



Financial Risk, Renewable Energy Technology Budgets, and Environmental Sustainability: Is Going Green Possible?

Mahmood Ahmad¹, Zahoor Ahmed^{2,3}, Beata Gavurova^{4*} and Judit Oláh^{5,6}

¹Business School, Shandong University of Technology, Zibo, China, ²Department of Accounting and Finance, Faculty of Economics and Administrative Sciences, Cyprus International University, Nicosia, Turkey, ³Department of Economics, School of Business, AKFA University, Tashkent, Uzbekistan, ⁴Faculty of Mining, Ecology, Process Control and Geotechnologies, Technical University of Košice, Košice, Slovakia, ⁵Faculty of Economics and Business, University of Debrecen, Debrecen, Hungary, ⁶Department of Public Management and Governance, College of Business and Economics, University of Johannesburg, Johannesburg, South Africa

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*Correspondence:

Beata Gavurova
Beata.Gavurova@tuke.sk

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Since the industrial revolution, countries have been facing the issue of climate change and environmental degradation. It is widely believed that the investment in research and development of renewable energy can play a pivotal role in fighting against climate change. However, the financial risk also increases, which can influence renewable energy technology R&D budgets and environmental sustainability. Nevertheless, the current literature is silent on the linkage between financial risk, renewable energy technology budgets, and environmental quality. Against this backdrop, this article attempts to explore the dynamic linkage between financial risk, renewable energy technology budgets, and ecological footprint under the Environment Kuznets Curve (EKC) framework in Organization for Economic Cooperation and Development (OECD) countries. For this purpose, yearly data from 1984 to 2018 is employed using the advanced panel data estimation methods that address the slope heterogeneity and cross-sectional dependence issues. The results indicate that improvement in the financial risk index significantly decreases footprints, and renewable energy technology budgets also promote environmental sustainability. Economic globalization poses a significant negative effect on the ecological footprint, while energy consumption adds to the footprint. Moreover, the findings validated the EKC hypothesis in OECD countries. In addition, a unidirectional causality is detected from financial risk to renewable technology energy budgets, while bidirectional causality exists between financial risk and ecological footprint, and between financial risk, and economic growth. Based on the empirical findings, policy suggestions are presented to promote environmental sustainability.

Keywords: financial risk, renewable energy technology budgets, environmental sustainability, OECD, CS-ARDL

INTRODUCTION

Undoubtedly, climate change is posing adverse effects on human life and the environment in every region. Decades of persistent efforts by the international community and environmentalists resulted in certain agreements and commitments to tackle the growing environmental challenges. In this context, the United Nations member nations agreed to pursue Sustainable Development Goals (SDGs) that offer guidance to solving various important global challenges (UN, 2021). All 17 SDGs are vital for safeguarding the foundations of life and supporting human prosperity; however, goal 13, which seeks immediate actions to address climate change, provides the foundation of sustainable development. This goal is closely linked with all other 16 goals that are important to pursue sustainable development.

The Paris Agreement was an important initiative to combat climate change and keep the global temperature increase below 2°C. The importance of the Paris Agreement cannot be denied; however, the commitments from all the signatories are insufficient to fulfill its objectives since the emissions level is not expected to change by 2030. Moreover, the global temperature level can reach 1.5°C by early 2030 and even 2°C level by 2050 (Almond et al., 2020). On the other hand, most nations are facing the issue of reducing biocapacity against the massively increasing ecological footprint (EF) (Mohammed et al., 2021), which indicates that resource consumption is augmenting and Earth's regenerative capacity is plummeting (GFN, 2021). Under such a situation, it becomes necessary to explore some new dimensions and factors that could influence climate change and EF.

Economic progress has long been considered the primary driver of environmental pollution (Alvarado et al., 2021b). Evidently, growth in almost every economy is fueled by energy (Alvarado et al., 2019), and the energy structure of most countries is constituted of fossil energy up to a great extent (Kanat et al., 2021; Oláh et al., 2021; Štreimikienė, 2021; Hussain et al., 2022b). Hence, it is not surprising that growth levels are closely knotted with environmental pollution (Ahmed et al., 2021a). However, the growth of nations and environmental deterioration association is generally discussed under the Environment Kuznets Curve (EKC) framework, which explains that environmental pollution upswings only at primary levels of growth, and growth beyond a specific level, can stimulate clean technologies, ecological laws, innovation, energy efficiency, etc. that can alleviate the rising level of environmental pollution (Alvarado et al., 2021a; Ahmad et al., 2022; Ali et al., 2022; Hussain, 2022). Thus, renewable technology budgets (RTB) are among the necessary factors that could lessen the destructive environmental repercussions of growth. RTB are among the basic elements of innovation in green energy, and providing global access to low-cost electricity, which is the target seven of SDGs, needs more investments in wind, solar, thermal, and other clean sources of energy. Boosting the innovation through RTB can produce some green technologies, which will augment renewables' share in the total energy mix, and lower the dependence on coal, gas, and oil (Ahmed et al., 2021b).

Hence, this research uncovers the impacts of renewable technology budgets (RTB), and financial risks (FR) on

environmental deterioration in the OECD nations. Ensuring the energy transition of economies entails investments from governments in the form of RTB as well as from the private sector. In this context, the financial risk levels of economies are expected to affect cleaner investments, and thus, the production of green energy can be significantly influenced by risk levels. In addition, FR of economies can decrease economic stability, climate protection preferences, and environmental regulations (Xue et al., 2022), which in turn can escalate EF. On the contrary, stable economic systems with fewer risks are beneficial for maintaining a persistent level of RTB and consistent environmental policies, which in turn can lessen pollution levels.

To apprehend the FR and RTB effects on EF, this study selected the sample of OECD because this group of nations has a massive 60% contribution to global GDP. Alongside, these countries are committed to reducing fossil energy and boosting clean energy since around 50% of the world's clean energy is utilized by OECD (BP, 2021). The OECD nations are among the fastest-growing economies that emit around 35% of the world's emissions (Majeed et al., 2022). In addition, the majority of member countries in the OECD group are dealing with high ecological deficits (GFN, 2021). Moreover, this group of countries is famous for its significant investment in cleaner technologies and carbon control research. Also, FR in the OECD group has significantly increased over the last 2 decades (ICRG, 2021).

Based on this background, this study complements the literature in several ways. Firstly, this study investigates the impact of the financial risk index on the ecological footprint in OECD countries. Secondly, this study integrates the financial risk index and renewable energy technology budgets into one framework to probe their impact on ecological footprint. No existing research has combined these three indicators together for environmental policies; thus, this study makes a unique contribution under the specific background of OECD. Lastly, this study employed the CS-ARDL method that handles cross-sectional dependence, endogeneity, and heterogeneity in data. Apart from this, the causal analysis at the end of the study is performed to disclose the causal flow among variables.

LITERATURE REVIEW

Since the UN climate conference (COP21) in Paris in 2015, countries are committing to becoming carbon neutral in the coming few decades. Allocation of financial resources towards renewable energy technological innovation is considered a viable way to reduce the dependence on fossil fuels and, at the same time, fulfill the dream of carbon neutrality. However, countries are facing internal and external challenges such as trade friction, anti-globalization trends, health-related issues (Covid-19 pandemic), and financial risk, which are increasingly influencing investment decisions that may affect climate-related goals. Consequently, the influence of financial risk on environmental quality has gained little consideration from academia and found contradictory results. For instance, Zhang and Chiu (2020) used the data of 111 nations from 1985 to 2014

to analyze the non-linear impact of country risk (i.e., economic, political risk, and financial) on CO₂ emissions. Their results illustrated that financial risk monotonically escalates environmental degradation across panel countries. On the contrary, Zhang (2011) reported that financial stability increases the CO₂ emissions in China. Nevertheless, Ozturk and Acaravci (2013) underlined that financial stability does not pose a significant impact on emissions in the long term. Recently, Zhao et al. (2021) disclosed that financial risk increases CO₂ emissions directly but also indirectly influences technological innovation.

Growing global concern about the devastating effect of fossil fuel energy use (e.g., coal, oil, and gas) on the environment has prompted many countries to shift their energy structure towards renewable energy sources. Indeed R&D in the renewable energy sector can be a viable way to boost its share in the primary energy mix and promote green growth (Alvarado et al., 2021a; Hussain et al., 2022a). For instance, the study of Shahbaz et al. (2018) underlines that energy research innovation significantly enhances environmental quality in France. They further highlighted that financial stability is an absolute prerequisite for energy innovation and improving environmental quality. Similarly, Jin et al. (2017) also reported that technological advancement in the energy sector curbs ecological degradation and documented the inverted U-shaped association between GDP and pollution in China. Similarly, another study was carried out by Baloch et al. (2021) in the context of OECD countries between 1990 and 2017. They concluded that the energy budget promotes environmental sustainability, and the inverted U-shaped association exists between GDP and emissions in OECD economies.

In recent empirical work, Altıntaş and Kassouri (2020) investigated the influence of energy technology expenditures on environmental degradation in 12 EU economies from 1985 to 2016. Their empirical findings show that energy budgets significantly promote environmental sustainability while positive shocks in budgets reduce emissions; however, negative shock does not affect carbon footprint. In contrast, Ahmad et al. (2021) studied the asymmetric and symmetric linkage between RTB and CO₂ in the United States from 1985 to 2017 using the ARDL method. The author disclosed that RTB do not pose a significant effect on emissions. Moreover, positive or negative changes in RTB could not significantly impede CO₂ emissions in the United States. Yang et al. (2022) studied the impact of RTB on environmental quality in G-7 countries from 1985 to 2019 and found that RTB decrease CO₂ emissions.

Conversely, Jordaan et al. (2017) claimed that energy technology investments are heavily weighted toward fossil fuels which increase emissions in Canada and hinder climate-related commitments. The author suggested that regional policies should be aligned with federal climate change policies to curb emissions and enhance clean energy innovation in Canada. Similarly, Koçak and Ulucak (2019) studied the influence of energy R&D expenditures on environmental quality in 19 OECD member countries from 2003 to 2015. Their empirical results revealed that the energy R&D disbursements for energy efficiency and fossil fuel have

an escalating impact on CO₂, while renewable R&D expenditures did not influence CO₂ emissions.

Based on the review of the literature, we can deduce the following aspects. Firstly, few studies examined the linkage between financial risk and ecological quality and demonstrated inconsistent conclusions. Besides, the possible association between financial risk, RTB, and EF is unexplored. Secondly, the literature is silent on how financial risk Granger causes RTB. Thirdly, the current literature extensively used carbon (CO₂) emissions as an indicator of environmental sustainability. While discussing the climate change goal, focusing merely on CO₂ emissions cannot provide a holistic view. Lastly, previous studies used the first-generation estimation methods and ignored panel data's problems, such as CD and slope heterogeneity, which may affect the estimator's consistency and lead to biased results. Against this backdrop, this study fills this gap and investigates the dynamic linkage between financial risk, RTB, and ecological footprint in OECD countries under the EKC framework.

MATERIAL AND METHODS

This study developed the following model to analyze the dynamic linkage between financial risk, RTB, and ecological footprint under the EKC framework.

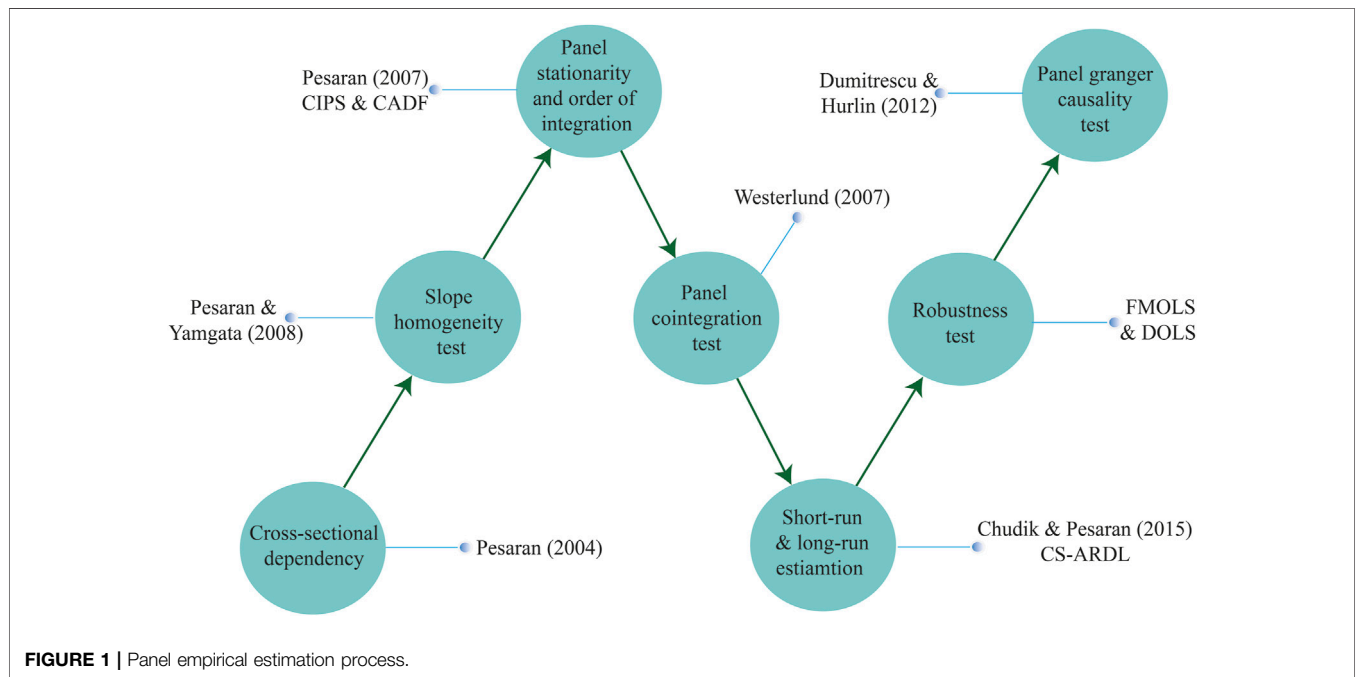
$$\ln EF_{it} = \alpha_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln GDP_{it}^2 + \beta_3 \ln FR_{it} + \beta_4 \ln RTB_{it} + \beta_5 \ln EG_{it} + \beta_6 \ln EC_{it} + \varepsilon_{it} \quad (1)$$

In **Equation 1**, the dependent variable is the ecological footprint (EF). Explanatory variables included the GDP and GDP² indicating the economic growth per capita (constant 2010\$) and its quadric term. Financial risk index (FR) is the core explanatory variable, which is established based on five indicators, i.e., 1) total foreign debt as % of GDP, 2) exchange rate stability, 3) current account as a percent of exports of goods and services, 4) international liquidity, and 5) debt service as % of EGS. The renewable energy research and development budgets (RTB) are in million \$ (2020 prices and PPP). Economic globalization (EG) is a broad index based on financial and trade globalization, while E.C. denotes the primary energy consumption per capita (gigajoule). α_0 and ε_{it} denote intercept and residual term, respectively. Lastly, t and i depict time dimension and country, respectively.

This paper used the data of 18 OECD countries from 1984 to 2018 for empirical analysis. As for as the data sources are concerned, the data of EF is obtained from GFN (2021). The financial risk data is obtained from the International Country Risk Guide database (ICRG, 2021). The data of RTB is acquired from IEA (2022). The data of the economic globalization index is sourced from the KOF Swiss Economic Institute developed by Gygli et al. (2019). The data on energy consumption and GDP are attained from BP (2021), and WDI (2021), respectively. All selected variables are transformed into their natural logarithm form before empirical estimation. **Table 1**

TABLE 1 | Variable's description.

Variable	Symbol	Measurement	Source
Ecological footprint	EF	Global hectares per capita	GFN (2021)
Economic Growth	GDP	Per capita (constant 2010US\$)	WDI (2021)
Financial risk	FR	Financial risk rating index—0 (High) → 50 (low)	ICRG (2021)
Renewable energy technology budget	RTB	Million US\$ (2020 prices and PPP)	IEA (2022)
Economic globalization	EG	Index based on financial and trade globalization	Gygli et al. (2019)
Energy consumption	EC	Primary energy consumption (Gigajoule per capita)	BP (2021)



depicts the details of variables used in this study for empirical analysis.

This article used advanced estimation methods for empirical assessment, primarily based on the following steps. The OECD economies are high-income countries and extremely integrated through social, economic, and political ways. Thus, it is crucial to consider the cross-sectional dependence (CD) issue among study variables because ignoring CD can lead to erroneous and invalid estimates. This research employed the CD test of Pesaran (2004) for this purpose. These economies share common traits in many ways; however, also differ in some aspects, such as geographical structure, culture, and allocation of funds towards RTB. Thus, ignoring slope heterogeneity may yield biased estimates. This study utilized the slope homogeneity test established by Pesaran and Yamagata (2008). Next, this study examines the stationarity characteristics of selected variables using the CIPS and CADF unit root test of Pesaran (2007). After primary analysis, the subsequent proposed step is to inspect the long-term equilibrium relationship, which is investigated by using the cointegration test (Westerlund, 2007). Afterward, we analyze the short-run and long-run relationship using the CS-ARDL method of Chudik and Pesaran (2015). The FMOLS and

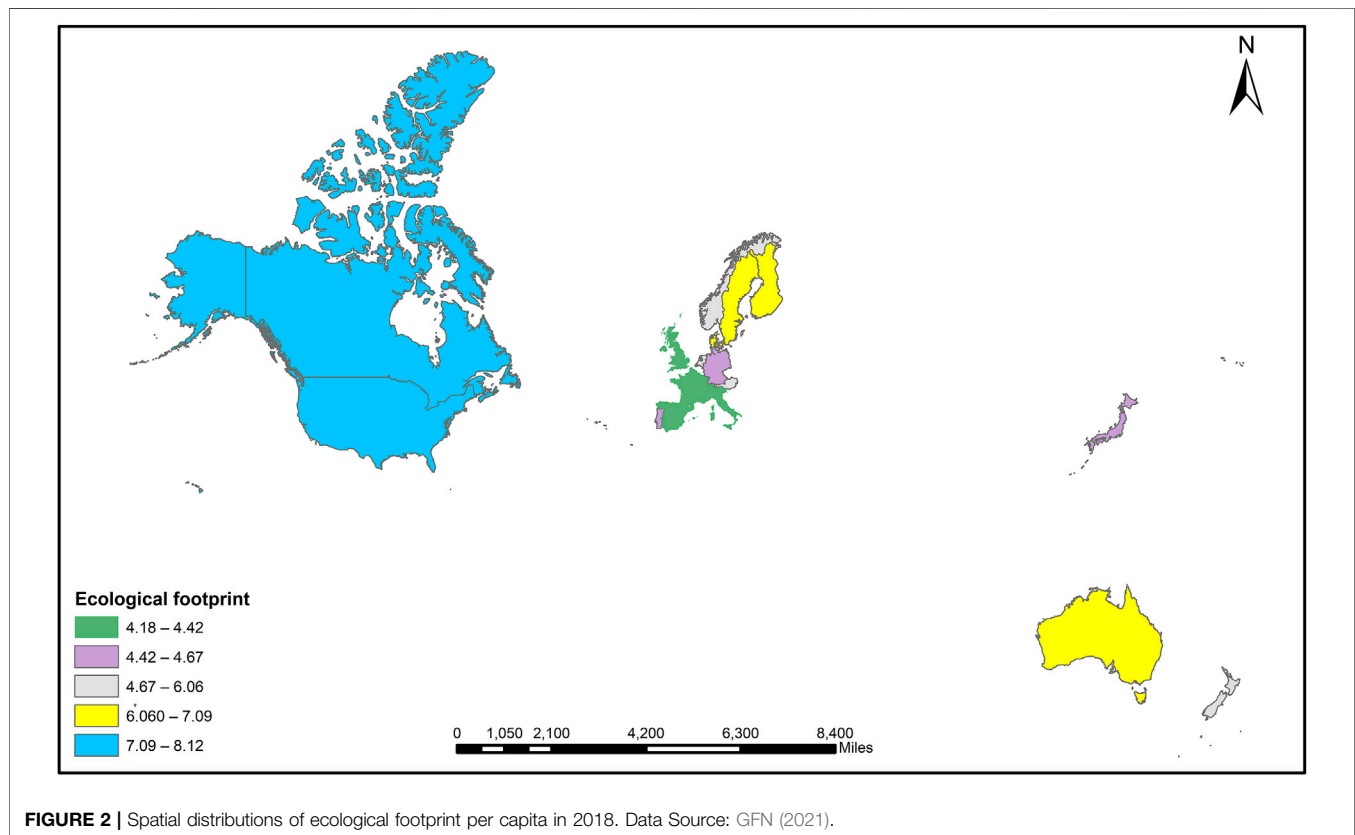
DOLS methods are utilized for robustness checks. Lastly, the causal flow among variables is examined using the Dumitrescu and Hurlin (2012) Granger causality method. **Figure 1** shows the estimation strategy visually.

RESULTS AND DISCUSSION

The descriptive statistics of the study variables are given in **Table 2**. The results indicate that the mean values of GDP, RTB, and energy consumption are high, while the standard deviation of these variables is also high as compared to other variables. The ecological footprint range between 2.60 and 11.20 global hectares per capita in the sample countries. **Figure 2** demonstrates the spatial distribution of ecological footprint in OECD for 2018, indicating that Canada, Australia, and United States have the highest per capita EF, while the United Kingdom and Spain have the lowest EF in the selected OECD countries. The financial risk rating index ranges between 26 and 50, with a mean value of 41.138. **Figure 3** shows the risk rating index in OECD countries for the year 2018. The mean value of RTB is 101.816 while it ranges between 198.182 and

TABLE 2 | Descriptive statistics.

Variables	Observations	Mean	Std. Dev	Minimum	Maximum
EF	630	6.168	1.530	2.600	10.429
GDP	630	42,252.876	15,078.916	12,288.434	91,964.258
FR	630	41.138	5.153	26.00	50.00
RTB	630	101.816	198.172	0.547	2638.454
EG	630	70.248	10.671	38.837	89.566
EC	630	205.104	85.643	52.877	444.047

**FIGURE 2** | Spatial distributions of ecological footprint per capita in 2018. Data Source: GFN (2021).

2638.45 million US\$, and it ranges between **Figure 4** depicts the trends in renewable energy technology budgets from 1984 to 2018, indicating that the United States and Japan have allocated more budgets towards energy research and development as compared to other OECD member economies.

Table 3 represents the variance inflation factor (VIF) test result. The maximum value of VIF is 2.31 of \ln GDP, while the average value of all the variables is less than 5. Therefore, the multicollinearity of variables could be ignored.

Table 4 represents the findings from the CD test and homogeneity test. The outcome disclosed that all the variables rejected the null hypothesis of cross-sectional independence at a 1% significance level. In addition, the value of correlation ranges between 0.42 and 0.96, indicating that all variables are related. The findings from the slope heterogeneity test depict the presence of heterogeneity in slope parameters, which is apparent from the delta and delta_adjusted values. Hence, the issues of CD and slope

heterogeneity need to be considered while performing the further empirical estimation.

Considering the existence of CD, and slope heterogeneity in panel countries, we employed the latest unit test of CADF and CIPS. The findings in **Table 5** indicates that FR, RTB, EG, and EC have unit root problem at the level in the CIPS test. Interestingly, except for RTB, all the variables show similar outcomes in CADF. In conclusion, the study variables have mix order of integration; however, all become stationary after taking the first difference. Thus, we can proceed with further investigation for the long-run cointegration relationship. The findings from the Westerlund cointegration test are presented in **Table 6**, indicating that there is a long-run stable relationship between ecological footprint as the dependent variable and financial risk and RTB as explanatory variables in the presence of some control variables.

After confirmation of cointegration in the model, we can proceed to investigate the short and long-term association

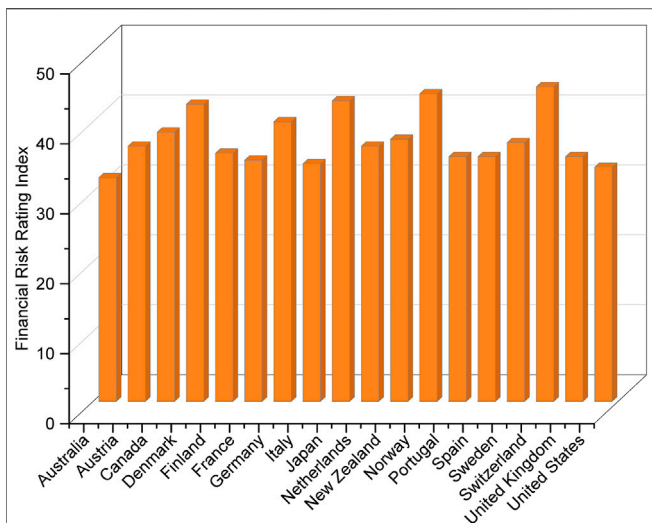


FIGURE 3 | Financial risk rating index of OECD economies for the year 2018. Data source: ICRG (2021)

TABLE 3 | VIF test results.

Variable	VIF	1/VIF
<i>lnGDP</i>	2.31	0.432
<i>lnFR</i>	1.23	0.815
<i>lnRTB</i>	1.19	0.839
<i>lnEG</i>	1.65	0.606
<i>lnEC</i>	1.54	0.650
Mean VIF	1.58	—

TABLE 4 | Cross-sectional dependency and slope homogeneity test.

Pesaran (2004) Cross-Sectional Dependency Test Results

Variables	Stat	Prob	Abs (Corr)
<i>lnEF</i>	24.507***	0.000	0.420
<i>lnGDP</i>	69.205***	0.000	0.946
<i>lnGDP²</i>	69.203***	0.000	0.946
<i>lnFR</i>	47.660***	0.000	0.655
<i>lnRTB</i>	42.142***	0.000	0.589
<i>lnEG</i>	68.760***	0.000	0.940
<i>lnEC</i>	31.273***	0.000	0.537

Pesaran and Yamagata (2008) slope heterogeneity test

$\bar{\Delta}$	16.894***	0.000	—
$\bar{\Delta}_{adjusted}$	19.234***	0.000	—

Notes: *** depicts the significance level at 1%.

between financial risk, RTB, economic globalization, energy consumption, and EF under the EKC framework. The CS-ARDL is utilized for this purpose, and the findings are shown in **Table 7**. The coefficient of GDP is significant in the short and long term, with the value of 0.803, and 0.423, respectively. The positive impact of GDP on EF portrays that OECD countries have compromised their environmental quality over economic growth. The rapid development in OECD countries has intensified resources and energy consumption leading to higher ecological degradation (Chen and Lei, 2018). The coefficient of GDP square is negative in the short-run and long-run with the value of -0.030 and -0.015 , respectively. The coefficient values of GDP and GDP square validated the presence of the EKC hypothesis in OECD countries. These results indicate that environmental-related

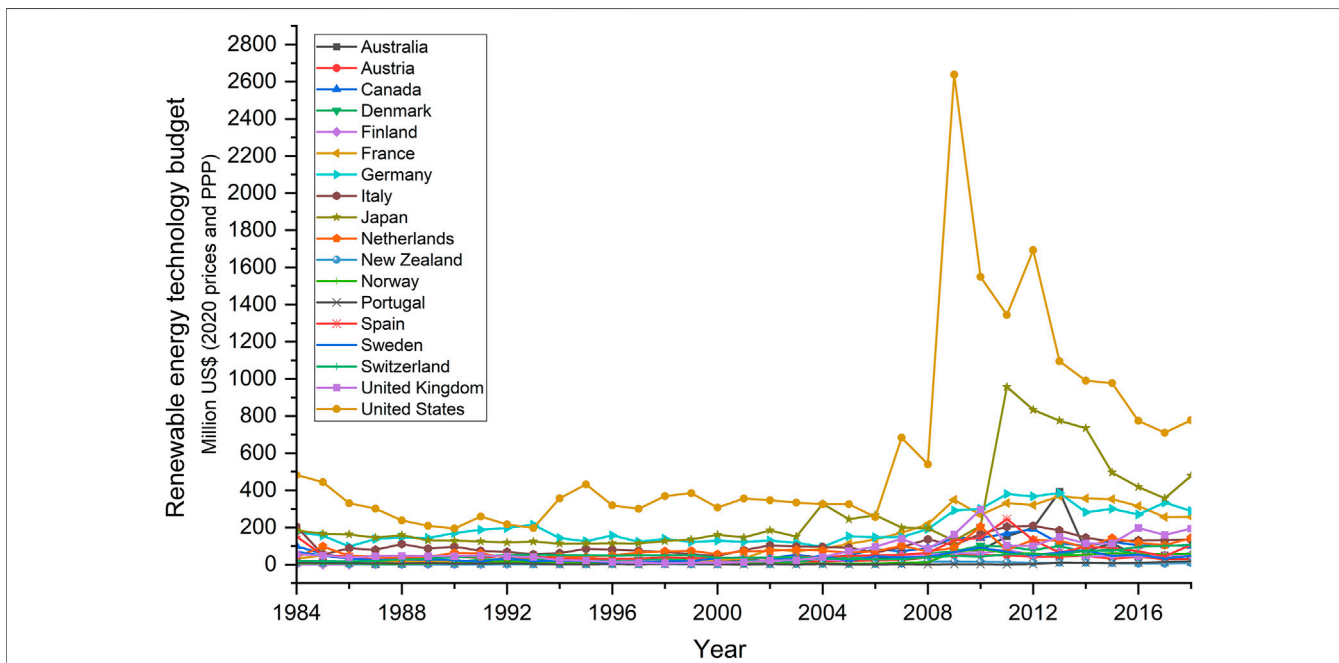


FIGURE 4 | Trends in renewable energy technology budget in OECD countries from 1984 to 2018. Data source: IEA (2022)

TABLE 5 | Unit root test results.

Variable	CIPS		CADF	
	Level	First-Difference	Level	First-Difference
<i>lnEF</i>	-2.073	-5.832***	-1.960	-4.300***
<i>lnGDP</i>	-1.578	-3.205***	-2.418	-3.055***
<i>lnGDP²</i>	-1.563	-3.222***	-2.390	-3.036***
<i>lnFR</i>	-3.199***	-5.976***	-2.621***	-4.892***
<i>lnRTB</i>	-3.118***	-5.748***	-2.285	-4.640***
<i>lnEG</i>	-2.633***	-5.409***	-2.667***	-4.244***
<i>lnEC</i>	-2.513***	-5.978***	-2.250**	-5.128***

Note: *** and ** depict the significance level at 1% and 5%, respectively.

TABLE 6 | Westerlund cointegration test results.

Statistic	Value	Z-value	p-Value
G_t	-3.856***	-5.947	0.000
G_a	-14.040	-0.092	0.463
P_t	-17.374***	-7.001	0.000
P_a	-15.579***	-2.700	0.004

Note: *** depicts the significance level at 1%.

TABLE 7 | Short-run and long-run test results.

	Coefficient	Standard Error	Z-value	P-value
Short-run results				
<i>lnGDP</i>	0.803***	0.226	3.550	0.000
<i>lnGDP²</i>	-0.030***	0.011	-2.640	0.008
<i>lnFR</i>	-0.015*	0.008	-1.930	0.053
<i>lnRTB</i>	-0.009*	0.006	-1.700	0.089
<i>lnEG</i>	-0.021**	0.009	-2.400	0.017
<i>lnEC</i>	0.297**	0.130	2.290	0.022
ECM (-1)	-0.835***	0.060	-13.890	0.000
Long-run results				
<i>lnGDP</i>	0.423***	0.120	3.520	0.000
<i>lnGDP²</i>	-0.015***	0.006	-2.640	0.008
<i>lnFR</i>	-0.009**	0.004	-2.110	0.035
<i>lnRTB</i>	-0.005*	0.003	-1.730	0.084
<i>lnEG</i>	-0.011**	0.005	-2.310	0.021
<i>lnEC</i>	0.159**	0.069	2.300	0.022

Note: ***, **, and * indicate the significance level at 1%, 5%, and 10%, respectively.

policies in OECD economies are going in the right direction, as income will decrease environmental degradation after reaching a certain point. These findings are consistent with Ahmad et al. (2020) for emerging economies, Yang et al. (2021) for and Xue et al. (2022) for France.

Concerning the effect of our core explanatory variable, the findings show that controlling the financial risk increases the ecological quality in OECD economies in the short and long term with the coefficient value of -0.015, and -0.009, respectively. According to ICRG financial risk index, a high score of the financial risk index (near 50) indicates less risk, while a low score (near 0) specifies the higher risk. Financial risk can affect the allocation of green finance and climate-related policies and

TABLE 8 | FMOLS and DOLS test results (Robustness check).

Variable	FMOLS		DOLS	
	Coefficient	T-statistic	Coefficient	T-statistic
<i>lnGDP</i>	2.048***	3.631	3.943***	2.814
<i>lnGDP²</i>	-0.092***	-3.464	-0.184***	-2.809
<i>lnFR</i>	-0.107***	-3.661	-0.151***	-2.592
<i>lnREB</i>	-0.009**	-2.549	-0.023***	-3.353
<i>lnEG</i>	-0.419***	-9.973	-0.297***	-3.059
<i>lnEC</i>	0.703***	23.495	0.603***	10.072

Note: *** and ** depict the significance level at 1% and 5%, respectively.

inevitably lead to economic and social disorder. In contrast, lower financial risk enhances financial development and can enable countries to boot the investment towards green finance and achieve carbon neutrality. Our outcome is contrary to the findings of Zhao et al. (2021), who found that financial risk leads to environmental degradation in 62 developing countries.

The results further suggest that RTB pose a negative and significant effect on EF in the short and long term with the coefficient values of -0.009, and -0.005, respectively. Our findings support the idea that government policy support for innovation in the renewable energy sector can play a pivotal role in environmental sustainability. This finding links to the fact that OECD countries are increasing their efforts for energy transition, which is evident from their RTB increase from 93.39 million USD (2020 prices and PPP) to 168.20 over 1984–2018 with an average growth rate of 1.70%. However, the growth rate is quite low; thus, policymakers should put more effort to boost investment in renewable energy research and development activities in order to stimulate environmental sustainability. This result is similar with Altuntaş and Kassouri (2020), and Yang et al. (2022). However, it contradicts Ahmad et al. (2021), who reported that RTB does not significantly affect EF in the United States.

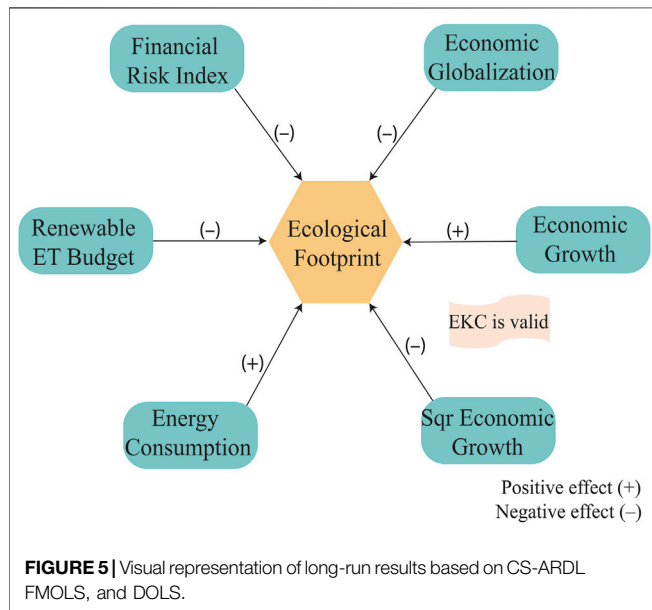
The findings indicate that ecological globalization (E.G.) pose a positive and significant effect on EF in the short-run and long-run with the coefficient value of -0.021 and -0.011, respectively. The mitigating effect of EG on footprint indicates that OECD countries benefit from globalization to enhance their environmental quality. Economic globalization enables countries to trade environmentally friendly products and attract investment for green projects. Our results oppose the results of Ahmad et al. (2021) for emerging countries, Wang et al. (2021) for G-7, and Rudolph and Figge (2017) for 146-panel countries. Lastly, energy consumption increases environmental degradation as indicated by the positive coefficient in the short and long term with the value of 0.297 and 0.159, respectively. This estimate is consistent with many studies that describe the detrimental environmental effects of energy consumption, for example, Danish and wang (2019) for the NEXT-11, Dogan et al. (2019) for and Shahzad et al. (2021) for the United States. The destructive effect of energy consumption is reasonable because fossil fuel energy dominates the total energy mix of OECD, i.e., oil 35.97%, natural gas 29.89%, and coal 10.87% (BP, 2021).

This study opted for the FMOLS and DOLS tests to reconfirm the long-run results. The findings given in **Table 8** endorse the

TABLE 9 | The DH non-causality test results.

Variables	<i>lnEF</i>	<i>lnGDP</i>	<i>lnFR</i>	<i>lnRTB</i>	<i>lnEG</i>	<i>lnEC</i>
<i>lnEF</i>	—	7.334***[0.000]	3.204***[0.001]	8.231***[0.000]	3.469***[0.001]	5.758***[0.000]
<i>lnGDP</i>	2.404**[0.014]	—	2.054**[0.040]	3.474***[0.000]	7.144***[0.000]	2.144**[0.032]
<i>lnFR</i>	2.276**[0.023]	10.875***[0.000]	—	1.643[0.100]	7.663***[0.000]	2.485**[0.013]
<i>lnRTB</i>	1.902*[0.057]	15.594***[0.000]	4.746***[0.000]	—	9.310***[0.000]	4.224***[0.000]
<i>lnEG</i>	0.595 [0.551]	2.143**[0.032]	3.766***[0.000]	0.390[0.695]	—	1.166[0.243]
<i>lnEC</i>	2.705***[0.001]	11.235***[0.000]	5.222***[0.000]	9.506***[0.000]	3.874***[0.000]	—

Note: ***, **, and * indicate the significance level at 1%, 5%, and 10%, respectively.



signs (i.e., positive or negative) of the regressors are consistent. Moreover, the long-run results are visually presented in **Figure 5**.

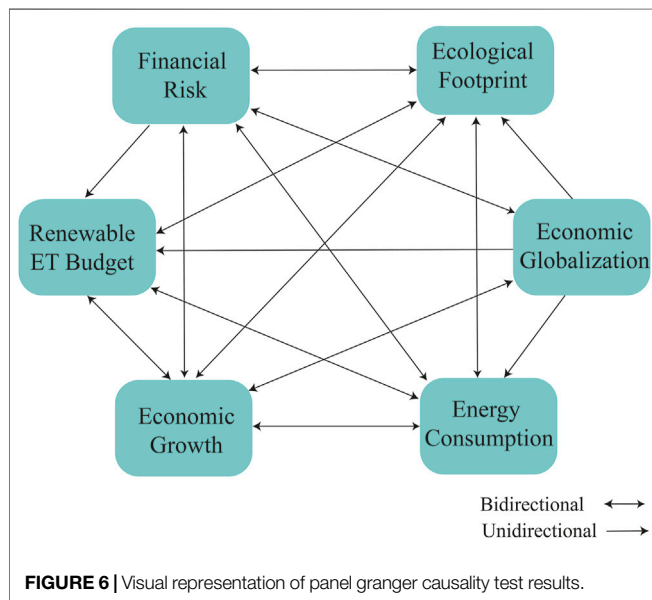
Finally, to examine the causal flow among studied variables, this study employed Dumitrescu-Hurlin causality, and the results are given in **Table 9**. Our study underlines the existence of causality from financial risk to RTB. This relationship has not been highlighted in the earlier studies. These results indicate that financial risk can, directly and indirectly, cause environmental deterioration through RTB. Thus, controlling financial risk can play a pivotal role in promoting RTB and ecological sustainability in OECD countries. Besides, a bidirectional causal relationship exists between RTB and ecological footprint. Thus, any policy changes in RTB will affect ecological footprint and vice versa. A similar casual association is also observed between GDP-RTB, and FR-GDP. In summary, controlling financial risk not only influences RTB and GDP but also environmental sustainability in OECD countries. Moreover, the panel granger test results are visually presented in **Figure 6**.

CONCLUSION AND POLICY IMPLICATIONS

Conclusion

This study empirically analyzed the dynamic linkage between financial risk, RTB, and EF in the presence of economic globalization and energy consumption under the EKC framework for OECD countries from 1984 to 2018. This study utilized Pesaran's (2004) and Pesaran and Yamagata's (2008) estimation methods to check the CD and slope heterogeneity among the variables. The CADF and CIPS tests of Pesaran (2007) and Westerlund, (2007) are employed to check the stationarity properties and long-run equilibrium relationship between the variables, respectively. The long and short-run relationships were examined using the CS-ARDL method of Chudik and Pesaran (2015), and FMOLS and DOLS are applied for robustness check. Afterward, Dumitrescu and Hurlin (2012) Granger causality test is employed to report mutual causal directions.

The empirical results unveiled that the model is suffering from the issue of slope heterogeneity and CD. The unit root tests' findings show that variables have mix order of integration, and all are stationary at the first difference. The cointegration test result indicates the existence of an equilibrium association among the selected variables. The CS-ARDL results disclosed that the financial risk index is negatively correlated with EF, indicating that controlling financial risk enhances environmental quality in OECD countries. The results further unfold that RTB and



CS-ARDL results inferring that our estimations are stable and authentic. Although the coefficient values of FMOLS and DOLS are slightly high from CS-ARDL, on the whole, the coefficient

economic globalization are negatively associated which implies that an increase in RTB and economic globalization will reduce the EF. Energy consumption intensifies EF and EKC is verified between income and EF. The panel causality results denote the unidirectional causality from financial risk to RTB, while bidirectional causality is detected between financial risk-EF and financial risk-GDP.

Policy Implications

The results of this study have important policy implications for OECD countries. Firstly, improvement in the financial risk index mitigates EF. Thus, it is beneficial for OECD nations to consider financial risk when making climate-related policies. Also, steps should be taken to boost the investment in renewable energy research and development. Besides that, economic globalization is negatively associated with EF; therefore, OECD countries should reduce trade barriers and encourage businesses to promote environmentally friendly globalization. Moreover, energy consumption was found to have a positive impact on EF in OECD economies, indicating that policies related to energy usage in these economies need careful monitoring. The government should facilitate firms and organizations for green technological transformation and increase the share of cleaner and renewable energy sources which can lead to the achievement of SDG-7.

This study explores the dynamic linkage between financial risk, RTB, and ecological footprint in OECD countries. Future studies can not only probe this nexus in other countries but also

include more variables in the model, such as fiscal policies, technological innovation, human capital, etc.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

MA: Conceptualization, data curation, formal analysis, writing original draft. ZA: Writing original draft, writing—review, and editing. BG: writing—review, and editing, funding acquisition. JO: supervision, project administration, writing—review, and editing.

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