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Green finance and foreign direct investment–environmental sustainability nexuses in emerging countries: new insights from the environmental Kuznets curve

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The primary objective of the present study is to identify the asymmetric relationship between green finance, trade openness, and foreign direct investment with environmental sustainability. The existing research utilizes the asymmetric approach to evaluate annual data from 1980 to 2021. The findings of this study show heterogeneous results. Therefore, the outcomes of the study confirm the nonlinear (NARDL) association between the variables in Pakistan. Moreover, the study describes the positive shock of foreign direct investment (FDI) as a significant and positive relationship with environmental degradation, while the negative shock of FDI shows a negative and significant relationship with the environment. Furthermore, the study scrutinizes the positive shock of green finance as a significant and negative relationship with environmental degradation; the negative shocks also show a negative relationship with environmental degradation in Pakistan. In addition, the consequences of the study suggest that the government should implement taxes on foreign investment and that investors should use renewable energy to produce goods. Furthermore, the results suggest that the government should utilize fiscal policy and fiscal funds to enhance carbon-free projects. Moreover, green securities should be used for green technologies. However, Pakistan can control its carbon emissions and achieve the target of a sustainable environment. Therefore, Pakistan's government should stabilize its financial markets and introduce carbon-free projects. Furthermore, the main quantitative achievement according to the outcomes suggests that policymakers make policies in which they suggest to the government to control foreign investment that causes carbon emissions because of trade openness and also invest the funds in renewable energy, which helps to control the carbon emissions.

KEYWORDS

environmental degradation, trade openness, green finance, economic growth, NARDL approach

1 Introduction

Since the 1960s, global climate change has been a major issue worldwide; for example, ecological cataclysm, environmental pollution, land issues, and depletion of resources have become major worldwide concerns. These issues include total heating (Adebayo et al., 2021; Alvarado et al., 2021; Chen et al., 2021; Fu et al., 2021). Therefore, the world is facing challenges such as food shortages, global warming, environmental degradation, and depletion of resources which harm human life (Dagar et al., 2021; Pan et al., 2022; Shao et al., 2022; Alola and Kirikkaleli, 2019). Furthermore, the sea level is rising daily due to the increasing temperatures, which is an alarming situation for the whole world (Wang et al., 2021). For these challenges, the United Nations introduced the 17 Sustainable Development Goals (SDG), which include affordable renewable energy consumption, and climate activities (United Nations Development Programme, 2020). Moreover, many environmental effects have been produced by carbon and other greenhouse gas emissions in Pakistan. These emissions are producing air pollution and raising the temperature in Pakistan, and the ecosystem has been destroyed by CO_2 and GHG emissions (Apergis N., 2016; Sadiq et al., 2021). Moreover, according to the IPCC report (2014), during the previous 1,400 years, Pakistan's warmest period was from 1983 to 2012. During the last decades, energy consumption, fossil fuels, and industrial areas are the major factors in GHG emissions. Likewise, approximately 76% of greenhouse gases contribute to Pakistan's carbon emissions. Other gases like methane (16%) and nitrous oxide (6%) also contribute to air pollution. Furthermore, almost 76% of greenhouse gas emissions have increased due to forestry, agriculture, and energy production since the 1970s. Furthermore, Pakistan ranks seventh among the high carbon emission countries, indicating that Pakistan's climate condition is adverse and alarming. This condition is challenging for Pakistan's food production and energy security (economic survey, 2017). Likewise, air pollution leads to the increased incidence of many diseases such as heart disease, stroke, and lung cancer (Rahman et al., 2022). For instance, air pollution has reduced young people's intelligence levels and growth in Pakistan (World Health Organization, 2019). Moreover, according to the World Bank report (2019), 7 million people worldwide die annually due to air pollution. The IPCC report (2022) indicated that we could control 4% of CO2 emissions and 10% of greenhouse gas emissions if governments reduce subsidies for fossil fuels. As a counter to these challenges, numerous nations have started to introduce green economic development (Zeng and Eastin, 2012; Zhang et al., 2019; Lu et al., 2021; Zhang et al., 2021).

Previous international literature has scrutinized CO_2 emissions with different determinants such as poverty, economic growth, agricultural sectors, industrialization, population density, fossil fuel consumption, innovations, economic development, green bonds, green finance, financial development, foreign direct investment, spatial effects of FDI, pollution heaven, pollution hollow, international trade, export variety, globalization, renewable energy consumption, technological development, clean energy consumption, and energy consumption (Qadri et al., 2023). Therefore, foreign direct investment, green finance, trade openness, and economic growth have collectively focused less on CO_2 emissions. Thus, the main objective of this research is to analyze the effects of these macroeconomic factors collectively on carbon emissions.

In economic growth, ecological quality initially corrupts and then starts to further develop in the wake of arriving at a specific limit. This inverse U-shaped gross domestic product contamination design is additionally demonstrated in the environmental Kuznets curve (EKC) (Grossman and Krueger, 1991; Grossman and Krueger, 1995; Bekun et al., 2019; Sarkodie and, Strezov, 2019; Brown et al., 2020). Overall, the adverse consequence of financial development on ecological quality during the underlying period of improvement occurs because of the scale impact of exchange receptiveness and expanded energy utilization. In any case, this would emphatically affect the climate at the ensuing stage because of the method and organization impact (Mrabet and Alsamara, 2017; Destek and Sarkodie, 2019; Hao et al., 2022; Wu et al., 2022). Regarding the scale impact, the natural quality debases because of additional monetary exercises (transportation, modern creation, and deforestation) and energy utilization because, in the first phase of improvement, more consideration is given to development rather than ecological quality. Later, during pay level expansions in the second transformative phase under strategy impact, individuals request cleaner climates to achieve a higher expectation for everyday comforts (Grossman and Krueger, 1991; Antweiler et al., 2001; Mahalik et al., 2018; Sarkodie, 2018). In this respect, the creation of merchandise dirty innovation is supplanted by cleaner innovation or by administration areas, which decidedly affects the climate and is known as the synthesis impact (Antweiler et al., 2001; Uddin et al., 2017; Udeagha and Ngepah, 2019; Akram et al., 2022).

Previous studies have applied different methods to evaluate the results of the macroeconomic factors; these methods include regression analysis, linear frameworks, the Granger causality test (Granger and Yoon, 2002), vector error-correction models, the VAR model, quantile regression analysis, quantile-on-quantile regression, the wavelet approach, FMOLS, and DOLS approaches by Cheng, Sinha, Ghosh, and Lu (2018). Furthermore, most of the previous studies applied a linear (ARDL) approach to identify the relationships between variables. In contrast, the present study applies the nonlinear (NARDL) asymmetric approach to examine the positive and negative shocks of exogenous variables with endogenous variables with CO_2 emissions because the linear framework may show misleading results.

The benchmark of economic development in Pakistan is highly affected by foreign direct investment, which raises carbon emissions. These emissions are caused by the deterioration of environmental quality in Pakistan (Qadri et al., 2022c). Furthermore, the inflow of foreign direct investment is increasing due to world economic development and international capital flow. Furthermore, FDI increases carbon emissions in the host countries and promotes an unfriendly environment. Thus, FDI has negative and significant effects on the host country. For instance, previous studies have investigated the increase in the inflow of FDI and reported that it may increase environmental degradation in developing countries. A recent study reported that the inflow of FDI increases air pollution and harms CO_2 emissions. Moreover, several studies have shown that the pollution haven hypothesis increases the aggregate of CO_2 emissions and harmful environmental degradation (Cole, 2004; Cole et al., 2011; Ur Rahman et al., 2019; Kheder and Zugravu, 2012; Rahman et al., 2021). Moreover, some studies have reported that the inflow of FDI mitigated the carbon emissions in host countries due to clean technology projects, enhanced financial development, and

helped promote a friendly environment; thus, FDI inflows have a positive and significant impact on CO_2 emissions (Nair-Reichert and Weinhold, 2001; Didas et al., 2015; Diaz and Moore, 2017; Destek M et al., 2018). Furthermore, a recent study by Huang et al. (2022) showed that the early stage of FDI inflow may increase carbon emissions; however, after reaching a threshold level, carbon emissions decrease due to increased FDI inflow. Moreover, recent studies by Manoli and Weber (2016), Mahmood and Tariq (2020), Xie et al. (2020), and Li et al. (2022) showed the negative impact of FDI on CO_2 emissions.

While green finance plays an important role, few studies have addressed this topic. In recent years, the finance sector has relied on green investments; thus, we cannot achieve sustainable economic growth (Sachs, 2015). Green finance tools can help achieve a green environment. In this way, financial brokers and markets have introduced financial tools such as green loans, green bonds, green home mortgages, and green environments. The view of green finance is not yet properly visible, and researchers are trying to reach a clear concept or definition (Zhang et al., 2019). Furthermore, green finance has inspired investment in different techniques and innovations that emerged from renewable energy (Yildiz et al., 2015; Meo and Abd Karim, 2021; Zakari et al., 2022) and green investments have positively contributed to a friendly environment. Furthermore, green finance benefits not only decreased energy consumption but also has a positive effect on economic development and CO_2 (Pao and Tsai, 2010; Rahman Z et al., 2019; Rehman et al., 2020; Shen et al., 2021; Zhu et al., 2021; Yi et al., 2023).

Trade openness plays an important role in developing countries, and each country transfers its resources and tries to enhance its export level, which is beneficial for the country's progress; however, trade openness harms the ecosystem. Furthermore, recent studies by Sarkodie and Strezov (2019), Shahzad et al. (2022), Shahbaz et al. (2018), and Shahzad et al. (2020) showed the positive and significant effects on the environment because different firms attracted to the trade are aware of spillovers upgrade to clean production through these spillovers, resulting in environmental benefits. Moreover, Salman et al. (2019) reported that trade has a significantly negative impact on the sustainable environment in Asia because when countries increase their exports, they produce more carbon emissions. Likewise, Shahzad et al. (2020) showed the negative impact on CO_2 emissions in Pakistan because the rapid expansion of trade openness has created environmental problems.

In developing countries, rapid economic growth increases energy consumption and carbon emissions through fossil fuels and crude oil. Raza et al. (2021) discussed a country that has non-renewable energy and has produced carbon emissions, and their study evaluated the negative impact of GDP on environmental sustainability. Moreover, most of the developing countries that have faced the poverty problem and want to decrease the poverty level start to increase their economic growth through industrialization; however, this rapid economic growth increases air pollution (Sadiq et al., 2021). Moreover, several studies have shown the positive impact of economic growth on environmental sustainability through the environmental Kuznets curve. Likewise, as reported by Grossman and Kruger (1991), in the first stage, the economy is interested only in economic growth; thus, in this thirst stage, carbon emissions increase, and when it gets to the threshold, it controls carbon emissions due to clean energy.

The current study presents four contributions in the context of previous literature. First, this study uses Pakistan as a sample, not by chance but due to background reasons. For instance, according to Greenpeace International (2006), Pakistan is among almost 90 countries with very high air pollution among 200 South Asian countries. Likewise, as reported by the World Economic Forum (2018), Pakistan is the highest-polluted country among the 19 highest-polluted nations worldwide. Likewise, concern about environmental pollution is a major problem among emerging countries, including Pakistan. Therefore, during the last decade, energy consumption, fossil fuels, and industrial area are the major factors in GHG emissions in Pakistan; for example, Pakistan's carbon emissions are comprised of 76% greenhouse gases, 16% methane, and 6% nitrous oxide (Economic survey, 2017). Moreover, according to Scheffen et al. (2021), carbon emissions will more than double by the end of 2050, making it the largest disaster for developing nations. Second, the basic objective of the present study is to scrutinize the nexus between foreign direct investments, green finance, trade openness, and economic growth with CO_2 emissions, as previous studies have not examined these variables with CO_2 emissions collectively. Moreover, previous studies have evaluated the environmental Kuznets curve to get a sustainable environment (Ullah et al., 2021). However, the present study evaluates other macro factors that affect the environment because of industrialization, urbanization, and energy consumption because most developing countries depend on inflows of FDI but have weak policies about FDI, which leads to environmental degradation. Moreover, the third objective of this study is to motivate Pakistan's government to invest in green projects such as renewable energy projects and green transportation. Similarly, Pakistan could reduce its carbon emissions. The novelty of the present study is its application of the asymmetric (NARDL) approach to obtain more accurate results because of the nonlinear behavior of the variables with environmental degradation. In contrast, most previous studies used symmetric linear frameworks to evaluate the macro-variables, potentially leading to misleading results because the world business and trade cycle has nonlinear behavior in real life (Ullah et al., 2020). Fourth, the present study is important for developing countries because these nations face many challenges, including environmental pollution; thus, the outcomes of the study will help policymakers to make policies that will help the government achieve a sustainable environment.

Following this introduction, the paper includes the following sections: Section 2 is the literature review, Section 3 describes the data and methodology, Section 4 evaluates the results and provides a discussion, and Section 5 presents the conclusions and policy recommendations.

2 Literature review

2.1 Foreign direct investment and environmental sustainability

As already established, FDI information can have both positive and negative effects on the environment of the host economy. As a result, the pollution haven hypothesis (PHH) is used to explain the

negative environmental effects of FDI, whereas the pollution halo effect hypothesis (PHEH) is used to understand the positive effects. According to PHH assumptions, financial globalization attracts foreign investments in unclean industrial processes, particularly in poor and emerging nations, wherein the CO_2 levels in the host economies are projected to increase. This phenomenon develops when rigid environmental regulations in developed countries force investors to invest in developing nations with flexible environmental laws; as a result, these investors take advantage of the lax environmental regulations in developing nations to invest in industries that produce large amounts of pollution. Therefore, the growth of polluting industries within the economies that welcome FDI raises those nations' respective FDI-led CO_2 emissions (Almulali et al., 2021; Qin and Ozturk, 2021). Furthermore, nations with large fossil fuel reserves can be anticipated to have a comparative advantage in the manufacturing of pollution-intensive goods. In such cases, these countries may serve as centers for luring unsavory FDIs, which increases the likelihood that their economies will develop into pollution hotspots (Banerjee and Murshed, 2020).
H_1: There is a significant relationship between foreign direct investment and environmental sustainability.

2.2 Green finance and environmental sustainability

One of the major dangers that the planet is currently facing is global warming. The Sustainable Development Goals (SDGs) of the United Nations (UN) drew attention to the growing concern over environmental contamination and the depletion of natural resources, which led to the introduction of contemporary ideas like sustainable growth. Green human resource management (HRM) practices aim to increase employee awareness of environmental issues and motivate them to take measures to decrease environmental emissions (Qadri et al., 2022a). The financial sector previously disregarded the ecosystem but has started to take environmental concerns more seriously and has launched a number of financial products explicitly aimed at environmental conservation, such as investment in renewable energy projects (Shahzad et al., 2022; Saeed et al., 2022; Hao and Chen, 2023). To date, few studies have connected economics and ecology. According to Wang and Zhi (2016), generating finance for solar energy can help achieve environmental sustainability. Environmental finance/sustainable financing is the most efficient strategy to stop environmental degradation, according to Xu et al. (2017). Green money and sustainable financing promote spending on emerging technologies and breakthroughs such as renewable energy (Jones et al., 2015).
H_2: There is a significant relationship between green finance and environmental sustainability.

2.3 Trade openness and environmental sustainability

Previous empirical studies on the relationship between foreign trade and emissions have produced conflicting findings, ranging from the claim that global trade causes CO_2 emissions to the denial of a causal connection between these two variables (Charfeddine and Ben Khediri, 2016; Shahbaz et al., 2016). Osathanunkul et al. (2018) reported that the types of indicator variables employed, the analytical methodologies used, and the study area's field of choice are the main causes of the differences in results. One cause of environmental contamination is the sharp increase in commodity production and consumption brought on by international trade (Kasman and Duman, 2015). Antweiler et al. (2001) investigated how pollutant concentrations are impacted by the global trade of products. The investigators used theoretical models to analyze three aspects of trade's influence on pollution: scale, composition, and technique. To identify connections between carbon emissions, urbanization, economic development, trade, energy depletion, and financial expansion, Dogan and Turkekul (2016) carried out a similar analysis in the United States. Their results showed that increased commerce benefits the US environment. However, there was no proof that emissions and world trade were causally related. The variables used by Dogan and Turkekul (2016) were also utilized by Farhani and Ozturk (2015) to investigate the link in Tunisia between 1971 and 2012. The "cointegrating Frontier" test, which demonstrates the long-term relationship between variables, was used to conduct the investigation. Many studies also employed a panel technique to conduct an empirical analysis of the causal linkage between similar factors used in industrialized economies by Hao (2023a), Dogan and Turkekul (2016), and Farhani and Ozturk (2015). The study discovered that variables are cointegrated using the Fisher panel cointegration approach. The causality test, however, did not identify any long-term causal nexuses between the variables. Despite these results, the study also discovered one-way causation between trade openness and short-term environmental carbon emissions. Toda and Yamamoto's Granger causality and the vector autoregression approach were both used by Michieka et al. (2013) to analyze the causative relationships among CO_2 emissions, coal use, and export commerce in China from 1970 to 2010.
H_3: There is a significant relationship between trade openness and environmental sustainability.

2.4 Economic growth and environmental sustainability

The argument over whether environmental degradation and economic advancement are possibly related began with the study of Grossman and Krueger in 1995. This influential work inspired numerous academics, leading to an increase in empirical studies on the environmental effects of economic growth (Dinda, 2004; Shahbaz et al., 2014; Shahbaz et al., 2017; Carvalho et al., 2018; Sarkodie, 2018; Adu and Denkyirah, 2019; He et al., 2021; Li et al., 2021; Shan et al., 2021; Yuping et al., 2021). The connection between economic development and the environment is based on the assumption that economies at an initial stage of growth concentrate on increasing production because their main goal is to advance economically as this can result in human welfare. This emphasis on development has a scale impact. Individual green values moderate employee behavior for better environmental performance (Li et al., 2023). Due to the scale effect, resource consumption in countries increases as a result of production without pollution control measures, which in turn exacerbates

Title	Author	Result
Do foreign direct investment inflows affect environmental degradation in BRICS nations?		FDI ↑ EP ↓
Does foreign direct investment asymmetrically affect the mitigation of environmental degradation in Malaysia?		FDI ↑ EP ↓
Role of environmental degradation and energy use for agricultural economic growth: Sustainable implications based on ARDL estimation		EG ↑ EP ↓
The influence of energy consumption and economic growth on environmental degradation in BRICS countries: an application of the ARDL model and decoupling index		EG ↑ EP ↓
Does trade openness mitigate the environmental degradation in South Africa?	Udeagha and Ngepah (2019)	TOP ↑ EP ↑
Environmental innovation, trade openness, and quality institutions: an integrated investigation about environmental sustainability	Khan et al. (2022)	TOP ↓ EP ↑
The role of green finance in reducing CO2 emissions: An empirical analysis	Saeed et al. (2022)	GF ↓ EP ↓
Nexus between green finance and climate change mitigation in N-11 and BRICS countries: empirical estimation through difference in differences (DID) approach	Nawaz et al. (2021)	GF ↑ EP ↓

ecological footprint (EF) and environmental degradation (Ulucak and Bilgili., 2018; Ahmed and Le, 2021). The scale effect is substantially influenced by globalization, which makes it possible for countries to generate more, even while domestic markets are experiencing a decline in demand (Ahmed and Le, 2021). Additionally, a well-developed financial system supplies capital to businesses, enabling them to generate more items (Saud et al., 2019). When the protection of environmental regulations is lax, FDI also increases foreign financial inflow, which can amplify the scale effect (Ahmed and Le, 2021; Soylu et al., 2021; Udemba et al., 2021). After this early phase, systemic modifications to the economic structure begin to take place and, because of the composition effect, countries gradually shift toward industrialized economies until finally becoming service economies. Since the service sector does less environmental harm, this structural change helps lower environmental strain (Qadri et al., 2022b). This point also marks the beginning of countries that produce less energy-intensive goods (Danish et al., 2019; Adebayo and Kirikkaleli, 2021; Bekun et al., 2021). In the third stage, advanced nations benefit from knowledge and creativity to produce superior technology. Additionally, economic development begins to reduce pollution levels while environmental concerns take precedence over economic goals, creating an inverted U-shaped relationship between disposable income and ecological decline (Ahmed and Wang, 2019; Kirikkaleli and Adebayo, 2021).

H_4: There is a significant relationship between economic growth and environmental sustainability.

3 Data and methodology

3.1 Data and variables

The present study uses a total of five variables, including environmental sustainability such as foreign direct investment, green finance, trade openness, and economic growth with carbon emissions. The annual data for Pakistan were obtained from the World Development Indicators from 1980 to 2021. We measured green financing in terms of the percentage of renewable energy consumption because Landenberg (2014) explained green investment in terms of renewable energy consumption in a broad sense. According to this, we can determine an environmentally sustainable goal after financial investment in environmental products, sustainable development projects, and policies that motivate the development of a sustainable economy (Nawaz et al., 2021). Furthermore, the present study measured the FDI as net inflow (% GDP), environmental pollution (Kt of CO_2 equivalent), GDP (GDP annual growth), and trade openness (export plus import of goods and services, % GDP), as shown in Table 1.

3.2 Methodology

3.2.1 Econometric form of the model

The present study uses the following table from Nawaz et al. (2021) and takes the logarithmic form of all variables and applies the asymmetric (NARDL) approach to identify the positive and negative shock effects of the variables on environmental pollution.

$$\Delta ES_t = \alpha_0 + \sum_{i=1}^{Z}\beta_1 \Delta ES_{i-1} + \sum_{i=0}^{Z}\beta_2 \Delta FDI_{t-i} + + \sum_{i=0}^{Z}\beta_3 \Delta GF_{t-i} + \sum_{i=0}^{Z}\beta_4 \Delta TOP_{t-i} + + \sum_{i=0}^{Z}\beta_5 \Delta EG + \pi_1\, lnES_{t-1} + \pi_2\, lnFDI_{t-1} + \pi_3\, lnGF_{t-1} + \pi_4\, lnTOP_{t-1} + \pi_5\, lnEG_{t-1} + \varepsilon_t.$$

This study scrutinizes the long-term linear relationships among variables such as foreign direct investment (FDI), green finance (GF), trade openness (TOP), and economic growth (EG) with carbon emissions (CO_2). This study postulates the following linear equation:

$$ES_t = \beta_0 + \beta_1 (FDI_t) + \beta_2 (GF_t) + \beta_3 (TOP_t) + \beta_4 (EG_t) + \varepsilon_t. \quad (1)$$

In this equation, ES, FDI, GF, TOP, and EG represent environmental sustainability, foreign direct investments, green finance, trade openness, and economic growth, respectively. While previous studies have also performed evaluations using linear frameworks, the existing study utilizes the asymmetric (NARDL) approach to identify the exact results for the variables.

TABLE 1 Descriptive statistics.

Variable	Symbol	Proxies/measurement of variables	Data source
Environmental sustainability	ES	(kt of CO_2 equivalent)	World development indicator
Foreign direct investment	FDI	(net inflow, % GDP)	World development indicator
Green finance	GF	(renewable energy consumptions, %)	World development indicator
Trade openness	TOP	(exports of goods and services, % GDP)	World development indicator
		(imports of goods and services, % GDP)	
Economic growth	EG	(annual GDP growth, %)	World development indicator

The reasons may be related to form, as according to Granger and Yoon (2002), a) the presence of hidden co-integration exists in a linear framework and b) the symmetric (ARDL) approach does not show structural breaks in the data. Therefore, the primary objective of the present research is to evaluate the asymmetric association among the variables, i.e., foreign direct investment, green finance, trade openness, and economic growth with environmental sustainability. The nonlinear equation is as follows.

$$ES = f(FDI^+, FDI^-, GF^+, GF^-, TOP^+, TOP^-, EG^+, EG^-). \quad (2)$$

3.2.2 Asymmetric (NARDL) approach

Previous literature has already shown the different outcomes of linear frameworks, such as the Granger causality co-integration test and the vector error correction model (VECM) by Olajide (2013), Wang and Wang (2018), and Lu (2018) which scrutinized the linear framework between the FDI, GF, TOP, and EG with CO_2 emissions. However, they did not clarify the results of exogenous variables and showed some misleading results (Pesaran et al., 2001). The asymmetric (NARDL) bounds testing approach changes the variables into negative and positive shocks and also shows the long-run and short-run results (Shin et al., 2014); moreover, this approach shows the dynamic NARDL graphs and CUSUM and CUSUM square graphs to describe the model stability. This study scrutinizes the long-term relationship between the explained variables as follows:

$$ES_t = \theta_0 + \theta_1(FDI^+) + \theta_2(FDI^-) + \theta_3(GF^+) + \theta_4(GF^-) + \theta_5(TOP^+) + \theta_6(TOP^-) + \theta(EG^+) + \theta_8(EG^-) + \varepsilon_t. \quad (3)$$

Eq. 3 shows that φ_i is the long-term parameter. The nonlinear (NARDL) impacts of foreign direct investments, green finance, trade openness, and economic growth are indicated as positive FDI^+, GF^+, TOP^+, and EG^+. Similarly, the negative shocks are presented as FDI^-, GF^-, TOP^-, and EG^-, respectively. FDI^+, FDI^-, GF^+, GF^-, TOP^+, TOP^-, EG^- are the positive and negative partial sums of foreign direct investments, green finance, trade openness, and economic growth. However, Eq. 1 shows only a long-term relationship; therefore, we re-specify Eq. 1 under the correction of the error term as follows:

$$\Delta ES_t = \delta_0 + \sum_{l=1}^{m}\delta_{1k}\Delta ES_{t-k} + \sum_{l=1}^{m}\delta_{2k}\Delta FDI_{t-k} + \sum_{l=1}^{m}\delta_{3k}\Delta GF_{t-k} + \sum_{l=1}^{m}\delta_{4k}\Delta TOP_{t-k} + \sum_{l=1}^{m}\delta_{5k}\Delta EG_{t-k} + \psi_1 ES_{t-1} + \psi_2 FDI_{t-1} + \psi_3 GF_{t-1} + \psi_4 TOP_{t-1} + \psi_5 EG_{t-1} + \varepsilon_t. \quad (4)$$

The error term provides the short-run and long-term coefficients in Eq. 4, while Δ_i represents a short-run coefficient and $\psi_1, \psi_2, \psi_3, \psi_4, and\ \psi_5$ indicate the long-term coefficients in the aforementioned equation. Moreover, the equation is assumed to have an asymmetric association among the explained variables. Thus, the primary objective of the present study is to evaluate the asymmetric relationship of FDI, GF, TOP, and EG in Pakistan. Therefore, this study finds the nonlinear effects of the projected variables and considers the asymmetric equation as follows. However, the decomposition of the equation is $\boldsymbol{c_t} = \boldsymbol{\theta^+ d_t^+ + \theta^- d_t^- + \varepsilon_t}$; therefore, $\theta^+ and\ \theta^-$ are the long-term coefficients, and the $\boldsymbol{d_t}$ decomposition of the vector regressors is as follows:

$$d_t = d_t^+ + d_t^-. \quad (5)$$

The current study decomposes the independent variables to find the changes in the partial sums of the positive and negative changes as $\boldsymbol{d_t^+}\ and\ d_t^-$ (Meo et al., 2018). Equations 6–13 indicate the partial sums of the positive and negative changes in foreign direct investments, green finance, trade openness, and economic growth.

$$FDI^+ = \sum_{l=1}^{m}\Delta FDI^+ = \sum_{l=1}^{m} max(\Delta FDI_i, 0), \quad (6)$$

$$FDI^- = \sum_{l=1}^{m}\Delta FDI^- = \sum_{l=1}^{m} min(\Delta FDI_i, 0), \quad (7)$$

$$GF^+ = \sum_{l=1}^{m}\Delta GF^+ = \sum_{l=1}^{m}\max(\Delta GF_i, 0), \quad (8)$$

$$GF^- = \sum_{l=1}^{m}\Delta GF^- = \sum_{l=1}^{m} min(GF_i, 0), \quad (9)$$

$$TOP^+ = \sum_{l=1}^{m}\Delta TOP^+ = \sum_{l=1}^{m} max\ (TOP_i, 0), \quad (10)$$

$$TOP^- = \sum_{l=1}^{m}\Delta TOP^- = \sum_{l=1}^{m} min\ (TOP_i, 0), \quad (11)$$

$$EG^+ = \sum_{l=1}^{m}\Delta EG^+ = \sum_{l=1}^{m} max\ (EG_i, 0), \quad (12)$$

$$EG^- = \sum_{l=1}^{m}\Delta EG^- = \sum_{l=1}^{m} min\ (EG_i, 0). \quad (13)$$

After this stage, the study changes the variables of FDI, GF, TOP, and EG in Eq. 4 by the $FDI^+, FDI^-, GF^+, GF^-, TOP^+, TOP^-, EG^+ and\ EG^-$ variables to complete the asymmetric formula:

TABLE 2 Descriptive statistics.

	ES	FDI	GF	TOP	EG
Mean	11.637	20.767	3.897	6.016	0.597
Median	11.683	20.738	3.873	6.701	0.768
Maximum	12.247	22.444	4.062	6.705	1.628
Minimum	11.007	19.317	3.731	3.114	−2.806
Std. dev.	0.343	0.909	0.085	1.414	0.939
Skewness	−0.165	0.104	0.040	−1.551	−1.917
Kurtosis	2.107	1.984	2.451	3.408	7.635
Jarque–Bera	1.094	1.342	0.370	12.652	39.207
Probability	0.578	0.511	0.830	0.331	0.233

$$\begin{aligned}\Delta ES_t = {} & \theta_0 + \sum_{l=1}^{m}\theta_{1l}\Delta ES_{t-l} + \sum_{l=1}^{m}\theta_{2l}\Delta FDI^{+}_{it-l} + \sum_{l=1}^{m}\theta_{3k}\Delta FDI^{-}_{it-l} \\ & + \sum_{l=1}^{m}\theta_{4l}\Delta GF^{+}_{i-l} + \sum_{l=1}^{m}\theta_{5l}\Delta GF^{-}_{it-l} + \sum_{l=1}^{m}\varphi_{6l}\Delta TOP^{+}_{it-l} \\ & + \sum_{l=1}^{m}\theta_{7l}\Delta TOP^{-}_{it-l} + \sum_{l=1}^{m}\theta_{8l}\Delta EG^{+}_{it-l} + \sum_{l=1}^{m}\theta_{9l}\Delta EG^{-}_{it-l} \\ & + \psi_1 ES_{t-1} + \psi\, FDI^{+}_{it-1} + \psi_3\, FDI^{-}_{it-1} + \psi_4\, GF^{+}_{it-1} \\ & + \psi_5\, GF^{-}_{it-1}\psi\gamma_6\, TOP^{+}_{it-1} + \psi_7 TOP^{-}_{it-1} + \psi_8 EG^{+}_{it-1} \\ & + \psi_9\, EG^{-}_{it-1} + \varepsilon_t. \end{aligned} \tag{14}$$

After scrutinizing Eq. 13, Shin et al. (2014), the present study applied the bounds test approach, which was estimated by Pesaran et al. (2001). Therefore, Pesaran's approach for bounds testing is suitable for Eq. 13 and Eq. 4 to decompose the projected variables into positive and negative changes, a model called the asymmetric (NARDL) model. The asymmetric model is an extension of the ARDL symmetric approach, which has many advantages over cointegration as the traditional model. For instance, it is easy to approach stationary limitations, while the traditional ARDL approach restricts at the same order stationary level (Engle and Granger., 1987), but the ARDL approach can easily be applied when all variables are stationary at I (0) and I (1) difference and or mixed results. Moreover, it is appropriate for small sample sizes and provides long- and short-term results (Panopoulou and Pittis, 2004).

3.3 Dynamic cumulative multiplier

This study utilizes the asymmetric (NARDL) model to develop the cumulative dynamic multipliers, which indicate the change in units as x^{+} *and* x^{-}. x^{+} *and* x^{-} show as decomposed variables (Rahman et al., 2022).

$$C^{+}_{k} = \sum_{h=0}^{q}\frac{\partial x_{i-h}}{\partial x^{+}_{i}},$$

$$C^{-}_{k} = \sum_{h=0}^{q}\frac{\partial x_{i-h}}{\partial x^{-}_{i}}, \quad k = 0, 1, 2, 3, 4 \ldots\ldots..$$

As $K \to \infty, c^{+}_{l} \to \beta^{+}$ and $c^{-}_{l} \to \beta^{-}$, where β^{+} and β^{-} are the asymmetric long – run coefficients and calculated as follows:

$$\beta^{+} = \frac{-\theta^{+}}{q} \text{ and } \beta^{-} = \frac{-\theta^{-}}{q}, \text{ respectively.}$$

3.4 Econometric strategy

This study uses the asymmetric ARDL approach presented by Shin et al. (2014) for time series data for emerging countries, including Pakistan. This technique is used to control the limitations of traditional approaches. Moreover, the present approach shows the positive and negative effects of the variables on environmental degradation. This flexibility allows heterogeneous results, which are useful for policymakers. Furthermore, the traditional ARDL regression approaches have not been used to show the positive and negative effects of macroeconomic variables in terms of environmental sustainability.

4 Empirical findings and explanations

The initial stage of the study involves scrutinizing the descriptive analysis. After that, we evaluate the unit root test to check that the variables are stationary using the ADF and PP tests. Finally, the asymmetric or nonlinear (NARDL) approach is applied to examine the long- and short-term relationships among the variables (Shin et al., 2014).

Table 2 demonstrates the results of the descriptive statistics. FDI has the highest mean value, while EG has a lower mean value. Furthermore, the results of the Jarque–Bera test show that the data are normal because all variable values are greater than the 1% level of significance (0.578, 0.511, 0.830, 0.331, and 0.233 > 0.001). Moreover, Table 2 describes the highest standard deviation value for TOP and the lowest value for GF, which means that there are different magnitudes of mean values. Therefore, the characteristics of the outcomes show the dependency on the asymmetric (NARDL) procedure.

The outcomes of the unit root test are displayed in Table 3. The aim of the first stage of the study is to confirm that no variables are stationary at I (2) because if any variables were to be stationary at the second difference, we would not be able to proceed with the

TABLE 3 Unit root test.

Variable	Augmented Dickey–Fuller		Phillip–Perron		Conclusion
	I (0)	I (1)	I (0)	I (1)	
ES	0.005***	0.000***	0.007***	0.000***	I (0)
FDI	0.129	0.01***	0.269	0.01***	I (1)
GF	0.02***	0.000***	0.02***	0.000***	I (0)
TOP	0.665	0.001***	0.228	0.001***	I (1)
EG	0.006***	0.000***	0.006***	0.000***	I (0)

***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

TABLE 4 Zivot and Andrews (1992) test for unit root.

Variable	Unit root at level I (0)	Years break	Unit root test at first difference (1)	Years break
	t-statistic		t-statistic	
ES	0.300	2012	0.00***	1996
FDI	0.01**	2003	0.01***	2009
GF	0.97	2006	0.06***	2000
TOP	0.12	2008	0.03***	2004
EG	0.22	1998	0.00***	2001

***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

asymmetric (NARDL) approach (Shin et al., 2014). Therefore, the asymmetric approach can be applied when the variables are stationary at I (0), I (1), or mixed. For this purpose, the present study utilizes the augmented Dickey and Fuller (1997) and Phillips–Perron (1988) tests. The study outcomes show that all variables are stationary at I (0) and I (1) and gave mixed results; thus, we are able to proceed with the long-term and short-term asymmetric approach.

The pragmatic suggestions made by the PP, Zivot, and Andrews tests are equivalent. According to Perron (1990), the stationary test for units should consider that traditional unit root tests may produce biased (one-sided) observational results. The root problem of the series may be the source of underlying aberrations. The unit root tests may acknowledge this by describing those cycles as stationary; a false null hypothesis is introduced, yet structural breaks can occur. The difficulty of encouraging unit root analysis and structural breaks is made worse by bias. In addition, Kim and Perron (2009) argued that traditional unit root tests produce dubious results because they deal with low instructive force and low magnitude circulation as an asymmetrically non-individual null hypothesis but similarly accessible alternative assumption in the absence of primary breaks. Utilizing unit root practice, which contains a single identifiable structural break, closes this gap (Zivot and Andrews, 1992). Additionally, both the null and alternative hypotheses of this experiment require a primary break point in the example work with an ambiguous date. The test results are shown in Table 4.

Table 5 reports the results of the symmetric (ARDL) and asymmetric (NARDL) analyses. The F-statistic values are shown in Table 4. The F-statistic value for asymmetric (ARDL) is 2.135, which is less than the lower bound of a 1% level of significance; thus, it is inconclusive. Table 4 demonstrates the result of asymmetric (NARDL). The F-statistic value is 4.256, which is greater than the upper bounds at the 1% level of significance, which means that hidden co-integration exists between the carbon emission and other explained variables, such as FDI, GF, TOP, and EG. However, the result of the bounds test pushes toward the asymmetric long-term and short-term procedure.

Table 6 reports the results of cumulative dynamics estimation. First, among the diagnostic tests, the results of the Breusch–Godfery and Breusch–Pagan–Godfery tests showed that the data were free from the serial and hetero-problem at a 5% significance level. Table 6 shows the R-squared value of 0.890, which indicates the high power of the independent variable of the model and evaluates the changes in independent variables. Table 6 also shows that the F-statistic value is greater than the probability value, which means our model is a good fit.

Table 7 shows the outcomes of the short-run estimation of the independent variables. The short-run table demonstrates the results of the speed of adjustment or cointegration values such as the value of ES (−1) as 0.575 (between 0 and 1). The negative sign shows how much time will take to return to the equilibrium point and the significance at the 1% level for all conditions is fulfilled; thus, we can say that long-term asymmetric (NARDL) exists among the variables. Moreover, the coefficients of FDI_POS and FDI-NEG are −0.575 and 0.021, respectively, and are significant at a 1% level of significance, which means that a 1% increase in FDI_POS will lead to a 0.57% increase in CO_2 emissions in Pakistan in the short term and has an inverse relationship between them. The FDI-NEG is also significant at a 1% level of significance, which means a 1% decrease in FDI will decrease the CO_2 emissions by

TABLE 5 Bound cointegration for linear and non-linear tests.

Test-statistic	F-statistic	Sig. level	Critical value bounds	Upper bound at 5%	Decision
			Lower bound at 5%		
Linear ARDL	2.135	1%	2.62	3.77	Inconclusive
Asymmetric ARDL	4.256	5%	1.11	3.15	Cointegration exists
		10%	1.85	3.85	

Note: The symmetric (ARDL) critical observation is derived from (Pesaran et al., 2001). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Moreover, F-statistic values greater than the upper bound confirm asymmetric long- and short-term relationships among the variables. However, $p = \theta^{+} = \theta^{-} = 0$ represents the null hypothesis of asymmetric cointegration.

TABLE 6 Dynamic non-linear estimation of environmental sustainability.

Variable	Coefficient	Std. error	t-Statistic	Prob.*
ES (-1)	0.425**	0.163	2.526	0.023
FDI_POS	0.021***	0.013	2.761	0.010
FDI_NEG	−0.015**	0.014	−2.754	0.046
GF_POS	−1.026***	0.331	−3.031	0.007
GF_NEG	−1.818***	0.213	−8.484	0.000
GF_NEG (-1)	0.582	0.437	1.335	0.208
TOP_POS	−0.070*	0.051	−2.367	0.098
TOP_POS(-1)	0.071	0.001	1.492	0.153
TOP_NEG	0.086**	0.375	3.216	0.031
TOP_NEG (-1)	−0.919**	0.403	−2.269	0.040
GDP_POS	0.012*	0.001	1.911	0.074
GDP_NEG	−0.003	0.005	−0.810	0.444
GDP_NEG (-1)	0.037***	0.045	2.909	0.013
C	6.351**	1.858	3.435	0.045
R-squared	0.890			
F-statistic	19.918			
Prob. (F-statistic)	0.000			
Serial correlation	0.221**	(0.041)		
heteroscedasticity	0.271**	(0.023)		

Note: "POS" and "NEG" indicate the cumulative positive and negative sums, respectively. $\beta^{+} = \frac{-\theta^{+}}{q}$ and $\beta^{-} = \frac{-\theta^{-}}{q}$ indicate the positive and negative long-term coefficient relationships in the given model, respectively. "Breusch–Godfery" and "Breusch–Pagan–Godfery" were evaluated as serial correlations and heteroscedasticity tests, respectively. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

0.021%, and has a direct relationship because when foreign investment in developing countries primarily wants to earn, profit, environmental impact is not considered; hence, FDI increases CO_2 emissions according to the environmental Kuznets curve in the first stage and technologies cannot mitigate the CO_2 emissions. Moreover, green finance in the short-run is insignificant, which means that in the short-run, the government or investors may not have invested in projects in Pakistan; thus, GF-POS is insignificant in the short-run. GF-NEG shows significance at the 1% level, which means that a 1% decrease in green finance will decrease carbon emissions by 1.226% in the short term (Khan et al., 2022). Furthermore, TOP-POS and TOP-NEG are significant at 1% and 5% levels of significance, respectively, which means that a 1% increase in TOP-POS will increase the carbon emissions, while a 1% decrease in TOP-NEG will decrease carbon emissions in Pakistan and TOP-POS harms the environment. Furthermore, EG_POS and EG-NEG are significant at the 10% and 5% levels of significance, which means that a 1% increase in EG will increase carbon emission in the short term, while a 1% decrease in EG will decrease CO_2 emissions in the short term (Table 8).

The results of long-run NARDL are shown in Table 7 and demonstrate the positive and negative changes of independent

TABLE 7 NARDL short-term results.

Variable	Coefficient	Std. error	t-Statistic	Prob.
C	6.355***	1.858	3.4305	0.005
ES (-1)*	−0.575***	0.163	−3.413	0.000
FDI_POS**	0.021***	0.013	2.761	0.010
FDI_NEG**	−0.015	0.019	−0.754	0.466
GF_POS**	1.026***	0.331	−3.031	0.007
GF_NEG (-1)	1.226***	0.431	−2.856	0.016
TOP_POS(-1)	6.945	0.008	−0.011	0.915
TOP_NEG (-1)	−0.833**	0.290	−2.832	0.019
EG_POS**	0.012*	0.001	1.911	0.074
EG_NEG (-1)	0.025**	0.070	2.498	0.020
D (GF_NEG)	−1.818***	0.213	−8.484	0.000
D (TOP_POS)	−0.070***	0.051	−2.367	0.008
D (TOP_NEG)	0.086**	0.375	2.216	0.031
D (EG_NEG)	−0.043	0.005	−0.810	0.434

*, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. "POS" and "NEG" indicate positive and negative changes in explanatory variables, respectively. The null hypothesis of the short-term series is denoted as $\sum_{h=0}^{q} x_i^{+}$ and $\sum_{h=0}^{q} x_i^{-}$, respectively.

TABLE 8 NARDL long-run results.

Variable	Coefficient	Std. error	t-statistic	Prob.
FDI_POS	0.051**	0.225	2.290	0.031
FDI_NEG	−0.019*	0.270	−4.694	0.093
GF_POS	−1.771**	0.792	−2.221	0.046
GF_NEG	−2.133***	0.260	−8.158	0.000
TOP_POS	0.021*	0.990	−5.016	0.095
TOP_NEG	0.478**	0.628	−2.390	0.032
EG_POS	0.025**	0.165	4.559	0.049
EG_NEG	0.048***	0.253	3.716	0.018
C	11.058***	0.022	3.898	0.000

Notes: ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively. The *p*-values are shown in parentheses.

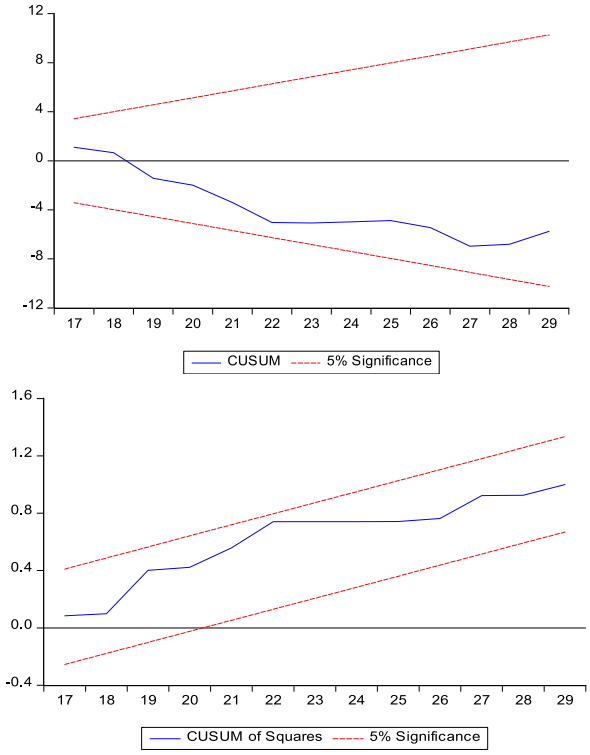
variables on the dependent variable. Therefore, the coefficients of FD-POS and FDI-NEG are 0.051 and −0.019, respectively, and are significant at the 5% and 10% levels, respectively. These results confirm the asymmetric relationship between the variables in the long term. Moreover, a 1% increase in FDI-POS will lead to a 0.051% increase in carbon emissions in Pakistan, consistent with previous results (Lin and Ma, 2022). Thus, in developing countries, when foreign projects and firms start their projects, they will produce more carbon emissions, which is harmful to Pakistan because Pakistan is already suffering from poor climate conditions. Therefore, FDI-NEG shows that a 1% decrease in FDI will reduce carbon emissions by 0.019%, and it has a direct relationship with carbon emissions. Likewise, the coefficient of GF-POS is −1.771 and is significant at a 5% level of significance, which means that a 1% increase in green finance will decrease the carbon emissions in Pakistan by 1.77% (Khan et al., 2022). GF-NEG shows a coefficient of 2.133, which is significant at a 1% level of significance, which means that a 1% decrease in green finance will increase carbon emissions by 2.133% (Meo and Abd Karim, 2021; Li et al.,

2022; Zakari et al., 2022) and has an inverse relationship. Moreover, the coefficients of TOP-POS and TOP-NEG are 0.025 and 0.478, respectively, and are significant at the 10% and 5% levels, which means that a 1% increase in trade openness will increase carbon emissions by 0.025% in Pakistan, while a 1% decrease in TOP-NEG will decrease the carbon emissions by 0.478%, and negative change is very effective in Pakistan compared to positive shock. 4. The empirical analysis portion needs (Hao, 2023b; Matar et al., 2023). Likewise, EG-POS and EG-NEG have coefficients of 0.025 and 0.048 and are significant at the 5% and 10% levels, respectively. The positive shocks show that a 1% increase in economic growth will lead to a 0.025% increase in carbon emissions. The negative shocks show that a 1% decrease in economic growth will lead to a 0.048% decrease in carbon emissions in Pakistan (Xie et al., 2022).

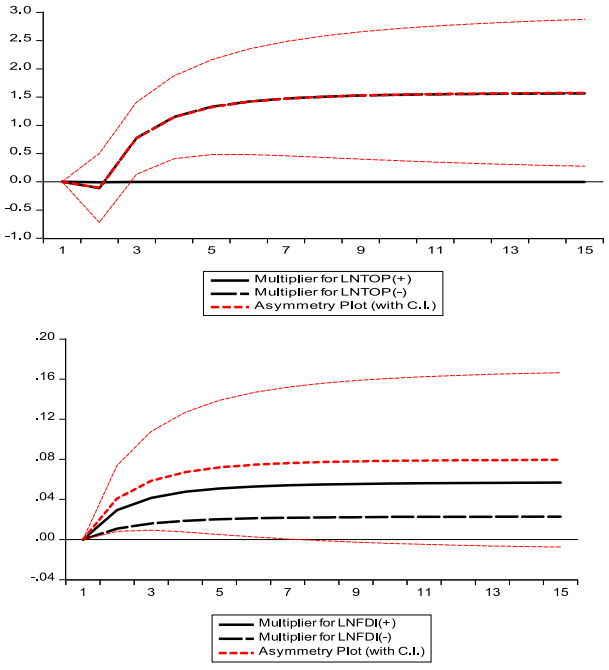
One major hazard the world is facing today is global warming. The Sustainable Development Goals (SDGs) of the United Nations (UN) focus on rising concerns about environmental degradation and the depletion of natural resources, which have opened the door for the introduction of contemporary ideas like sustainable growth. The financial sector previously disregarded the ecosystem, but it has started to take environmental concerns more seriously and has launched several financial products explicitly aimed at environmental conservation, such as green bonds. However, to our knowledge, no research has been conducted that empirically analyzes the relationship between green financing and CO_2 emissions using an asymmetric ARDL technique. Previous studies have examined the association between CO_2 emissions and other macroeconomic factors. The link between green financing, foreign direct investment, and CO_2 emissions might depend on the economic cycle as well as the amount and type of green finance, making this strategy particularly intriguing in this context (renewable energy consumption). As a result, with other controlled variables, it is anticipated that CO_2 emissions will react differentially to both positive and negative changes in green finance and foreign direct investment. Because of both positive and negative changes in green finance and foreign direct investment, CO_2 emissions are anticipated to react differently. CO_2 emissions often remain high during periods of strong economic boom and fall during periods of economic contraction. The nature of the relationship between CO_2 emissions and green finance can vary depending on the state of the economy, even though CO_2 is a complex and multifaceted phenomenon whose relationships with green finance and foreign direct investment depend on many factors (expansion or recession). Therefore, positive rather than negative changes in green finance and foreign direct investment may have a greater impact on CO_2 emissions because renewable energy can mitigate the carbon emissions from the environment (Hao et al., 2022). According to the theory of the environmental Kuznets curve, in the first stage, carbon emissions increase due to economic growth, but after this stage, they become environmentally friendly because of clean energy or technological innovation. According to the outcomes, positive shocks show that carbon emissions are increasing due to production, while negative shocks show decreased CO_2 emissions after using clean energy.

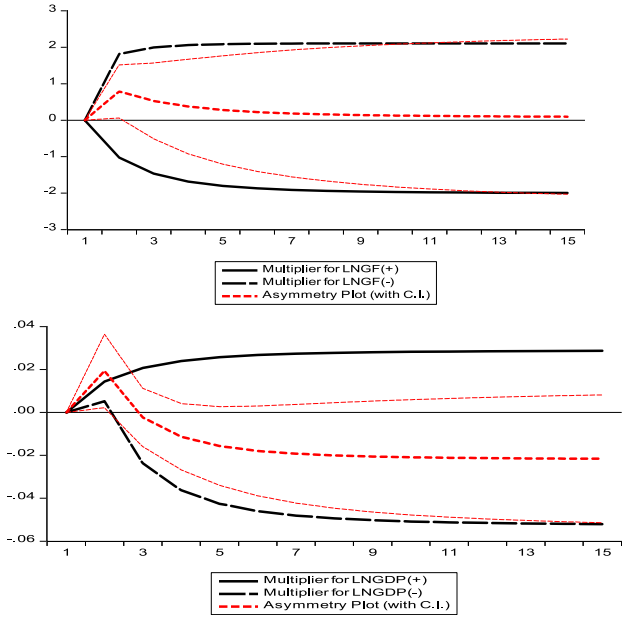
4.1 Model stability test

CUSUM and CUSUM-SQUARE tests are used to examine the stability of the model. The blue lines of both are between the lower and upper bounds, which means that all variables are stable in the data (Brown and Vincent, 1987).



4.2 Dynamic multiplier graphs





4.3 Dynamic multiplier effects

The effects of multipliers show the condition of speed of adjustment and the behavior of adjustment before shock and after shock. However, the present study scrutinizes the asymmetric short- and long-term effects through dynamic multiplier graphs. These graphs evaluate the short- and long-term positive and negative changes in FDI, GF, TOP, and EG on CO_2 emissions. Moreover, the graphs show the dynamic multiplier effects among FDI, GF, TOP, and EG with carbon emissions. For instance, solid black lines describe the positive changes of FDI, GF, TOP, and EG, while the negative shocks of independent variables are indicated by dotted black lines. On the other hand, dark dotted red lines indicate a nonlinear relationship, while thin red lines indicate critical bounds. Therefore, the results of all graphs confirm the dynamic nonlinear relationship that exists among the variables.

5 Conclusion and policy recommendation

Although previous literature has classified different macro-determents with carbon emissions in Pakistan, none have described the nonlinear effects of foreign direct investment on a sustainable environment. The present study scrutinizes the asymmetric short- and long-term effects on environmental conditions in Pakistan. Additionally, previous studies have not provided sufficient dynamic results on the relationship of foreign direct investment with environmental conditions because while most of these studies explain sustainable environment with the "environmental Kuznets curve" in Pakistan, none explain the dynamic asymmetric effects of FDI on the sustainable environment with another controlled variable, such as green finance, trade openness, and economic growth. However, the present study applies the dynamic asymmetric approach described by Shen et al. (2021) to data from 1986 to 2021. Therefore, this study shows how host companies and multinational companies produce carbon emissions in developing countries like Pakistan. Moreover, the present research evaluates the effects of "green finance" on CO_2 emissions and explains the importance of these effects in Pakistan, which is a developing country already suffering poor financial conditions that affect its environmental conditions. Furthermore, the augmented Dickey and Fuller (1997) and Phillips–Perron (1988) tests were applied to check that the variables were stationary, which showed mixed results. The following bound cointegration test and the F-statistic value were significant at a 1% level of significance. This study also investigates diagnostic tests like serial correlation and heteroscedasticity tests to show that the data were free from all these conditions and that the model was normal by the Jarque-Bera Test. Furthermore, this study investigates the short- and long-term results. In the long term, positive shocks of FDI increase carbon emissions and negative shock shows a decrease in carbon emissions but has a negative relationship. Furthermore, green finance plays an important role in the long term because positive shocks show that a 1% increase in green finance will increase environmental sustainability and reduce carbon emissions in Pakistan. On the other hand, negative shock shows that decreased green finance increases carbon emissions. Moreover, the positive shocks of TOP and EG increase carbon emissions and their negative shocks decrease carbon emissions in Pakistan. Furthermore, the results indicate that economic expansion in Pakistan increases environmental pollution and has an adverse effect on the improvement of environmental quality and confirm the EKC hypothesis of an inverted U-curve interaction.

5.1 Policy recommendations

Pakistan has the highest carbon emissions among the top 10 countries with high CO_2 emissions, which is dangerous for Pakistan's climate. The present study suggests some implications for the government and policymakers.

The results of this study suggest that the government of Pakistan should impose maximum tariffs and taxes on foreign companies, investors, and foreign projects associated with the production of high carbon emissions in the host areas. The results of the current research recommend that policymakers should make policies about clean technologies and carbon-free production, implicating that the government should give incentives and reduce taxes on clean technologies for the investors of Pakistan. Moreover, Pakistan's government should apply limitations and restrictions on foreign investors because foreign countries coming into a host country want only to earn profit and do not care about the environmental impact of their investment. Moreover, developing countries already suffer from different problems like poverty, unemployment, and many other issues; therefore, they also do not care about the environment and want primarily to profit from foreign projects. Furthermore, the

results of this study suggest that the government should develop projects within the country to help investors to invest their income in the country's production and reduce foreign investments, which are the main cause of environmental pollution. Pakistan's government is required to develop a clean environment for foreign direct investment; thus, it would achieve stronger economic performance and be able to reduce environmental pollution.

Nowadays, the global task is to reduce the negative impact of external human economic activities. Many researchers and policymakers strongly support the consequences of green finance on the environment, which helps reduce carbon emissions without compromising economic growth and also helps lessen external human activities. Furthermore, based on the negative association of green finance with environmental quality, the present study provides some suggestions to help increase green finance development. Moreover, the study suggests that Pakistan's government should utilize fiscal policies for the development of green finance, use fiscal funds for carbon-free projects, and promote green finance as green securities and social capital as green investment. Furthermore, the government should provide green securities, in the form of green bonds, to investors and recommend that investors use these green securities for green technologies. For instance, the government should use its fiscal funds in underdeveloped areas and give securities as green bonds to investors in these regions. Moreover, the government should improve its financial market conditions; the study shows that green finance would help the country to control carbon emissions. The government should also give loans to investors at lower interest rates to increase production growth. Likewise, the findings suggest that developing countries should promote their fiscal funds for low carbon emission production and should start green investments in clean energy projects, which benefit the environment.

This study's proposal for policymakers is to develop policies involving exports so that the government can control its investment in import production and increase its exports and domestic production because trade openness negatively affects the environmental condition of Pakistan. Furthermore, the heterogeneous results of trade openness recommend that policymakers and scholars study imports and exports separately because exports help the country to reduce carbon emissions. The results of this study also suggest that policymakers should scrutinize the heterogeneous effects of international trade on carbon emissions and separately consider import and export when formulating policies for achieving the goal of a sustainable environment.

Moreover, the results of this study suggest that policymakers should make policies for governments and investors wherein they advise that the government balance the demand and supply ratio because economic growth is the main mitigating factor of environmental damage in developing nations. Furthermore, the outcomes of this research recommend that governments promote low-carbon-emission technology to produce goods and develop strategies for producers to help promote clean energy production. Furthermore, the government should apply limitations on the supply side. This study has various limitations. First, the sample size is small; from 1980 to 2021, only 42 data samples from Pakistan were available, which leaves out important factors like geographical heterogeneity and economic disparity. Second, the ecological footprint and other environmental pollutants (such as sulfur dioxide (SO_2), nitrous oxide (N_2O), Freon, and methane (CH_4)) are not considered in this analysis; only CO_2 emissions are. Third, the model for how FDI spending affects CO_2 emissions does not consider macro-variables in the context of economic globalization, such as urbanization, population, government assistance, inflation rate, and industrialization.

5.2 Future study

The study recommends that researchers scrutinize the same determinates for the top ten carbon emissions countries. Moreover, the present study measures the single proxy as kt of CO_2 equivalent for the sustainable environment of Pakistan; however, future studies can use different proxies like ecological footprints, N_2O, and SO_2. Furthermore, cross-sectional studies may also be informative.

Data availability statement

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

Author contributions

SUQ: conceptualization. ANN: Data Analysis and Interpretation and Results SR: methodology and interpreted results. LB: software, formal analysis, investigation resources, and visualization. SUQ, SR, AA, MSA, LB, ANN, and XS: validation, and writing—original draft preparation and review and editing. SUQ, ANN, and XS: data curation. XS and MSA: project administration. All authors have read and agreed to the published version of the manuscript. LB: Finally Review the Manuscript and SUQ: Final Complete and Review Draft.

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.

Publisher's note

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