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Green finance development and environmental sustainability: A panel data analysis

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This study considers five regions, i.e., South Asia, South-East Asia, China, Middle Eastern countries, and European countries, and took their data for 15 years. This study makes a significant contribution to the literature by examining the impact of green finance on environmental sustainability. Green finance development is represented by GDP, investment in renewable energy sources, investment in research and development (R&D) for eco-friendly projects, and public–private partnership investment in renewable energy projects. Green financing development in the chosen panel exhibits a distinct geographical cluster effect, with significant regional variances. The most important influencing elements are regional GDP, regional innovation level, and air quality, whereas the degree of financial development and industrial structure optimization are insignificant. The degree of financial development and industrial structure optimization are related to the amount of green finance development mostly *via* spillover effects. The degree of financial development has a positive spillover impact, but industrial structure optimization has a negative spillover effect. This study reveals that an increase in the production of energy from renewable sources, an increase in R&D, and the evolution of public–private partnership investment in renewable energy reduce CO_2 emissions. It is evidenced that green finance in renewable energy sources is necessary to achieve environmental sustainability. There is a strong need to increase green finance in renewable sources to target the minimization of global CO_2 emissions. There should be cross-border trade of renewable energy between regions/countries to mitigate CO_2 emissions globally. Moreover, this study ranks the regions based on environmental sustainability, which may help researchers and decision-makers to entice foreign direct and private investment in these regions. The implications of the findings of the study suggest that environmental sustainability benefits greatly from green financing and investing in renewable energy sources through public–private partnerships, which represents one of the best ways to ensure environmental sustainability.

KEYWORDS

green finance, environmental sustainability, CO_2 emissions, public–private partnership, renewable energy resources

1 Introduction

Green finance has become one of most discussed topics as the current generation is now becoming aware of the importance of a sustainable environment (Che et al., 2021). The term green finance is defined as the provision of financial services for environmental protection projects, i.e., "the collection of economic activities that revitalize the environment and optimize resource usage" (Peng & Zheng, 2021), encompassing the sustention of energy, clean and safe energy, environment-friendly transportation, and green buildings projects. If only the term "green" is considered, then this refers to those activities leading to decreased pollution, saving natural resources, and achieving sustainable green development (Shan et al., 2018). The development of green finance includes credit availability to obtain a sustainable green environment (Xie et al., 2020). Green finance includes green securities, green credit sources, green investment, and carbon finance.

From a broader perspective, it is believed that green finance development causes the optimization of the whole structure of an economy in the form of supply-side quality improvement, demand-side awareness, and the maintenance of growth (Zhang et al., 2021). From a narrower perspective, green finance development can enable entrepreneurs to innovate green products through the green production processes, to make the product available in such a way that decreases the transaction costs, and to promote the product in a way that guides consumers (Usman et al., 2019).

Green finance plays a role as a driving force in transforming ecological development in two ways. First, it encourages entrepreneurs to engage in safe environmental processes and products, and second, it decreases pollution levels, replacing high-energy equipment with energy-efficient equipment. Green finance development is also helping in poverty alleviation in cases where the awareness of green products is provided to farmers. Farmers must be encouraged to grow green and organic crops without the use of any ingredients causing environmental degradation (Wang and Zheng, 2020).

Green finance development is more effective if all sectors adopt the same national policy at the same time (Zhang et al., 2022). All sectors of the economy, including agriculture, industry, and services, should follow the same national strategy. With the promotion of rural regeneration, green finance needs to be inserted into ecological and environmentally safe projects. Moreover, governments should target high environmental quality and encourage other sectors through the use of various financial tools to speed up green development. Hence, the characteristics of green finance development are considered to be of great significance (Lee and Min, 2015; Bashir et al., 2020).

Green finance development has been focused on in terms of a theoretical framework, production functions, and the role of technology in the economy. The environmental quality has to be improved as sustainable development is a major concern of the world today (Nasim et al., 2022a; Nisar et al., 2022). There is a need to save the environment for future generations. The quality of the environment determines the quality of life. The cost of advanced industry is rising pollution in various forms, which affects all living creatures. The deterioration of the environment is a huge problem that is constantly worsening, and there is an obvious need to clean this toxic environment with full awareness of green finance. All of these negative environmental consequences have associated negative effects on ensuring human health, which is the broader purpose of human existence. The environment is a public, not a private, concern, and it is no secret that humanity today is confronting an environment hostile to its goals for a better life (Rafiq et al., 2022).

Environmental quality is a regular economic good with two distinct meanings. The first is related to the fact that a clean environment is a common commodity for which economic agents are prepared to pay (although prices may fall). As economic expansion and technological progress coexist, it is plausible to assume that citizens in wealthier nations have access to technological advancements that make improving local air quality substantially less expensive (Nisar et al., 2022). As a result, individuals in affluent nations consume proportionately more air quality than those in poorer ones. The second meaning is related to the fact that individuals are prepared to spend more on the environment when their income rises, even if the price remains constant. These two inferences suggest a negative link between pollution and per capita income. Because of the nature of externality, the environment will not be cleansed by individual efforts unless the whole of society collectively plans to do so through government involvement, such as taxes, standards, and tradeable emissions control (Morelli, 2011). Through induced policy response, a stronger correlation between income and pollution may be established.

Human factors may have a significant impact in influencing severe temperatures and rising CO_2 emissions. Those who oppose globalization believe that the environmental impacts are two-fold. First and foremost, pollution havens occurs when trade reforms of liberalization enable polluting industries to be relocated to regions with less stringent regulatory controls (Wang, Huang, and Xiang, 2021). It is also likely that pollution will rise in low-income or emerging nations as a result of globalization until they reach a certain degree of economic development. Pollution and income have a quadratic

(or inverted U-shaped) connection, known as the environmental Kuznets curve (EKC).

All economic sectors, in their unique ways, contribute to the destruction of the environment. To achieve long-term prosperity, every country has turned its attention to environmental concerns. Environmental quality is described as a collection of environmental features and qualities that impact human beings and all other living things. The only way to ensure long-term prosperity is to take advantage of green financing. It is a way to compare the state of the environment to the wants and requirements of all kinds of living things. As a result of the quality of one's home environment, human health and well-being are improved. This enhances mental health and allows individuals to recuperate from stress and carry out physical activities more effectively, resulting in more enjoyment and better mental health. Green finance is related to the importance of public and private projects creating a clean environment. It also reflects the impacts of climate change and pollution on human lives, as well as showing the social benefits and long-run returns of such financing (Bhattacharyya, 2022).

Consumers' changing tastes for products and services illustrate the influence of environmental quality on economic output. All sectors are obligated to meet the needs of customers and behave accordingly. As long as customers are willing to pay more for environmentally friendly products, the agricultural and industrial sectors will follow suit (Jie et al., 2022). Furthermore, environmental deterioration would be reduced if governments regulate sectors to adhere to environmental quality improvements. Agricultural disasters, such as floods, harm the ecosystem. Additionally, this industry is responsible for many environmental issues, such as pollution, overgrazing, and the production of greenhouse gases (Shan et al., 2018). By using pesticides and fertilizers, as well as through deforestation, this industry contributes to global warming and other environmental problems. By using pesticides and fertilizers, agricultural output has been improved; however, this does not imply that the health quotients of those goods are boosted. There is a cause-and-effect link between agricultural production and environmental quality. Organic foods have become more popular since environmental quality has become a frequent problem across the globe. Because of the rising popularity of nutritious foods and the resulting rise in demand, environmental quality has a direct influence on agriculture. The contribution of green finance to reducing the usage of fertilizers and CO_2 emissions is massive. The research inferences are providing a scientific basis for China's actions (Guo et al., 2022).

To meet the rising demand for organic food products, agriculture's productivity is likely to shift toward the cultivation of these products. Natural food may be obtained in many retail outlets, including supermarkets and farmers' markets (Jie et al., 2022). Demand for organic foods and the price farmers charge for their produce boosts agricultural production, as does the demand for organic food. Farmers will be able to boost their output of these goods as a result of increased public knowledge. It is the mixture of marketing mixes that directly affects consumer desire for foodstuffs such as organic products (Sohail et al., 2020). Environmental quality regulation is a community effort to restore a better environment both for present and future generations, so big changes in productivity may occur. Unlike customary financial actions, green finance focuses more on environmental advancement and pays more attention to environmental protection projects (Wang and Zhi, 2016).

The quality of the environment also influences the industrial sector in a more environmentally friendly direction. There is an industrial revolution taking place throughout the globe to satisfy the demands of an expanding population, rising living standards, and diminishing natural resources. Manufacturers are polluting the air and water through their use of chemicals and fossil fuels (Martins et al., 2022). Increased emphasis on environmental quality is necessary in light of industry's significant negative influence on the environment. Industrial pollution is not only harmful to human health, it also harms the environment. Changes in weather patterns, ozone depletion due to greenhouse gas emissions, CO_2 emissions, and other chemo-emissions are all results of these causes. In addition to the aforementioned problems, the overabundance of cars and trucks on the highways also contributes to pollution, which needs the serious attention of concerned authorities, along with financial assistance for the replacement of old transportation means. Financial development for the green revolution is measured in terms of domestic credit to the public and private sector for green environment projects and, to a certain extent, the nature of foreign direct investment (Afzal et al., 2021).

Green innovations are fully reconciling the association between financial resources and finance performance, while partly reconciling the association between financial resources and environmental quality (Khan et al., 2022). Specific tasks have also been described for the environmental protection sector, the existing level of knowledge (industry), and the gap between the information needed and what is now known. An industry that produces and sells environmentally friendly products and services is referred to as an "environmental protection industry." There are many major issues concerning environmental protection linked to the existing condition of a business, such as the difficulty in analyzing and monitoring the sector it is operating in. As a result, it might be seen as a strategy that is distinct from regulated sectors. For example, it has been recommended that industrial advantages should be given mainly to provide additional expenses for environmental protection to control such companies.

There is a need to identify the important subjects for green finance development and plan the strategies that enhance green financing in such a way that it will also be profitable (Ozili, 2022). A huge investment is required to decarbonize the environment to

slow down global warming (Murshed et al., 2021; Yu et al., 2022). A large difference has been found between the consequences of regulations in China and those in the United States. Environmental changes have a direct impact on the allocation of resources and company activity across sectors. Increases in productivity may be attributed in large part to resource reallocation, which shows that resources in developing nations are often misused. Addressing this issue could reduce the large differences in productivity (Restuccia and Rogerson, 2013).

Companies and markets will be stimulated by this kind of legislation, which is likely to result in increased productivity. Environmental rules that encourage polluting companies to innovate may also help highlight and boost productivity, as can environmental policies. Innovations based on a lower technological level are expected to perform better in underdeveloped nations than in developed ones. Low production outputs and high emissions might be a result of new advancements in this area. Financial institutions are also offering discounted and promotional loans for green projects to restrict CO_2 emissions and pollution (Xu, 2013). Environmental regulation's net beneficial impact on industrial performance may be achieved *via* either an offset effect or a net negative effect.

Regarding the invention and uses of new renewable energy resources, research and development (R&D) is required to formulate specific projects to focus on the problems of economic production and green innovations in the economy (Ullah et al., 2022). For this purpose, institutional support has evolved around the financial provision for such green projects (Naqvi et al., 2021). Yafi et al. (2021) explained green finance development as a way to invest in environmentally safe businesses and the attitude of entrepreneurs towards identifying the incentives and benefits. According to the findings of various studies, policymakers should actively stimulate R&D for low-carbon technology and investment in renewable energy (Akbar et al., 2020). In particular, industries with higher energy use, and hence higher consumption-based CO_2 emissions, should be targeted for reductions in nonrenewable energy sources (Rafiq et al., 2022).

The study aims to explore the effect of green finance on environmental sustainability by considering five regions (South Asia, Southeast Asia, China, Middle Eastern countries, and European countries) for 15 years. This study represents a significant addition to the literature by providing evidence of green finance's impact on environmental sustainability. Green finance development is represented by GDP, investment in renewable energy sources, R&D for eco-friendly projects, and public–private partnership investment in renewable energy projects. The research questions addressed are as follows:

Q1: Is there any significant positive relationship between R&D expenditure for eco-friendly projects and environmental sustainability, and does this relationship reduce CO_2 emissions?

Q2: Can public–private partnership investment projects significantly impact environmental sustainability and reduce CO_2 emissions?

The remainder of this study is structured as follows. The literature review is presented in Section 2 and the methodology is presented in Section 3. Section 4 covers the results and a discussion of various econometric tools. Finally, Section 5 concludes the study and provides recommendations.

2 Literature review

Environmental sustainability and green transition are strongly associated with each other; green transition without energy and environmental sustainability can only be partial and inadequate (Hall et al., 2018; Ji et al., 2021). There is a need for cross-border renewable energy trade for long-term environmental sustainability and to mitigate climate change (Sun et al., 2020; Taghizadeh-Hesary et al., 2021; Ferrat et al., 2022). Renewable alternatives to fossil fuels, such as wind and solar, are seen as an effective method of restoring environmental balance throughout the world (Murshed et al., 2021).

The growing awareness of carbon emissions in Iran's agricultural sector was examined by Pakrooh et al. (2020) to get a better understanding of the driving forces behind CO_2 emissions. In the last decade, the agriculture sector has been confronted with increased carbon emissions, ineffective government regulations, and rising fossil fuel consumption rates. An investigation into the link between agricultural productivity and greenhouse gas emissions in Latin America and the Caribbean was conducted by Saravia-Matus et al. (2019). This research presented a performance ratio for comparison, computed as greenhouse gas emissions over agricultural production in 2015, to analyze progression in these two regions. Insights into the relationship between agricultural production and greenhouse gas emissions may be gained by examining the variations in elasticities among land management strategies. The research found that only a small number of nations could offset agricultural emissions using land-use-related carbon sequestration techniques in these regions.

In their study, Zhang et al. (2019) used data from China's major grain-producing regions from 1996 to 2015 to examine the connection between carbon emissions, energy consumption, and economic development in the agricultural sector. China Rural Statistical Yearbook data from 1996 to 2015 were used for the ARDL model and Granger causality test. Estimated carbon emissions from the agriculture sector in major grain-producing regions were found to agree with the EKC theory. For the years 2001–2012, Fei and Lin (2017) conducted research on China's agricultural sector's CO_2 emission efficiency. A proxy for environmental deterioration was developed by the researchers, and it was used in conjunction with two other

important factors: the technology gap and management failure. Different areas of China, such as the eastern, central, and western regions, revealed differences in the agricultural industry.

Inter-annual instabilities and long-term trends in land demand for food supply, such as crops, animal products, and biomass-derived products (Chen et al., 2019), were the topic of a study conducted by Sandströmet al. (2014) between 1961 and 2007. It was difficult to locate the data and merge the statistics, empirical estimation coefficients, and parameters in the research because of several uncertainties. An increased number of strategies, including land discharges due to deforestation, are needed to analyze the inter-annual changes in land demand and supply and the environmental implications of agricultural goods. However, since the world's population seeks the finest sustainable mixtures of ecosystem services, it was advocated to enhance agricultural systems.

Nasim et al. (2022b) conducted a study to explore the effectiveness of environment quality and trade along with human capital by using a pool of 63 countries, applying a panel ARDL approach. Wang et al. (2019) noted that OECD economies have implemented a green economic growth strategy by establishing and enforcing environmental rules and regulations. Studying the impact of environmental regulations on green production in a specific location was the focus of this research. The rigor of anti-degradation policies on the development of green output was examined using a set of panel data. In a restricted degree of rigidity, the Porter hypothesis proved that environmental policy has a beneficial influence on growth in environmentally friendly production. Innovation activities were shown to help maintain technological dynamism, possibly exceeding passive green expenditures incurred as a result of environmental legislation to create a green Earth.

Based on the World Bank's world development indicators, Wasti and Zaidi (2020) examined the relationship between environmental degradation, energy consumption, and Kuwait's economic growth and trade liberalization using yearly data from 1970 to 2017. According to Wang, Sun, and Guo (2019), carbon emissions have had a large and prominent influence on current environmental crises all over the world. As a result, it is necessary to investigate new approaches to boosting energy efficiency to reduce environmental damage while simultaneously supporting China's rapid economic growth.

R&D includes efforts to create and launch new goods and services. Typically, it is the initial step in the development process. Usually, the objective is to sell new goods and services (Karim et al., 2022). Environmental quality increases as a result of energy innovation. Policymakers should consider increasing public spending, notably in the energy sector, to encourage technological innovation and, in turn, reduce CO_2 emissions (Ferrat et al., 2022). As part of their research, Fernández et al. (2018) looked at how the United States, the European Union (EU), and China's CO_2 emissions changed from 1994 to 2013. R&D expenditures have had a favorable influence on reducing CO_2 emissions in the United States and the EU. As a result of favorable social and economic externalities and financial incentives, investment in green finance has increased in recent decades. It is worth noting that renewable energy funds were unable to outperform more conventional energy funds during COVID-19, underscoring the need for more capital injections. Nevertheless, contrary to popular belief, the majority of research has found that the most effective way to create a carbon-neutral economy is to encourage the development of carbon-neutral investments. It has been shown that green funds have outperformed their non-green equivalents (Ji et al., 2021). Volatility in green funds is lower than in high-emission funds, according to research. As an alternative to fossil fuels, the use of renewable energy sources is thought to improve environmental conditions. As a result, it is critical to discover ways to reduce the world's dependence on fossil fuels to guarantee that economic and environmental progress are linked (Murshed, 2020).

According to other research, the creation of a green financial intermediation channel is essential for the realization of carbon-free economies. Using two distinct credit risk indicators, Umar et al. (2021) showed that exposure to carbon-neutral lending is inversely associated with default risk. The findings were similar across all bank sizes, indicating that green financing had the same effect on credit risk regardless of bank size. As a result of a decrease in credit risk, financial institutions may reduce their loan loss provisions and capital needs. This incentive is essential for increasing carbon-neutral credits and contributing to environmental objectives.

Based on a review of the literature, this research reveals an affinity between green finance and environmental sustainability, highlighting the significance of public–private partnership investment for renewable and efficient energy projects and economic growth, as well as other relevant variables. As a result, various factors not previously considered in previous research are included in this investigation into the effects of green financing on environmental sustainability. This research is based on the following hypotheses:

H_1: The R&D expenditure for eco-friendly projects has a significant positive impact on the sustainable environment and reduces CO_2 emissions.

H_2: Public–private partnership investment projects have a significant positive impact on the sustainable environment and reduce CO_2 emissions.

3 Methodology

To rationalize the objective of the study, data were collected for five geographical regions and analyzed through quantitative methods. The sample size is five heterogeneous cross-sections for 15 periods from 2007 to 2021 in time series. The data are analyzed in the form of balanced panel data. Panel data also

take into account individual heterogeneity, and analysis can be done through three methods: common effect model, fixed effect model, and random effect model.

3.1 Research design and method

The study is quantitative and empirical in nature, involving a panel of five regions (South Asia, Southeast Asia, China, Middle Eastern countries, and European countries). As all the regions are geographically and demographically different, the study considers all the panels as heterogeneous. The heterogeneity can be captured in the variation of the random term of the model. The selection of this model is based on two reasons: the study is based on heterogeneous panels, and the Hausman test is used to validate the model. Therefore, the panel data random effect model is used in this study. The data are a collection from various sources, including the International Energy Agency, the World Bank, and the US Energy Information Administration.

3.2 Granger causality

Granger causality is a statistical hypothesis to test the causality between two series or variables. The study used Ganger causality to test the nature of causality among the variables of the study. The causality can be unidirectional, bi-directional, or neutral.

3.3 Sample

The sample size is five heterogeneous cross-sections for 15 periods from 2007 to 2021. Data are analyzed in the form of balanced panel data to evaluate the impact of green finance on environmental sustainability. Environmental sustainability is measured through investment in, and financing for, energy efficiency projects, as well as renewable energy. China, being the largest economy, is separately compared to other regions. The sample regions include the following countries:

- China: Mainland China, Hong Kong, and Macau;
- South Asia: Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka, and Maldives;
- Southeast Asia: Brunei, Burma (Myanmar), Cambodia, Timor-Leste, Indonesia, Laos, Malaysia, the Philippines, Singapore, Thailand, and Vietnam;
- Middle Eastern countries. Cyprus, Lebanon, Syria, Iraq, Iran, Israel, Jordan, Saudi Arabia, Kuwait, Qatar, Bahrain, United Arab Emirates, Oman, and Yemen;
- European Union countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden

TABLE 1 Descriptive statistics.

	LNCEM	LNGDP	LNPPP	REDE	INRES
Mean	15.4949	30.11693	22.40159	1.939818	21.30401
Median	15.55423	30.35111	22.29392	2.194788	19.96625
Maximum	16.40901	31.63504	25.1505	2.734596	38.68666
Minimum	14.22808	27.81008	19.85926	0.544314	14.73231
Std. dev.	0.659002	1.047821	0.99781	0.703903	5.589615
Skewness	−0.14148	−0.46735	0.137179	−0.91419	1.201174
Kurtosis	1.631345	2.314446	2.954355	2.417144	3.86468
Jarque–Bera	6.104004	4.198846	0.241735	11.50848	20.3717
Probability	0.047264	0.122527	0.886151	0.003169	0.000038
Sum	1162.118	2258.77	1680.119	145.4863	1597.801
Sum sq. dev.	32.13698	81.24673	73.67629	36.66546	2312.041
Observations	75	75	75	75	75

TABLE 2 Correlations.

Variable	LNCEM	LNGDP	LNPPP	REDE	INRES
LNCEM	1				
LNGDP	−0.37017	1			
LNPPP	−0.38697	0.310388	1		
REDE	−0.36181	0.779267	0.051632	1	
INRES	0.389303	0.335671	0.09898	0.388035	1

4 Results and discussion

Table 1 elaborates descriptive statistics for times series data of all variables, which are as follows:

LNGDP = GDP;
LNCEM = CO_2 emissions;
REDE = R&D expenditure for eco-friendly projects;
INRES = investment in renewable energy sources; and
LNPPP = public–private partnership investment in renewable energy projects.

The model is considered more robust if the distribution is normally distributed. The values of skewness and kurtosis determine the normality of the variables. According to Hair et al. (2010) and Byrne (2010), the values of skewness and kurtosis should be between the positive and negative values of 2 and 7, respectively. The empirics of the variables confirm that the distribution is normal. The measures of central tendency and dispersion are also calculated and reported in Table 1.

TABLE 3 Dumitrescu-Hurlin panel Granger causality test.

Null hypothesis	W-stat.	Z-bar-stat.	Prob.
LNGDP does not homogeneously cause LNCEM	8.10121	3.22229	0.0013
LNCEM does not homogeneously cause LNGDP	5.70504	1.80154	0.0716
LNPPP does not homogeneously cause LNCEM	3.11378	0.2651	0.7909
LNCEM does not homogeneously cause LNPPP	9.32978	3.95074	0.0000
REDE does not homogeneously cause LNCEM	5.39008	1.61478	0.1064
LNCEM does not homogeneously cause REDE	12.2079	5.65725	0.0000
INRES does not homogeneously cause LNCEM	3.7168	0.62266	0.5335
LNCEM does not homogeneously cause INRES	3.5485	0.52287	0.6011
LNPPP does not homogeneously cause LNGDP	1.14166	−0.90422	0.3659
LNGDP does not homogeneously cause LNPPP	4.49564	1.08445	0.2782
REDE does not homogeneously cause LNGDP	9.45614	4.02567	0.0001
LNGDP does not homogeneously cause REDE	10.6086	4.70898	0.0000
INRES does not homogeneously cause LNGDP	12.1837	5.64293	0.0000
LNGDP does not homogeneously cause INRES	2.05629	−0.36191	0.7174
REDE does not homogeneously cause LNPPP	7.27693	2.73355	0.0063
LNPPP does not homogeneously cause REDE	2.71882	0.03092	0.9753
INRES does not homogeneously cause LNPPP	3.1657	0.29589	0.7673
LNPPP does not homogeneously cause INRES	9.0585	3.78989	0.0002
INRES does not homogeneously cause REDE	7.12375	2.64272	0.0082
REDE does not homogeneously cause INRES	2.89996	0.13832	0.89

4.1 Correlations

Table 2 contains the results for correlations between variables. A correlation matrix is helpful to detect the severity of multicollinearity in the model. The results of the correlation matrix are given below, confirming that the presence of multicollinearity is at an acceptable level.

4.2 Granger causality test

Choosing the best technique for capturing the effects is always problematic. As the dataset used in the study has more time series than cross-sections, Dumitrescu and Hurlin's (2012) panel Granger causality test was deemed the most appropriate for exploring the causal relationships among the variables of the study.

Table 3 reports the output for the Dumitrescu–Hurlin test. As shown, at both 5% and 10% levels of significance, the probability values are too large/small to justify the presence of causal relationships between the variables. This demonstrates that the current study finds the relationship between GDP and CO_2 emissions, and between GDO and REDE, to be valid for bi-directional causality, whereas CO_2 emissions cause REDE, INRES causes GDP, REDE causes PPP, PPP causes INRES, and INRES causes REDE uni-directionally. If we observe the results more closely, it can be seen that no evidence is found to support the null hypothesis that there is no bi-directional Granger causality between the variables INRES and LNCEM, and LNPP and PNGDP. However, uni-directional causality is not found from LNPPP to LNCEM, INRES to LNPPP, LNGDP to INRES, and REDE to INRES.

TABLE 4 IPS and LLC tests.

Variable	IMS		LLC	
	W-stat.	Prob.	*t*-stat.	Prob.
LNCEM	−0.72459	0.0234[b]	−2.72304	0.0032[a]
LNGDP	−1.86	0.0314[b]	−3.2513	0.0006[a]
LNPPP	−3.27784	0.0005[a]	−2.42653	0.0076[a]
INRES	−2.51996	0.0343[b]	−2.03046	0.0212[b]
REDE	−2.60036	0.0047[a]	−2.72684	0.0032[a]

[a]Null hypothesis that the series contains a unit root is rejected at 1%.
[b]Null hypothesis that the series contains a unit root is rejected at 5%.

4.3 Panel unit root test

The application of the panel data unit root test assumes the null hypothesis that the series contains a unit root, and the alternative is that the series is stationary. As the output indicates in Table 4, the Levin–Lin–Chu (LLC) test assumes a common autoregressive parameter for all panels, so this test does not allow for the possibility that some countries' growth rates contain unit

TABLE 5 White cross-section panel EGLS (period random effects).

Variable	Co-efficient	Standard error	*t*-stat.	Prob.
LNGDP	0.256045	0.035473	7.218061	0
LNPPP	−0.35064	0.017832	−19.664	0
REDE	−0.89363	0.051562	−17.3312	0
INRES	0.079649	0.002865	27.80403	0
C	15.67514	0.828022	18.93082	0
R-squared	0.663103			
Adjusted R-squared	0.643852			

roots, while other countries' growth rates do not (Levin et al., 2002). Each test was performed on all variables of the study along with the Im–Pesaran–Shin (IPS) test to validate the results (Im et al., 2003). The IPS test assumes that all series are non-stationary under the null hypothesis. The results of the two panel unit root tests are presented in Table 4. The results of both tests confirm that all panel data series are stationary.

4.4 Panel EGLS random effect model

The results for panel EGLS random effects are reported in Table 5, taking LNCEM as the dependent variable, analyzed through the panel random effect model after considering the results of the IPS and LLC test results. The coefficients of the independent variables and their respective standard errors, *t*-statistics, and probability values are reported in Table 5. LNGDP exerts a positive and significant impact on LNCEM. The *t*-statistic of the LNGDP coefficient is greater than 2, and the probability value is also very high. This significant value validates the impact of LNGDP in increasing environmental degradation. The results suggest that increasing GDP deteriorates the environment.

If the estimated coefficient values of LNPPP and REDE are taken into consideration, then this has a negative impact on CO_2 emissions, indicating that public–private partnerships will create a cleaner environment. Public–private partnership can be enhanced by providing funds. R&D finance also shows a significant and negative relationship with CO_2 emissions and a positive relationship with environmental quality. Investment in renewable energy has a positive but very low impact on CO_2 emissions.

4.5 Hausman test

The panel EGLS random effect model was the best match for the Hausman test findings. The Hausman test is used to distinguish between random and fixed effect models. The best model is selected using the following statistical technique:

TABLE 6 Correlated random effects: Hausman test.

Test summary	Chi-sq. statistic	Chi-sq. d.f.	Prob.
Period random	1.43828	4	1.0000

H_0: Select random effect ($p > 0.05$),
H_1: Select fixed effect ($p < 0.05$).

As shown in Table 6, the study used a random effect model based on heterogeneity and the results of the Hausman test used for validation. The probability of the estimated value clarifies not rejecting the null hypothesis, which means that random effect model is the most suitable method for our dataset.

5 Conclusion

According to the findings, environmental sustainability benefits greatly from green financing. Investing in renewable energy sources through public–private partnerships is one of the best ways to ensure environmental sustainability. According to this research, this leads to greater renewable energy investment and higher environmental sustainability. This is the same result found by Chowdhury et al. (2013). Renewable energy sources' development has a considerable negative influence on CO_2 emissions, which implies that a rise in the percentage of total power generation from renewable sources is important to minimize CO_2 emissions. This discovery is consistent with that of Wang et al. (2019 and Murshed et al. (2021).

The development of new renewable energy sources has a huge influence on CO_2 emissions, which means that the world should invest more in R&D to find ways to minimize these emissions. A similar conclusion was reached by Koçak and Ulucak (2019), Álvarez-Herránz et al. (2021), and Wang et al. (2019, 2021). Public–private partnership investments in renewable energy are increasing because of the negative effects on CO_2 emissions that

come with such investment. Ahmad and Raza (2020), Balsalobre-Lorente et al. (2019), and Shahbaz et al. (2020) found the same thing in the short term.

The overall GDP of a region has a considerable influence on CO_2 emissions, which indicates that the output rise is connected to the increased usage of energy; according to this study, renewable energy sources should be given greater weight and attention to address the problem. A similar conclusion was reached by Nordin and Sek (2018). This study has certain limitations as it uses public–private partnership and R&D expenditures to represent green finance. The term "green finance" can be expanded and explored further by introducing more specific proxies that may have potential effects on environmental sustainability. Moreover, the data sample is small; future studies can address this by adding more cross-sections and can increase the sample size, as well as including more indicators of green finance.

5.1 Future recommendations

This research found that green finance has a substantial effect on environmental sustainability. A precise assessment of carbon emissions is essential for designing an effective climate policy to address ecological challenges. Based on updated carbon emission figures, a significant climate policy response is possible. To fulfill the Paris Agreement commitment by the world's nations to "hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (UNFCCC, 2015, p.3), the present study suggests focusing on green finance to achieve environmental sustainability. There is a strong suggestion to expand investments in renewable energy to combat global CO_2 emissions. Globally, there is also a need to promote green bonds at the municipal, provincial, and national levels. Industrialized nations should significantly enhance their renewable energy investments in poorer nations. To reduce global CO_2 emissions, there should be international commerce in renewable energy across regions/countries. Thus, policies geared toward globalization, economic expansion, and the use of renewable energy will have a substantial impact on CO_2 emissions. There is a need for increased investment in R&D for technical innovation to halt environmental deterioration.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Afzal, A., Rasoulinezhad, E., and Malik, Z. (2021). Green finance and sustainable development in Europe. *United kingdom Economic Research-Ekonomska Istraživanja* 36, 1–14.

Ahmad, M., and Raza, M. Y. (2020). Role of public-private partnerships investment in energy and technological innovations in driving climate change: Evidence from Brazil. *Environ. Sci. Pollut. Res.* 27, 30638–30648. doi:10.1007/s11356-020-09307-w

Akbar, A., Alam Rehman, I. U., Zeeshan, M., and Afridi, F. E. A. (2020). Unraveling the dynamic nexus between trade liberalization, energy consumption, CO_2 emissions, and health expenditure in Southeast Asian countries. *Risk Manag. Healthc. Policy* 13, 1915–1927. doi:10.2147/rmhp.s272801

Balsalobre-Lorente, D., Shahbaz, M., Jabbour, C. J. C., and Driha, O. M. (2019). *The role of energy innovation and corruption in CO2 emissions: Evidence based on the EKC hypothesis. Energy and environmental strategies in the era of globalization*. Cham: Springer, 271–304.

Bashir, F. ., Asghar, N. ., Nasim, I., and Ahmad, R. (2020). Energy and industrial sector in developing countries: A comparative study. *Pak. J. Soc. Sci.* 40 (1), 159–170. Retrieved from Available at: http://pjss.bzu.edu.pk/index.php/pjss/article/view/829.

Bhattacharyya, R. (2022). Green finance for energy transition, climate action and sustainable development: Overview of concepts, applications, implementation and challenges. *Green Finance* 4 (1), 1–35. doi:10.3934/gf.2022001

Byrne, B. M. (2010). *Structural equation modeling with Amos: Basic concepts, applications, and programming*. 2nd ed. New York: Routledge.

Che, C., Chen, Y., Zhang, X., Zhao, L., Guo, P., and Ye, J. (2021). Study on emission reduction strategies of dual-channel supply chain considering green finance. *Front. Environ. Sci.* 9, 687468. doi:10.3389/fenvs.2021.687468

Chen, H., Chen, K., Ren, S., Clark, J. H., Fan, J., Luo, G., et al. (2019). Characterization and utilization of aqueous products from hydrothermal conversion of biomass for bio-oil and hydro-char production: A review. *Green Chem.* 21 (7), 1553–1572. doi:10.1039/c8gc03957g

Chowdhury, T. U., Datta, R., and Mohajan, H. K. (2013). Green finance is essential for economic development and sustainability. *Int. J. Res. Commer.* 3 (10), 104–108.

Dumitrescu, E. I., and Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels. *Econ. Model.* 29 (4), 1450–1460. doi:10.1016/j.econmod.2012.02.014

Fei, R., and Lin, B. (2017). Estimates of energy demand and energy saving potential in China's agricultural sector. *Energy* 135, 865–875. doi:10.1016/j.energy.2017.06.173

Fernández, Y. F., López, M. F., and Blanco, B. O. (2018). Innovation for sustainability: The impact of R&D spending on CO2 emissions. *J. Clean. Prod.* 172, 3459–3467. doi:10.1016/j.jclepro.2017.11.001

Ferrat, Y., Daty, F., and Burlacu, R. (2022). Short- and long-term effects of responsible investment growth on equity returns. *J. Risk Finance* 23 (1), 1–13. doi:10.1108/jrf-07-2021-0107

Guo, L., Zhao, S., Song, Y., Tang, M., and Li, H. (2022). Green finance, chemical fertilizer use and carbon emissions from agricultural production. *Agriculture* 12 (3), 313. doi:10.3390/agriculture12030313

Hair, J., Black, W., Babin, B., and Anderson, R. (2010). *Multivariate data analysis, a global perspective*. 7th ed. New Jersey: Pearson Prentice Hall.

Hall, S., Roelich, K. E., Davis, M. E., and Holstenkamp, L. (2018). Finance and justice in low-carbon energy transitions. *Appl. Energy* 222, 772–780. doi:10.1016/j.apenergy.2018.04.007

Im, K. S., Pesaran, M. H., and Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *J. Econ.* 115 (1), 53–74. doi:10.1016/s0304-4076(03)00092-7

Ji, X., Chen, X., Mirza, N., and Umar, M. (2021). Sustainable energy goals and investment premium: Evidence from renewable and conventional equity mutual funds in the Euro zone. *Resour. Policy* 74, 102387. doi:10.1016/j.resourpol.2021.102387

Jie, W., Poulova, P., Haider, S. A., and Sham, R. B. (2022). Impact of internet usage on consumer impulsive buying behavior of agriculture products: Moderating role of personality traits and emotional intelligence. *Front. Psychol.* 13, 951103. doi:10.3389/fpsyg.2022.951103

Karim, S., Naeem, M. A., Mirza, N., and Paule-Vianez, J. (2022). Quantifying the hedge and safe-haven properties of bond markets for cryptocurrency indices. *J. Risk Finance* 23 (2), 191–205. doi:10.1108/jrf-09-2021-0158

Khan, R. U., Arif, H., Sahar, N. E., Ali, A., and Abbasi, M. A. (2022). The role of financial resources in SMEs' financial and environmental performance; the mediating role of green innovation. *Green Finance* 4 (1), 36–53. doi:10.3934/gf.2022002

Koçak, E., and Ulucak, Z. Ş. (2019). The effect of energy R&D expenditures on CO 2 emission reduction: Estimation of the STIRPAT model for OECD countries. *Environ. Sci. Pollut. Res.* 26 (14), 14328–14338. doi:10.1007/s11356-019-04712-2

Lee, K. H., and Min, B. (2015). Green R&D for eco-innovation and its impact on carbon emissions and firm performance. *J. Clean. Prod.* 108, 534–542. doi:10.1016/j.jclepro.2015.05.114

Levin, A., Lin, C. F., and Chu, C. S. J. (2002). Unit root tests in panel data: Asymptotic and finite-sample properties. *J. Econ.* 108 (1), 1–24. doi:10.1016/s0304-4076(01)00098-7

Martins, J. M., Haider, S. A., Pereira, J. M., Mata, M. N., and Abreu, A. (2022). "Innovation management on waste biorefineries," in *Handbook of waste biorefinery* (Cham: Springer), 915–932.

Morelli, J. (2011). Environmental sustainability: A definition for environmental professionals. *J. Environ. Sustain.* 1 (1), 1–10. doi:10.14448/jes.01.0002

Murshed, M. (2020). An empirical analysis of the non-linear impacts of ICT-trade openness on renewable energy transition, energy efficiency, clean cooking fuel access and environmental sustainability in South Asia. *Environ. Sci. Pollut. Res.* 27 (29), 36254–36281. doi:10.1007/s11356-020-09497-3

Murshed, M., Elheddad, M., Ahmed, R., Bassim, M., and Than, E. T. (2021). Foreign Direct Investments, Renewable Electricity output, and Ecological Footprints: Do financial globalization facilitate renewable energy transition and environmental welfare in Bangladesh? *Asia-Pac. Financ. Mark.* 29, 33–78. doi:10.1007/s10690-021-09335-7

Naqvi, B., Mirza, N., Rizvi, S. K. A., Porada-Rochoń, M., and Itani, R. (2021). Is there a green fund premium? Evidence from twenty seven emerging markets. *Glob. Finance J.* 50, 100656. doi:10.1016/j.gfj.2021.100656

Nasim, I. ., Ahmad, R. ., Bashir, F. ., and Noreen, S. (2022a). Trade openness as a determinant of sectoral growth in Pakistan: A time series analysis. *Rev. Educ. Adm. Law* 5 (2), 73–83. doi:10.47067/real.v5i2.219

Nasim, I., Chaudhry, I. S., and Bashir, F. (2022b). Effects of trade, environment quality and human capital on industrial sector output in developing countries: A panel data analysis. *iRASD J. Eco.* 4 (1), 107–116. doi:10.52131/joe.2022.0401.0065

Nisar, Q. A., Akbar, A., Naz, S., Haider, S. A., Poulova, P., and Hai, M. A. (2022). Greening the workforce: A strategic way to spur the environmental performance in the hotel industry. *Front. Environ. Sci.* 110. doi:10.3389/fenvs.2022.841205

Nordin, S. K. B. S., and Sek, S. K. (2018). "Comparing the relationship among CO2 emissions, energy consumption and economic growth in high and low income countries: Panel Granger causality and cointegration testing," in AIP Conference Proceedings, November 30–December 13, 2015 (New York, United States: AIP Publishing LLC), 040014. doi:10.1063/1.5041688.1974

Ozili, P. K. (2022). Green finance research around the world: A review of literature. *Int. J. Green Econ.* 16 (1), 1. doi:10.1504/IJGE.2022.10048432

Pakrooh, P., Hayati, B., Pishbahar, E., Nematian, J., and Brännlund, E. R. (2020). Focus on the provincial inequalities in energy consumption and CO2 emissions of Iran's agriculture sector. *Sci. Total Environ.* 715, 137029. doi:10.1016/j.scitotenv.2020.137029

Peng, J., and Zheng, Y. (2021). Does environmental policy promote energy efficiency? Evidence from China in the context of developing green finance. *Front. Environ. Sci.* 299. doi:10.3389/fenvs.2021.733349

Rafiq, M., Akbar, A., Maqbool, S., Sokolová, M., Haider, S. A., Naz, S., et al. (2022). Corporate risk tolerance and acceptability towards sustainable energy transition. *Energies* 15 (2), 459. doi:10.3390/en15020459

Restuccia, D., and Rogerson, R. (2013). Misallocation and productivity. *Rev. Econ. Dyn.* 16 (1), 1–10. doi:10.1016/j.red.2012.11.003

Sandström, V., Saikku, L., Antikainen, R., Sokka, L., and Kauppi, P. (2014). Changing impact of import and export on agricultural land use: The case of Finland 1961–2007. *Agric. Ecosyst. Environ.* 188, 163–168. doi:10.1016/j.agee.2014.02.009

Saravia-Matus, S. L., Hörmann, P. A., and Berdegué, J. A. (2019). Environmental efficiency in the agricultural sector of Latin America and the Caribbean 1990–2015: Are greenhouse gas emissions reducing while agricultural production is increasing? *Ecol. Indic.* 102, 338–348. doi:10.1016/j.ecolind.2019.02.050

Shahbaz, M., Raghutla, C., Song, M., Zameer, H., and Jiao, Z. (2020). Public-private partnerships investment in energy as new determinant of CO2 emissions: The role of technological innovations in China. *Energy Econ.* 86, 104664. doi:10.1016/j.eneco.2020.104664

Shan, S., Lin, Z., Li, Y., and Zeng, Y. (2018). Attracting Chinese FDI in Africa: The role of natural resources, market size and institutional quality. *Crit. Perspect. Int. Bus.* 14, 139–153. doi:10.1108/cpoib-11-2016-0055

Sohail, M., Iqbal, S., Asghar, W., and Haider, S. A. (2020). Corporate social responsibility for competitive advantage in project management: Evidence from multinational fast-food companies in Pakistan. *J. Bus. Soc. Rev. Emerg. Econ.* 6 (4), 1277–1288. doi:10.26710/jbsee.v6i4.1411

Sun, H., Mohsin, M., Alharthi, M., and Abbas, Q. (2020). Measuring environmental sustainability performance of South Asia. *J. Clean. Prod.* 251, 119519. doi:10.1016/j.jclepro.2019.119519

Taghizadeh-Hesary, F., Rasoulinezhad, E., Yoshino, N., Sarker, T., and Mirza, N. (2021). Determinants of the Russia and Asia–Pacific energy trade. *Energy Strategy Rev.* 38, 100681. doi:10.1016/j.esr.2021.100681

Ullah, I., Rehman, A., Svobodova, L., Akbar, A., Shah, M. H., Zeeshan, M., et al. (2022). Investigating relationships between tourism, economic growth, and CO2 emissions in Brazil: An application of the nonlinear ARDL approach. *Front. Environ. Sci.* 52. doi:10.3389/fenvs.2022.843906

Umar, M., Ji, X., Mirza, N., and Naqvi, B. (2021). Carbon neutrality, bank lending, and credit risk: Evidence from the eurozone. *J. Environ. Manag.* 296, 113156. doi:10.1016/j.jenvman.2021.113156

UNFCCC (2015). "Report of the conference of the parties on its twenty-first session, held in Paris from 30 November to 13 December 2015," Part one: Proceedings, United Nations (UNFCCC). Retrieved from Available at: https://unfccc.int/documents/9096.

Wang, Q., and Zhang, F. (2020). Does increasing investment in research and development promote economic growth decoupling from CO2 emission growth? An empirical analysis of BRICS countries. *J. Clean. Prod.* 252, 119853. doi:10.1016/j.jclepro.2019.119853

Wang, X., Huang, J., and Xiang, Z. (2021). Nexus between green finance, energy efficiency, and carbon emission: Covid-19 implications from BRICS countries. *Front. Energy Res.* 9. doi:10.3389/fenrg.2021.786659

Wang, Y., and Zhi, Q. (2016). The role of green finance in environmental protection: Two aspects of market mechanism and policies. *Energy Procedia* 104, 311–316. doi:10.1016/j.egypro.2016.12.053

Wang, Y., Sun, X., and Guo, X. (2019). Environmental regulation and green productivity growth: Empirical evidence on the Porter Hypothesis from OECD industrial sectors. *Energy Policy* 132, 611–619. doi:10.1016/j.enpol.2019.06.016

Wasti, S. K. A., and Zaidi, S. W. (2020). An empirical investigation between CO2 emission, energy consumption, trade liberalization and economic growth: A case of Kuwait. *J. Build. Eng.* 28, 101104. doi:10.1016/j.jobe.2019.101104

Xie, H., Zhang, Y., Wu, Z., and Lv, T. (2020). A bibliometric analysis on land degradation: Current status, development, and future directions. *Land* 9 (1), 28. doi:10.3390/land9010028

Xu, L. (2013). On the evaluation of performance system incorporating "green credit" policies in China's financial industry. *J. Financial Risk Manag.* 02 (02), 33–37. doi:10.4236/jfrm.2013.22005

Yafi, E., Tehseen, S., and Haider, S. A. (2021). Impact of green training on environmental performance through mediating role of competencies and motivation. *Sustainability* 13 (10), 5624. doi:10.3390/su13105624

Yu, B., Li, C., Mirza, N., and Umar, M. (2022). Forecasting credit ratings of decarbonized firms: Comparative assessment of machine learning models. *Technol. Forecast. Soc. Change* 174, 121255. doi:10.1016/j.techfore.2021.121255

Zhang, C., Cheng, X., and Ma, Y. (2022). Research on the impact of green finance policy on regional green innovation-based on evidence from the pilot zones for green finance reform and innovation. *Front. Environ. Sci.* 10, 762. doi:10.3389/fenvs.2022.896661

Zhang, D., Mohsin, M., Rasheed, A. K., Chang, Y., and Taghizadeh-Hesary, F. (2021). Public spending and green economic growth in BRI region: Mediating role of green finance. *Energy Policy* 153, 112256. doi:10.1016/j.enpol.2021.112256

Zhang, L., Pang, J., Chen, X., and Lu, Z. (2019). Carbon emissions, energy consumption and economic growth: Evidence from the agricultural sector of China's main grain-producing areas. *Sci. Total Environ.* 665, 1017–1025. doi:10.1016/j.scitotenv.2019.02.162