted net savings within the OECD context. As a nation's per capita income expands, there tends to be an increased capacity for savings and investment, which can subsequently be directed towards endeavors promoting sustainable development. Economic growth facilitates the allocation of greater financial resources by individuals and the government towards sectors such as education and renewable energy, which in turn fosters sustainable development. Thus, by prioritizing sustainable investments, countries possess the ability to foster a future that encompasses sustainability and inclusivity for their current population as well as future generations.

The robustness test in Table 7 is established on the CuP-FM and CuP-BC, indicating that financial development, geopolitical risk, eco-innovation, and economic growth have positive coefficients, while natural resource rents have a negative coefficient. Thus, the results determined from the CuP-FM and CuP-BC are reliable and similar to the outcome of CCEMG.

Table 7
Robustness check.

	CuP-FM		CuP-BC	
Variable	Coefficient	T-statistics	Coefficient	P-value
FD	0.644*	12.136	0.635*	16.894
GPR	0.052*	19.133	0.043*	12.620
EI	0.340*	24.810	0.122*	29.477
NRR	−0.334*	−6.352	−0.243*	−3.157
GDP	0.570*	10.233	0.452*	14.943

Note: The symbol * denotes a significance level of 1%.

Table 8 presents the results of the panel Granger causality. The findings indicate that FD, EI, NRR, and GPR Granger cause SD, but not the other way around. Moreover, two-way causality exists between GDP and SD. It means policies related to GDP can Granger cause SD and vice versa. Moreover, the results indicate bidirectional causality between FD and EI. It suggests that financial development can contribute to eco-innovation by providing firms with the necessary financial resources to invest in research and development and materials required for eco-innovation. Furthermore, proficient financial markets offer paths for capital acquisition via initial public offerings (IPOs) or the issuance of green bonds, thereby attracting investors with a vested interest in promoting eco-innovation. Conversely, eco-innovation also Granger causes financial development. As societal awareness of environmental challenges and the preference for sustainable solutions grows, the demand for green products rises. This demand presents potential avenues for entrepreneurs and businesses to allocate resources towards research and development, thereby fostering the growth of environmentally sustainable industries and facilitating the generation of employment opportunities within these sectors. The expansion of these sectors can, in return, promote financial markets and institutions by drawing investments, facilitating the movement of capital, and encouraging the creation of dedicated financial institutions and markets that cater to the funding requirements of environmentally friendly enterprises. GPR Granger causes FD, EI, NRR, and GDP. Also, FD, EI, NRR, and GDP Granger cause GPR posing a feedback effect. These results highlighted the significance of geopolitical risk that can impact a country's FD, eco-innovation, and NRR. Geopolitical risk can harm financial development by creating instability and uncertainty, which can result in reduced investment and investor confidence, ultimately hindering FD. On the other hand, financial development can also shape geopolitical risk by promoting economic growth and stability. Geopolitical risks, such as political instability and conflicts, can disrupt the production and extraction of natural resources, reducing resource rents. It is worth noting that the existence of valuable natural resources can also serve as a catalyst for geopolitical tensions and conflicts as the competition to gain control and access to these resources becomes more intense. The reciprocal relationship between political stability and the utilization of natural resources emphasizes the significance of implementing sustainable resource management strategies and efficient conflict resolution mechanisms in order to reduce the negative impacts of geopolitical risks on resource revenues.

5. Conclusion and policy implications

The study investigates the impact of financial development, eco-innovation, NRR, and GDP on sustainable development in OECD countries. Additionally, the study analyzes the role of geopolitical risk in this model. The study employed advanced econometric estimation methods using the data from 1990 to 2019. The empirical outcomes depict that

Table 8
Panel Granger causality test.

Variable	SD	FD	GPR	EI	NRR	GDP
SD	–	2.767* [0.005]	1.868*** [0.061]	1.783*** [0.074]	2.351** [0.018]	3.071* [0.002]
FD	1.029 [0.303]	–	2.056** [0.039]	2.641* [0.008]	3.474* [0.000]	2.790* [0.005]
GPR	0.915 [0.360]	2.611* [0.009]	–	1.864*** [0.062]	2.601* [0.009]	2.975* [0.003]
EI	0.989 [0.322]	2.194** [0.028]	2.355** [0.018]	–	4.531* [0.000]	7.638* [0.000]
NRR	1.069 [0.285]	0.750 [0.452]	3.192* [0.001]	1.158 [0.246]	–	4.299* [0.000]
GDP	5.766* [0.000]	4.030* [0.000]	7.126* [0.000]	3.457* [0.000]	4.081* [0.000]	–

Note: The symbols *, **, and *** denote significance levels of 1%, 5%, and 10%, respectively.

financial development and eco-innovation significantly promote sustainable development in OECD countries. In addition, reducing geopolitical risk significantly and positively impacts sustainable development in these countries. However, NRR impedes sustainable development, supporting the resource curse hypothesis in OECD countries. Moreover, economic growth is significantly and positively related to sustainable development. The panel Granger causality test indicates unidirectional causality running from financial development, geopolitical risk, eco-innovation, and NRR towards sustainable development. Moreover, geopolitical risk Granger causes financial development, eco-innovation, and NRR and vice versa.

Based on the findings of this study, the policy implications are suggested as follows: Firstly, the results suggest that there is a positive relationship between financial development and sustainable development. Therefore, it is imperative for policymakers to give precedence to initiatives that focus on bolstering financial development. These may include initiatives to enhance financial infrastructure, expand the availability of financial services, and foster financial literacy. Furthermore, it is imperative to undertake initiatives aimed at establishing a conducive atmosphere for investment, encompassing the implementation of legal and regulatory structures that safeguard the interests of investors while fostering transparency. Also, the implementation of policies that promote competition and foster innovation within the financial sector can also contribute to the advancement of sustainable development. The COP27 meeting underscored the importance of innovative climate and development funding. Nonetheless, current flows of climate financing are insufficient and are not scaling up at the requisite pace to align with the targets set forth in the Paris Agreement. The conference underscores the imperative for a global shift to a low-carbon economy, necessitating annual investments of at least USD 4–6 trillion. To mobilize such financial resources, a rapid and comprehensive transformation of the financial system, including its structures and processes, is imperative. This transformation requires concerted efforts from governments, central banks, commercial banks, institutional investors, and other financial stakeholders (COP27, 2022).

Secondly, geopolitical risk poses a significant impact on sustainable development. The government should augment its diplomatic endeavors and conflict resolution mechanisms to mitigate geopolitical risks. Active participation in international organizations and multilateral initiatives, such as the United Nations, offers distinct advantages in promoting the attainment of amicable resolutions between nations. According to the World Economic Report (2023), escalating geopolitical conflicts, such as the Russian-Ukraine war and trade tensions between the United States and China, are pivotal to the effective functioning of the global economic system and pose a severe threat to sustainable development. Consequently, policymakers should formulate policies aimed at fortifying international cooperation and integration through trade and investment among neighboring nations to mitigate geopolitical tensions.

Thirdly, natural resource rents pose a detrimental effect on sustainable development. Therefore, it is suggested that the government should lessen reliance on natural resources by facilitating investments in alternative economic sectors, particularly the service industry and renewable energy sector. It is imperative for nations involved in resource production and importation, along with extractive industries, to collaborate in order to transition the extractive sector into a catalyst for sustainable development characterized by low-carbon emissions, climate resilience, inclusivity, and long-term viability. The OECD Policy Dialogue on Natural Resource-based Development (PD-NR) functions as an intergovernmental forum fostering the exchange of ideas and information among OECD and non-OECD countries engaged in natural resource extraction and consumption in a sustainable manner. Fourthly, eco-innovation poses a favorable impact on sustainable development. In the present scenario, it is imperative for governments to extend financial and regulatory assistance towards eco-innovation. This entails allocating funds for research and development of environmentally friendly technologies, offering incentives to encourage businesses to adopt sustainable practices, and actively promoting the adoption of green technologies across all sectors. Furthermore, policymakers should encourage and foster collaboration among governmental entities, businesses, and academic institutions to effectively facilitate the advancement and implementation of eco-innovation. This could be accomplished by fostering public-private partnerships, establishing platforms for disseminating knowledge, and exchanging best practices. The United Nations Framework Convention on Climate Change (UNFCCC) and COP27 underscore the significance of scaling up and enhancing the effectiveness of innovation in addressing climate change and contributing to the achievement of the United Nations' Sustainable Development Goals (SDGs).

5.1. Limitations and future directions

The current study has identified a few limitations and offers recommendations for future research endeavors. One limitation of this study is its focus solely on the panel of OECD countries, which restricts the generalizability of the findings to a broader global context. Additionally, this study relies on data collected from the years 1990–2019, indicating the potential for further investigation by incorporating data from subsequent years to extend the temporal scope. Future studies can further analyze the model by employing Artificial Intelligence tools for analysis and predictions. Furthermore, the imminent COP 28 conference, scheduled at the end of the current calendar year, is poised to prioritize the attainment of reductions in global warming, aligning with the overarching goal of realizing the 1.5 °C target stipulated in the 2015 Paris Agreement, aiming to mitigate the deleterious impacts of climate change. Within this framework, prospective research endeavors may focus on the examination of parameters discussed in this paper particularly resource abundance, geopolitical risk, and eco-innovation. Given that this study does not focus on carbon neutrality targets, the objective of future inquiries can be to elucidate the influence of these factors on the realization of carbon neutrality objectives, thereby proffering nuanced policy recommendations conducive to the attainment of carbon neutrality by the mid-point of the twenty-first century.

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CRediT authorship contribution statement

Mahmood Ahmad: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing - original draft. **Zahoor Ahmed:** Conceptualization, Data curation, Formal analysis, Validation, Writing - original draft. **Rafael Alvarado:** Writing - review & editing. **Nazim Hussain:** Project administration, Resources, Supervision, Writing - review & editing, Writing - review & editing.

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.

Data availability

Data will be made available on request.

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