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Uneven Paths to Environmental Sustainability: Nonlinear Impacts of Financial Development in BRICS-T Countries

Hakan Yıldırım [1], Magdalena Radulescu [2,3,4], Anıl Lögün [5], Tuba Özkan [6] and Mesut Dogan [7,*]

[1] Department of Management Information Systems, Mersin University, 33740 Mersin, Türkiye; hakan_emin_yildirim@hotmail.com
[2] Department of Finance, Accounting and Economics, National University of Science and Technology Politehnica Bucharest, Pitesti University Center, 110040 Pitesti, Romania; magdalena.radulescu@upit.ro
[3] Institute of Doctoral and Post-Doctoral Studies, University Lucian Blaga of Sibiu, 550024 Sibiu, Romania
[4] UNEC Research Methods Application Center, Azerbaijan State University of Economics (UNEC), Istiqlaliyyat Str. 6, Baku 1001, Azerbaijan
[5] Department of Econometrics, Atatürk University, 25240 Erzurum, Türkiye; anil.logun@atauni.edu.tr
[6] Department of Finance and Banking, Atatürk University, 25610 Erzurum, Türkiye; tuba.ozkan@atauni.edu.tr
[7] Department of Finance, Banking and Insurance, Bilecik Seyh Edebali University, 11210 Bilecik, Türkiye
* Correspondence: mesutdogan07@gmail.com

Abstract: Greenhouse gas emissions are a major driver of global climate change, prompting increasing attention to the role of financial systems in supporting environmental sustainability. In this context, understanding how financial development influences emissions in emerging economies has become critically important. According to the findings of the long-term estimation, financial development has a direct negative impact on total greenhouse gas emissions and carbon dioxide emissions. Meanwhile, economic growth, trade openness, and population growth exert positive effects on these emissions. Although financial development negatively influences emissions, its interaction with economic growth and population dynamics is complex and may indirectly affect emissions through these factors. In addition, the error correction coefficient found for each country is negative and significant. The panel causality results indicate a unidirectional causal relationship between economic growth and total greenhouse gas emissions and carbon dioxide emissions. These findings are important for governments developing environmental policies, as they show how financial development can improve environmental impacts and help create sustainability-focused policies.

Keywords: greenhouse gas emission; carbon dioxide emission; financial development; environmental quality; sustainability; BRICS-T countries

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1. Introduction

Financial development (FD) is crucial for fostering economic growth. It catalyzes the distribution of financial assets among productive segments of the economy, thereby stimulating the accumulation of material capital, accelerating economic growth, and improving the welfare of society. While there is a general agreement on the favorable influence of FD on economic development, the relationship between FD and environmental quality (EQ) is still a subject of contention [1–3]. The escalating demand for natural resources due to rapid economic growth and progress is leading to alterations in climatic conditions, environmental pollution, soil degradation, loss of biodiversity, and increased vulnerability in emerging countries [4,5].

Four different ways exist for FD to influence carbon dioxide (CO_2) emissions. Initially, the capitalization channel argues that CO_2 emissions may decrease with increasing FD, leading to increased investment and the consumption of green goods. Nevertheless, concurrently, this occurrence might result in a rise in CO_2 emissions as a consequence of the escalated utilization of energy-intensive commodities. While the second path, known as technological impact, suggests that FD may positively impact CO_2 emissions by promoting the development of green products, new innovations may also negatively impact CO_2 emissions by increasing the demand for natural resources. The third path is called income impact. It is emphasized that FD can reduce CO_2 emissions by increasing households' appetite for green goods, but at the same time, increased incomes can lead to increased energy consumption. Finally, the fourth path, known as regulatory influence, indicates that financial institutions can help limit CO_2 emissions by providing loans for green initiatives. This concept theoretically suggests that the impact of FD on CO_2 emissions can be either favorable or unfavorable [6,7]. The impact of economic activities on environmental degradation (ED) has become the focus of scholarly attention. In this context, the Environmental Kuznets Curve (EKC) theory stands out as a key concept to explain the correlation between income levels and ED. According to the EKC theory, ED tends to rise in the early stages of economic development. However, after a specific threshold is reached, further economic advancement leads to environmental benefits. This results in a link between economic growth and the environment that follows an inverted U-shaped pattern [8].

According to Čihák et al. [9], FD involves five major improvements across a wide range. This includes providing information about potential investments and allocating capital accordingly; facilitating control of risks, their variations, and commerce; supervising households and businesses and ensuring compliance with corporate governance after resource allocation; accelerating the exchange of goods, amenities, and monetary instruments; and streamlining and aggregating savings. Because of its potential impact on national economies, FD is one of the leading topics studied by policymakers and researchers. Various fields have recently started studying FD in the context of environmental sustainability. Different perspectives assist research into the environmental impact of FD. Despite its important function in improving economic efficiency, FD can also have a negative impact of providing financing opportunities to consumers and businesses, thereby accelerating the purchase and production of assets such as equipment, air conditioners, and automobiles that increase energy consumption and contribute to environmental protection [10]. This view is supported by studies showing that FD increases energy consumption and leads to ED (e.g., [10–14]). However, in contrast to these studies, there are also studies that find positive effects of FD on the EQ (e.g., [15,16]). According to the view that FD has a negative effect on ED, FD encourages investment in green projects and R&D, thereby reducing ED. Shahbaz et al. [17] argue that financial institutions should promote the use of renewable energy sources that do the least harm to the environment by investing in efficient technology.

Numerous studies have examined the impact of FD on ED, as previously mentioned. Many of these studies used CO_2 indicators (such as per capita emissions, total CO_2 emissions, etc.) to represent ED (see [18–21]). Some studies [22–24] prefer total greenhouse gas emissions (GHG) as the indicator of ED. In addition, many of these studies have selected individual indicators such as private sector credit/GDP and bank deposits/GDP as indicators of FD (see [20,21,25–33]). Some studies ([34,35], etc.) represented FD as an index that measured multiple dimensions simultaneously. Furthermore, several research have specifically examined the linear relationship between FD and ED. In some cases (e.g., [20,21,36], etc.), the nonlinear relationship between FD and ED has been examined.

This study investigates the impact of FD on ED in BRICS-T countries (Brazil, Russia, India, China, South Africa, and Türkiye). Countries such as China and Russia, which are among the largest economies in the world, are classified in this study as developing economies due to their high growth potential and environmental vulnerabilities. This classification is justified by their shared characteristics in terms of both economic development levels and sustainability and environmental challenges. A review of the literature reveals a lack of comprehensive studies that examine the nonlinear relationship between FD and ED using multivariate indicators within this specific group. The inclusion of Türkiye in this analysis is justified not only by its similar dynamics in economic growth and FD compared to the BRICS countries, but also due to its increasing environmental pressures and energy-intensive production structure. Türkiye has recently experienced rising carbon emissions, industrialization-driven environmental stress, and challenges in aligning its financial system with environmental policies—making it a meaningful case for comparative analysis with BRICS nations. The main contribution of this study lies in exploring the mechanisms through which FD shapes environmental outcomes, offering valuable insights into the formulation of sustainable development strategies. A detailed examination of the relationship between FD and EQ provides policymakers—especially in developing economies—with a guiding framework to support environmental sustainability. Furthermore, the findings can serve as essential references for developing financial policies aimed at improving EQ in BRICS-T countries. The study's results on the influence of FD on greenhouse gas emissions offer policy recommendations that assist governments and regulatory bodies in constructing sustainable financial systems and strengthening environmental regulations.

The study is divided into five sections: Section 1 is the introduction. Section 2 discusses the concepts of FD and ED and the relationship between these concepts. Section 3 provides a brief overview of studies examining the factors influencing ED, particularly those investigating the relationship between ED and FD. In Section 4, cross-sectional panel dependence tests, unit root tests, the ARDL model, the fixed effects model, and the panel causality method are used to examine the relationship between ED and FD. Finally, Section 5 discusses the results of the analysis in light of the theoretical and empirical literature.

2. Literature Review

In recent years, the literature examining the relationship between FD and ED has revealed that this interaction is nonlinear, context-dependent, and multidimensional. Studies highlight varying effects across both developed and developing countries, emphasizing that the environmental consequences of FD are shaped by country-specific characteristics, institutional structures, energy policies, and external factors.

Numerous studies, in line with the EKC hypothesis, have identified an inverted U-shaped relationship between FD and ED. For instance, Ganda and Ruza [37] found that bank-based FD contributes to environmental benefits in BRICS and G7 countries, whereas capital market development may lead to more polluting outcomes. Similarly, Sun et al. [38] reported that in South Asian countries, FD initially increases the carbon footprint but reduces emissions after surpassing a certain threshold level. Aslam et al. [39] identified an "inverted N-shaped" relationship in developing economies.

Ruza and Caro-Carretero [40] identified an inverted U-shaped relationship between FD and methane emissions in G7 countries while finding a U-shaped relationship between CO_2 and total greenhouse gas emissions. These contrasting results suggest that the environmental impact of FD may vary depending on the specific environmental indicator used. This context-dependent dynamic is further supported by studies conducted by Shahbaz et al. ([20]—Indonesia; [21]—Malaysia; [25]—South Africa) and Shahbaz et al. ([41]—India),

which emphasize the heterogeneity of the FD–environment nexus across national settings. For example, Shahbaz et al. [21] showed that FD reduces CO_2 emissions in Malaysia, whereas their [25] study found that increased financialization in South Africa led to higher emission levels. Additionally, Das [42] found a long-term asymmetric relationship between FD and CO_2 emissions in Bangladesh. Duan et al. [43] reported that in China, FD initially exacerbates emissions through scale and structural effects, but after surpassing a certain threshold, technological efficiency becomes the dominant factor.

Ju et al. [44] demonstrated that FD exacerbates ED in Arab countries; however, foreign direct investment (FDI), governance quality, and technological innovation play a mitigating role in this relationship. Similarly, Shehzad et al. [45] found that in Pakistan, strong governance enhances EQ, whereas FD exerts both positive and negative environmental effects. Chu, Truong, and Hoang [46] revealed that the FD–ED nexus varies across income groups and is influenced by geopolitical risk in a sample of 40 countries. Geopolitical risk not only aggravates ED but also moderates the impact of FD.

The early literature also highlights this diversity. Yuxiang and Chen [7] showed that in China, FD influences environmental performance through technological progress and regulatory mechanisms. In contrast, Zhang [15] reported that FD in China contributes to higher CO_2 emissions. Al-Mulali and Che Sab [47] emphasized that in Sub-Saharan Africa, energy consumption is closely linked to both economic growth and FD.

Lee, Chen, and Cho [48] found no clear relationship between FD and emissions in OECD countries, whereas Dogan and Turkekul [49] identified a long-run cointegration between the two in the United States. Kocak [16] reported that FD enhances EQ in Türkiye. Similarly, Lahiani [6] found that the impact of FD on CO_2 emissions in China is asymmetric.

Koca and Sevinc [34] confirmed the EKC hypothesis in BRICS-T countries and emphasized the mitigating role of FD in reducing ED. Yang et al. [35] similarly reported the positive environmental effects of FD in Gulf countries. Adams and Klobodu [28] found that CO_2 emissions in Africa have a positive effect on FD and per capita income. Charfeddine and Khediri [36] validated the EKC in the UAE, showing that FD initially increases emissions but later reduces them. Farhani and Ozturk [27] demonstrated that per capita income, urbanization, trade openness, and FD have a positive impact on emissions in Tunisia. Butabba [50] noted that while economic growth improves EQ, FD contributes to greater ED. Finally, Ozturk and Acaravci [26] confirmed the EKC hypothesis for Türkiye but found no significant relationship between FD and ED.

Jalil and Feridun [19] emphasized that FD reduces ED in China. Tamazian and Bhaskara Rao [51], along with Tamazian et al. [18], validated the EKC hypothesis for BRICS countries and transition economies, but also found that weak institutional frameworks can amplify the negative environmental impacts of FD. Kumbaroglu et al. [52] argued that FD contributes to environmental improvement by fostering innovation in energy supply systems.

Table 1 presents a comprehensive synthesis of the existing literature addressing the impact of FD on ED.

Table 1. Summary of the literature on the effects of FD on ED.

Author(s)	Sample	Period	Methods	Findings
Ganda and Ruza [37]	BRICS and G7 countries	1990–2019	Panel Quantile Regression (EKC framework)	Inverted U-shaped relationship in low emission countries; bank-based finance is less polluting than market-based.
Aslam et al. [39]	Developing countries (Paris Agreement signatories)	1996–2021	MMQR (Method of Moments Quantile Regression)	Inverted N-shaped relation; GDP and population increase emissions; Paris Agreement reduces degradation.

Table 1. *Cont.*

Author(s)	Sample	Period	Methods	Findings
Chu, Truong and Hoang [46]	40 countries	2000–2018	Panel regression (income level and geopolitical risk context)	Finance improves the environment in high-income countries and worsens it in middle-income; geopolitical risk is a key moderator.
Shehzad et al. [45]	Pakistan	1990–2018	ARDL and NARDL (with governance quality)	Finance increases CO_2 emissions asymmetrically; good governance improves, but poor governance worsens the environment.
Sun et al. [38]	South Asian countries	2000–2018	CS-ARDL (EKC hypothesis test)	Inverted U-shaped EKC; tech innovation and renewables reduce emissions; FDI worsens the environment.
Ju et al. [44]	Arab countries	1991–2019	CS-ARDL, NARDL, and causality analysis	Finance raises CO_2; FDI, good governance, and tech reduce degradation; asymmetric impacts found.
Duan et al. [43]	28 provinces of China	2005–2021	PSTR model	Finance first increases, then reduces emissions; FDI and efficiency increase pollution; gradual transition.
Das [42]	Bangladesh	1980–2020	NARDL	Asymmetric long-term relation; credit expansion increases CO_2, contraction does not equally reverse effect.
Ruza and Caro-Carretero [40]	G7 countries	1990–2019	FEKC hypothesis-based nonlinear analysis	Inverted U for methane, U-shaped for CO_2 and GHGs; finance positively affects ANS; no significant effect on ecological footprint.
Koca and Sevinc [34]	BRICS-T Countries	1991–2017	Static panel data analysis; Random Effects Model	Confirms EKC with an inverted U-shaped income–pollution relationship; FD reduces, while trade openness increases ED.
Yang et al. [35]	6 Gulf Cooperation Council (GCC) countries	1990–2017	Second-generation panel data methods (e.g., CS-ARDL); ecological footprint as an indicator	Globalization, FD, and energy use significantly deteriorate environmental sustainability across GCC countries; the results emphasize the need for targeted policy interventions.
Lahiani [6]	China	1977–2013	NARDL	FD reduces CO_2 emissions asymmetrically; positive shocks have a stronger impact than negative ones.
Adams and Klobodu [28]	26 African Countries	1985–2011	Panel data analysis; Generalized Method of Moments (GMM) estimation	FD significantly contributes to ED, with the impact varying across different political regimes.
Kocak [16]	7 Countries (Emerging Economies)	1982–2010	Panel cointegration, DOLS, and panel VECM-based Granger causality analysis	FD reduces CO_2 emissions; unidirectional causality from FD to CO_2 emissions.
Dogan and Turkekul [49]	USA	1960–2010	ARDL bounds testing and Granger causality	EKC not supported; energy use and urbanization increase CO_2 emissions; trade reduces emissions; FD has no significant effect.
Charfeddine and Khediri [36]	United Arab Emirates	1975–2011	Cointegration analysis with structural breaks; regime-switching techniques	Validates EKC; FD initially worsens, then improves EQ.

Table 1. *Cont.*

Author(s)	Sample	Period	Methods	Findings
Lee et al. [48]	25 OECD countries	1971–2007	Panel FMOLS; cross-sectional dependence regression	FD reduces CO_2 emissions in select countries; EKC is not supported.
Farhani and Ozturk [27]	Tunisia	1971–2012	ARDL bounds testing, ECM, and Granger causality	FD and GDP increase CO_2 emissions; EKC is not supported.
Shahbaz et al. [41]	India	1970–2012	Bayer–Hanck cointegration and ARDL bounds testing	Globalization, economic and FD, and energy consumption increase CO_2 emissions; EKC is not supported.
Boutabba [50]	India	1971–2008	ARDL bounds testing and VECM	FD increases CO_2 emissions; EKC is not supported.
Shahbaz et al. [20]	Indonesia	1975Q1–2011Q4	ARDL bounds testing, VECM Granger causality, and Zivot–Andrews unit root test	Economic growth and energy consumption increase CO_2 emissions; FD and trade openness reduce emissions.
Shahbaz et al. [21]	Malaysia	1971–2011	ARDL bounds testing and Granger causality analysis	FD reduces CO_2 emissions; energy consumption and economic growth increase emissions.
Shahbaz et al. [25]	South Africa	1965–2008	ARDL bounds testing, ECM, and structural break unit root test	Economic growth and coal consumption increase CO_2 emissions; FD and trade openness reduce emissions; EKC confirmed.
Ozturk and Acaravci [26]	Türkiye	1960–2007	ARDL bounds testing and VECM Granger causality	EKC confirmed; FD has no significant long-run effect on CO_2 emissions.
Al-mulali and Che Sab [47]	30 Sub-Saharan African Countries	1980–2008	Panel data analysis	Energy consumption boosts economic growth and FD but increases CO_2 emissions.
Jalil and Feridun [19]	China	1953–2006	ARDL bounds testing	FD reduces CO_2 emissions; EKC hypothesis confirmed.
Zhang [15]	China	1980–2009	Cointegration analysis, Granger causality test, and variance decomposition	FD increases CO_2 emissions; financial intermediation scale has the strongest impact.
Yuxiang and Chen [7]	China	1999–2006	Panel data analysis	FD reduces industrial pollution; environmental performance improves with financial sector growth.
Tamazian and Bhaskara Rao [51]	24 Countries	1993–2004	Panel GMM estimation and reduced-form modeling	EKC confirmed; financial and institutional development reduce ED.
Tamazian et al. [18]	BRIC Countries	1992–2004	Feasible Generalized Least Squares (FGLS) estimation	Confirms EKC; economic and FD reduce CO_2 emissions.
Kumbaroglu et al. [52]	Türkiye	2005–2030 (projections)	Aggregate economic equilibrium model with endogenous technological learning and willingness-to-pay (WTP) functions	Stabilizing CO_2 emissions at the 2005 levels may reduce GDP by up to 23% by 2030; accelerated RET adoption mitigates economic losses.

A clear consensus on the nature of this relationship remains elusive. While some studies argue that FD exacerbates ED, others suggest that it enhances EQ or find no significant relationship at all. This divergence in the findings can largely be attributed to differences in research design, including the country samples analyzed, econometric methodologies employed, variable selection, and the time periods covered.

However, the prevailing approach in the literature tends to examine the relationship between FD and ED primarily through linear models. Yet, emerging evidence increasingly points to the possibility that the environmental effects of FD may follow nonlinear patterns. In particular, the assumption that the impact of FD on EQ may change direction beyond a certain threshold—implying regime-dependent dynamics—remains underexplored in the current body of research.

Against this backdrop, the present study aims to address a significant gap in the literature. Focusing on the BRICS-T countries, the research investigates the relationship between FD and ED through nonlinear modeling techniques, with particular emphasis on testing the presence of regime-dependent structures. By extending beyond the conventional linear framework, this approach offers more realistic and context-sensitive insights into environmental sustainability.

Moreover, the originality of this study lies not only in its methodological approach but also in its contextual focus. The BRICS-T countries represent a critical group in terms of environmental sustainability given their high levels of carbon emissions, rapid economic growth potential, and increasing degrees of financialization. Examining the environmental impacts of FD within regime-dependent structures in these economies provides valuable insights for the formulation of sustainable finance policies.

In conclusion, this study offers a meaningful contribution to the literature through both its country focus and methodological framework. It underscores the importance of accounting for nonlinear relationships in the formulation of policies aimed at the sustainable transformation of financial systems and provides a novel perspective for designing environmentally friendly growth strategies.

3. Data–Model–Method

3.1. Data

The paper focuses on the BRICS-T countries and analyzes data from 1992 to 2019 to investigate the influence of FD on ED. These countries constitute a group worth examining due to their rapid economic growth potential, evolving financial systems, and increasing environmental pressures. The dataset consists of annual observations consisting of a total of 168 panel data points for 6 countries and 28 years. It was preferred to use total GHG emissions to represent ED. In order to verify the accuracy and reliability of the findings, CO_2 emissions, which are widely used in the existing research and are one of the subcomponents of total GHG, were preferred as the second dependent variable in the study. Most studies examining the various impacts of FD typically use single indicators such as private sector credit/GDP and bank deposits/GDP to represent FD. However, there are different aspects of FD and different metrics associated with these dimensions. Thus, this research employed the FD Index. Most studies examining the various impacts of FD typically use single indicators such as private sector credit to GDP and bank deposits to GDP to represent FD (see [20,21,25–28]). The index is an index calculated by the International Monetary Fund (IMF) using various indicators covering aspects such as depth, accessibility, and efficiency. FD is conceptualized along three main dimensions: depth, access, and efficiency. The depth dimension includes indicators such as the ratio of banking and financial market assets to GDP. The access dimension captures the degree to which households and firms can reach financial services, including metrics like the number of bank branches and credit availability. The efficiency dimension takes into account criteria such as interest rate spreads, banking sector profitability, and the efficient use of financial assets. The index, constructed by the IMF, is calculated by normalizing and equally weighting sub-indicators across these three dimensions. It is reported separately for financial institutions and financial markets, and takes values between 0 and 1, with higher values indicating a more advanced financial

system. Moreover, to increase the significance of the constructed models, additional variables such as economic growth (GDP per capita in dollars), trade openness (represented by the percentage of foreign trade volume in GDP), and total population were included. These variables were transformed into logarithmic form prior to estimation. GHG and CO_2 emission data were retrieved from the CLIMATEWATCH database, while the FD Index was obtained from the IMF database. Additional control variables—namely GDP per capita, trade openness, and total population—were sourced from the World Bank database [53,54].

3.2. Methods–Models

The study began by examining the cross-sectional dependence of the variables required to conduct appropriate panel root tests. It was important to see if the variables showed cross-sectional dependence. To do this, the Breusch–Pagan LM (Lagrange multiplier), Pesaran scaled LM, and Pesaran CD (cross-sectional dependence) methods were used. For each test, the null hypothesis postulated that the variables were cross-dependence independent. Following these tests, the variables were subjected to unit root tests, with Pesaran's [55] panel unit root test serving as the approach in cases of cross-sectional dependence between variables.

When ordinary least squares (OLS) is used to estimate autoregressive distributed lag (ARDL) models, the results can be asymptotically biased [56]. Pesaran et al. [57] presented the pooled mean group (PMG) estimator, which produces asymptotically normal estimates of variables analyzed using the ARDL model, independent of their stationarity at level I(0) or I(1) [58]. In this study, the panel ARDL model was employed due to its flexibility in handling variables that are stationary at level and at first difference within a single estimation framework. Moreover, the ARDL approach allows for the simultaneous estimation of both short-run and long-run dynamics and incorporates an error correction mechanism (ECM) for each cross-sectional unit, which makes it particularly appropriate for heterogeneous country groups such as BRICS-T. The ARDL technique also provides reliable and asymptotically normal estimators in small sample settings [57]. In particular, the pooled mean group (PMG) estimator enables the analysis of dynamic disequilibrium by allowing short-run heterogeneity while assuming long-run homogeneity.

Another advantage of this model lies in its ability to partially address potential endogeneity and omitted variable bias. The inclusion of a lagged dependent variable mitigates the bias arising from reverse causality among variables. Furthermore, the ECM structure allows for modeling both short-run deviations and long-run equilibrium, thereby enabling a robust assessment of long-term relationships among variables. In addition, a panel causality analysis was also conducted in this study to empirically determine the direction of causality, thereby enhancing the structural consistency of the model.

Taking into account the EKC modeling, which deals with the nonlinear structure, the following equations are generated:

$$lnGHG_{i,t} = \partial_0 + \partial_1 lnFD_{i,t} + \partial_2 (lnFD_{i,t})^2 + \partial_3 lnEG_{i,t} + \partial_4 lnPOP_{i,t} + \partial_5 lnTRADE_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$lnCO2_{i,t} = \alpha_0 + \alpha_1 lnFD_{i,t} + \alpha_2 (lnFD_{i,t})^2 + \alpha_3 lnEG_{i,t} + \alpha_4 lnPOP_{i,t} + \alpha_5 lnTRADE_{i,t} + \varepsilon_{2i,t} \quad (2)$$

In Equation (1), ln represents the natural logarithm. GHG shows the total GHG emissions, FD shows FD, FD2 shows FD squared, EG shows economic growth, POP shows the total population, and TRADE shows trade openness. ∂_0 refers to the constant coefficient; ∂_1, ∂_2, ∂_3, ∂_4, and ∂_5 refer to the slope coefficients; and $\varepsilon_{i,t}$ refers to the error term. In Equation (2), CO_2 represents carbon dioxide emissions and α_1, α_2, α_3, α_4, and α_5 refer to education coefficients. $\varepsilon_{2i,t}$ is the error term.

The ARDL model established to examine the impact of FD on total GHG emissions is defined as Equation (3).

$$\begin{aligned}\Delta lnGHG_{i,t} = \beta_0 + \quad & \beta_1 lnGHG_{i,t-1} + \beta_2 lnFD_{i,t-1} + \beta_3 (lnFD_{i,t-1})^2 + \beta_4 lnEG_{i,t-1} \\ & + \beta_5 lnPOP_{i,t-1} + \beta_6 lnTRADE_{i,t-1} + \sum_{h=1}^{p-1} \alpha_{ij} \Delta lnGHG_{i,t-h} \\ & + \sum_{j=0}^{l-1} \eta_{ij} \Delta lnFD_{i,t-j} + \sum_{u=0}^{m-1} \theta_{iu} (\Delta lnFD_{i,t-u})^2 \\ & + \sum_{v=0}^{n-1} \varphi_{iv} \Delta lnEG_{i,t-v} + \sum_{x=0}^{p-1} \mu_{ix} \Delta lnPOP_{i,t-x} \\ & + \sum_{y=0}^{q-1} \delta_{iy} \Delta lnTRADE_{i,t-y} + \varepsilon_{1i,t}\end{aligned} \tag{3}$$

The ARDL model established to examine the impact of FD on CO_2 emissions is as defined in Equation (4).

$$\begin{aligned}\Delta lnCO2_{\mathrm{i,t}} = \alpha_0 + \quad & \alpha_1 lnCO2_{\mathrm{i,t-1}} + \alpha_2 lnFD_{\mathrm{i,t-1}} + \alpha_3 (lnFD_{\mathrm{i,t-1}})^2 + \alpha_4 lnEG_{\mathrm{i,t-1}} \\ & + \alpha_5 lnPOP_{\mathrm{i,t-1}} + \alpha_6 lnTRADE_{\mathrm{i,t-1}} + \sum_{h=1}^{p-1} \psi_{\mathrm{ij}} \Delta lnCO2_{\mathrm{i,t-h}} \\ & + \sum_{j=0}^{l-1} \eta_{\mathrm{ij}} \Delta lnFD_{\mathrm{i,t-j}} + \sum_{u=0}^{m-1} \theta_{\mathrm{iu}} (\Delta lnFD_{\mathrm{i,t-u}})^2 + \sum_{v=0}^{n-1} \varphi_{\mathrm{iv}} \Delta lnEG_{\mathrm{i,t-v}} \\ & + \sum_{x=0}^{p-1} \mu_{\mathrm{ix}} \Delta lnPOP_{\mathrm{i,t-x}} + \sum_{y=0}^{q-1} \delta_{iy} \Delta lnTRADE_{\mathrm{i,t-y}} + \varepsilon_{2\mathrm{i,t}}\end{aligned} \tag{4}$$

lnGHG is the natural logarithm of total GHG emissions, ln *CO*2 is the natural logarithm of CO_2 emissions, lnFD shows the natural logarithm of FD, lnFD2 shows the square of the natural logarithm of FD, lnEG shows the natural logarithm of economic growth, lnPOP shows the natural logarithm of total population, and lnTRADE shows the natural logarithm of trade openness in Equations (3) and (4). Using the PMG estimator, the ARDL model can reveal the short-term and long-term relationships between the variables [59]. Equations (3) and (4) allow us to formulate the long-term relationship between the variables as follows:

$$\begin{aligned}lnGHG_{\mathrm{i,t}} = \mu_0 + \beta_1 lnGHG_{\mathrm{i,t-1}} + \beta_2 lnFD_{\mathrm{i,t-1}} + \beta_3 (lnFD_{\mathrm{i,t-1}})^2 + \beta_4 lnEG_{\mathrm{i,t-1}} \\ + \beta_5 lnPOP_{\mathrm{i,t-1}} + \beta_6 lnTRADE_{\mathrm{i,t-1}} + \varepsilon_{1\mathrm{i,t}}\end{aligned} \tag{5}$$

$$\begin{aligned}lnCO2_{\mathrm{i,t}} = \alpha_0 + \alpha_1 lnCO2_{\mathrm{i,t-1}} + \alpha_2 lnFD_{\mathrm{i,t}} + \alpha_3 (lnFD_{\mathrm{i,t}})^2 + \alpha_4 lnEG_{\mathrm{i,t}} \\ + \alpha_5 lnPOP_{\mathrm{i,t}} + \alpha_6 lnTRADE_{\mathrm{i,t}} + \varepsilon_{2\mathrm{i,t}}\end{aligned} \tag{6}$$

All the variables in Equations (5) and (6) are defined in the same way as in Equations (3) and (4) to show long-term relationships. The model indicating the short-term relationship among the variables for GHG and CO_2 is defined as Equations (7) and (8), respectively:

$$\begin{aligned}\Delta lnGHG_{\mathrm{i,t}} = \omega_0 \quad & + \sum_{h=1}^{p-1} \alpha_{\mathrm{ij}} \Delta lnGHG_{\mathrm{i,t-h}} + \sum_{j=0}^{l-1} \eta_{\mathrm{ij}} \Delta lnFD_{\mathrm{i,t-j}} + \sum_{u=0}^{m-1} \theta_{\mathrm{iu}} (\Delta lnFD_{\mathrm{i,t-u}})^2 \\ & + \sum_{v=0}^{n-1} \varphi_{\mathrm{iv}} \Delta lnEG_{\mathrm{i,t-v}} + \sum_{x=0}^{p-1} \mu_{\mathrm{ix}} \Delta lnPOP_{\mathrm{i,t-x}} \\ & + \sum_{y=0}^{q-1} \delta_{iy} \Delta lnTRADE_{\mathrm{i,t-y}} + \gamma ECT_{i,t-1} + \varepsilon_{1\mathrm{i,t}}\end{aligned} \tag{7}$$

$$\Delta lnCO2_{i,t} = \omega_0 + \sum_{h=1}^{p-1} \alpha_{ij} \Delta lnCO2_{i,t-h} + \sum_{j=0}^{l-1} \eta_{ij} \Delta lnFD_{i,t-j} + \sum_{u=0}^{m-1} \theta_{iu} (\Delta lnFD_{i,t-u})^2 + \sum_{v=0}^{n-1} \varphi_{iv} \Delta lnEG_{i,t-v} + \sum_{x=0}^{p-1} \mu_{ix} \Delta lnPOP_{i,t-x} + \sum_{y=0}^{q-1} \delta_{iy} \Delta lnTRADE_{i,t-y} + \vartheta ECT_{i,t-1} + \varepsilon_{2i,t} \quad (8)$$

In Equations (7) and (8), Δ denotes the differenced forms of the variables in Equations (3) and (4) in addition to their definitions. The appropriate lag length for an ARDL model can be determined using the Akaike Information Criterion (AIC) and the Schwarz Bayesian Criterion (SBC). The coefficients γ and ϑ are the error correction terms (ECTs) in Equations (7) and (8), respectively. These coefficients are expected to be statistically significant and negative. A significant error correction coefficient indicates a long-term relationship and reflects the speed at which the variable returns to equilibrium [60]. Conversely, the insignificance of the coefficients γ and ϑ suggests that there is no long-term relationship between the variables [61].

Dumitrescu and Hurlin [62] proposed an approach to study the causal relationship between stationary variables. The equation derived from stationary variables for panel data is as follows:

$$\Delta y_{i,t} = \beta_0 + \sum_{k=1}^{K} \gamma_{ik} y_{it-k} + \sum_{k=1}^{K} \delta_{ik} x_{it-k} + + \varepsilon_{i,t} \quad (9)$$

In Equation (9), the constant term β_0 refers to the regression coefficients γ_{ik} and δ_{ik} for k lag and i unit. $y_{i,t}$ refers to the dependent variable and x_{it} refers to the independent variables.

4. Findings

Table 2 presents the descriptive statistics of the dataset that was analyzed. According to the statistics, POP has the highest average and FD has the lowest average. POP has the largest standard deviation, indicating the highest level of volatility, while TRADE has the lowest standard deviation, indicating the lowest level of volatility. The variables FD, EG, and TRADE have negative skewness values. The kurtosis values show that the FD2 and EG series have a leptokurtic distribution. Furthermore, the kurtosis values suggest that other series also exhibit a more platykurtic distribution characteristic.

Table 2. Descriptive statistics.

Series	Mean	Standard Deviation	Maximum	Minimum	Skewness	Kurtosis
GHG	7.178	1.071	9.399	5.291	0.081	2.332
CO_2	6.801	1.073	9.222	4.889	0.383	2.650
FD	−0.901	0.407	−0.313	−2.303	−0.681	2.984
FD^2	0.976	0.870	5.303	0.098	1.671	6.684
EG	8.405	0.811	9.388	6.303	−1.172	3.158
POP	19.241	1.275	21.065	17.547	0.343	1.539
TRADE	3.696	0.363	4.706	2.749	−0.666	2.831

Note: Series natural logarithms are taken.

The results of the Pesaran CD tests are shown in Table 3. The results show that the null hypothesis, which states that there is no cross-sectional dependence, is rejected at a level of significance of 1% for all the variables, except for CO_2 in Pesaran CD. These results highlighted the cross-sectional relationship across all the variables. Therefore,

using Pesaran's [55] unit root approach, which includes cross-sectional dependence, the stationarity of the variables was examined.

Table 3. Results of cross-sectional dependence tests.

	Breusch–Pagan LM	Pesaran Scaled LM	Pesaran CD
GHG	194.557 * (0.000)	32.782 * (0.000)	2.864 * (0.004)
CO_2	224.797 * (0.000)	38.304 * (0.000)	2.416 (0.150)
FD	320.445 * (0.000)	55.766 * (0.000)	17.858 * (0.000)
FD^2	302.614 * (0.000)	52.511 * (0.000)	17.346 * (0.000)
EG	375.332 * (0.000)	65.787 * (0.000)	19.363 * (0.000)
POP	370.046 * (0.000)	64.822 * (0.000)	8.039 * (0.000)
TRADE	164.021 * (0.000)	27.207 * (0.000)	5.492 * (0.000)

Note: * indicates significance at the 1% level. The values included in parenthesis indicate the probability values.

Table 4 presents the results of Pesaran et al.'s [55] unit root test. According to the results, the hypothesis that FD, FD2, EG, and POP have a unit root is rejected at least at the 10% significance level, indicating their stationarity. However, the unit root hypothesis for GHG, TRADE, and CO_2 cannot be rejected. Thus, the first differences were taken and it was concluded that ΔGHG, ΔTRADE, and ΔCO_2 are stationary at the 1% significance level.

Table 4. Results of Pesaran (2007) panel unit root test [55].

Variables	Statistics
GHG	−1.779
CO_2	−1.801
FD	−2.444 **
FD^2	−3.101 ***
EG	−3.351 ***
POP	−2.313 *
TRADE	−1.812
ΔTRADE	−3.071 ***
ΔGHG	−4.321 ***
ΔCO_2	−4.049 ***

Note: ***, **, and * signify the 1%, 5%, and 10% significance levels, respectively. The significance levels are −2.58 for 1%, −2.33 for 5%, and −2.21 for 10%, respectively. Δ indicates the first difference in the series.

Table 5 shows the short- and long-run estimation results of the ARDL panel model with GHG as the dependent variable. The long-run results conclude that FD and FD2 are negative and statistically significant at least at the 5% significance level. This means that a 1% increase in FD and FD2 will result in a decrease in GHG emissions of 0.48% and 0.30%, respectively. In the long run, the impact of the EG, POP, and TRADE variables on GHG emissions is found to be significant and positive. This effect on GHG emissions is achieved by approximately 0.71%, 0.76%, and 0.16%, respectively, with a 1% increase in EG, POP, and TRADE.

Table 5. Results of ARDL model estimation (GHG).

Variables	Coefficients	Standard Error	t Statistics	*p*-Value
Long-Run				
FD	−0.480 **	0.239	−2.008	0.047
FD^2	−0.303 ***	0.112	−2.705	0.008
EG	0.708 ***	0.075	9.440	0.000
POP	0.758 ***	0.241	3.145	0.002
TRADE	0.158 ***	0.046	3.435	0.001
Short-Run				
ΔFD	0.444	0.477	0.931	0.354
ΔFD^2	0.279	0.362	0.771	0.442
ΔEG	0.479	0.319	1.502	0.136
ΔPOP	11.431 **	4.664	2.451	0.016
ΔTRADE	−0.050	0.046	−1.087	0.284
ECT(-1)	−0.316 ***	0.092	−3.435	0.001
c	−4.547 ***	1.307	−3.479	0.001
Error Correction Coefficients for Each Country				
Brazil	−0.277 ***	0.019	−14.579	0.001
Russia	−0.042 *	0.172	−0.244	0.097
India	−0.646 ***	0.025	−25.840	0.000
China	−0.398 ***	0.019	−20.947	0.000
South Africa	−0.453 ***	0.026	−17.423	0.000
Türkiye	−0.089 ***	0.003	−29.667	0.000

Note: ***, **, and * signify the 1%, 5%, and 10% significance levels, respectively. Δ indicates the first difference in the series. The coefficient values are provided for each country. ECT is the error correction term.

In the short-run estimation results presented in Table 5, although FD, FD2, and EG are positive, they are not statistically significant. Similarly, even though the TRADE has a negative effect on GHG emissions, it is not statistically significant. The effect of the POP on GHG emissions is found to be statistically significant at the 5% significance level. A 1% increase in the POP will result in an approximately 11.43% increase in GHG emissions. The finding that population has a substantial short-term impact on GHG—approximately 11.43%—is particularly noteworthy. Although this value may initially appear high, the estimated coefficient gains significance when interpreted in the context of both the logarithmic transformation of the population variable and the demographic characteristics of the BRICS-T countries. The countries included in the study exceed the global average in terms of both population size and growth rate. In countries such as India, China, and Brazil, rapid population growth is often accompanied by industrialization and urbanization, which in turn drive high levels of energy consumption and fossil fuel use. These dynamics can lead to notable surges in greenhouse gas emissions in the short term, thereby explaining the relatively high coefficient observed. Accordingly, the impact of population on energy demand—and thus on greenhouse gas emissions—can be considered both meaningful and consistent with theoretical expectations. Although all the variables have a significant effect on long-run GHG emissions, only the POP is statistically significant for the short-run results.

The ECT (−1) coefficient for all units is, as expected, negative and statistically significant. The adjustment to equilibrium in the first year for any shock to the GHG equation is approximately 32%. Analyzing the error correction coefficients obtained for each country, it can be seen that they are statistically significant and negative at the 1% significance level for all countries. Among these countries, India is the fastest to return to equilibrium in the long run, and Russia is the slowest.

Table 6 presents the short- and long-run estimation results of the ARDL panel model with the dependent variable CO_2. The long-run estimation results show that all the variables have a significant impact on CO_2 emissions. While FD and FD2 have a negative impact on CO_2 emissions, EG, POP, and TRADE have a positive effect. An increase of 1% in FD and FD2 will result in a reduction in CO_2 emissions of approximately 1.48% and 0.97%, respectively. For the variables with a positive effect, namely EG, POP, and TRADE, an increase of 1% will increase CO_2 emissions by approximately 0.74%, 1.46%, and 0.16%, respectively.

Table 6. Results of ARDL model estimation (CO_2).

Variables	Coefficient	Standard Error	t Statistics	*p*-Value
Long-Run				
FD	−1.484 ***	0.376	−3.947	0.001
FD^2	−0.969 ***	0.195	−4.969	0.000
EG	0.742 ***	0.089	8.337	0.000
POP	1.459 ***	0.385	3.789	0.000
TRADE	0.160 **	0.072	2.222	0.027
Short-Run				
ΔFD	0.824	0.744	1.108	0.271
ΔFD^2	0.515	0.563	0.915	0.362
ΔEG	0.632	0.400	1.580	0.117
ΔPOP	18.093 **	7.404	2.444	0.016
ΔTRADE	−0.067	0.063	−1.063	0.289
ECT(-1)	−0.301 ***	0.096	−0.315	0.002
c	−8.862 ***	2.876	3.081	0.003
Error Correction Coefficients for Each Country				
Brazil	−0.312 ***	0.019	−16.421	0.001
Russia	−0.019 ***	0.001	−19.000	0.002
India	−0.614 ***	1.684	−0.365	0.000
China	−0.440 ***	0.018	−24.444	0.000
South Africa	−0.389 ***	0.020	−19.450	0.000
Türkiye	−0.029 ***	0.001	−29.000	0.000

Note: *** and ** signify the 1% and 5% significance levels, respectively. Δ denotes the first difference in the series. The coefficient values are provided for each country.

According to the short-run estimation results shown in Table 6, only POP and ECT (-1) are statistically significant. A 1% increase in the POP will result in an 18.09% increase in CO_2 emissions. As shown in Table 5, the long-run results show that all the variables have a statistically significant effect on CO_2 emissions.

Table 6 shows a negative and statistically significant coefficient of ECT (-1) for all the units. Any shock to the CO_2 equation is found to return to its previous equilibrium within about 30% of the first year. When examining the error correction coefficients obtained for each country, they are found to be statistically significant and negative at the 1% significance level for all the countries.

The fixed effects method (FEM) approach is used along with ARDL model estimation to test the consistency of the results. The study consists of data from 27 observations and six units. Due to the smaller cross-sectional size compared to observations, a fixed-effects model is preferred. Table 7 presents the results of the FEM assessment of GHG and CO_2 emissions. According to the fixed effects model applied to FD, all the variables are statistically significant at least at the 5% significance level. EG, POP, and TRADE have a positive effect on GHG emissions. Specifically, a 1% increase in EG, POP, and TRADE

emissions results in a corresponding increase in GHG emissions of approximately 0.68%, 0.81%, and 0.15%. In addition, FD and FD2 have a negative impact on GHG emissions. A 1% increase in FD and FD2 results in a reduction in GHG emissions of approximately 0.85% and 0.25%, respectively.

Table 7. Results of fixed effect estimation.

Variables	GHG			CO_2		
	Coefficient	**Std. Error**	***p*-Value**	**Coefficient**	**Std. Error**	***p*-Value**
FD	−0.846 ***	0.194	0.000	−1.542 ***	6.259	0.000
FD^2	−0.247 ***	0.069	0.001	−0.479 ***	0.298	0.001
EG	0.675 ***	0.050	0.000	0.872 ***	0.107	0.000
POP	0.809 ***	0.217	0.000	1.075 ***	0.077	0.000
TRADE	0.150 **	0.070	0.034	0.273 **	0.335	0.034
Constant	−15.149 ***	4.073	0.000	−23.146 ***	0.108	0.000

Note: *** and ** signify the 1% and 5% significance levels, respectively.

According to the FEM estimation results shown in Table 7 for CO_2, all the variables are statistically significant at least at the 5% significance level. Although the influence of FD and FD2 on CO_2 is negative, the influence of EG, POP, and TRADE on CO_2 is positive (Figure 1). A 1% increase in FD and FD2 results in a decrease in CO_2 of approximately 1.54% and 0.48%, respectively. On the other hand, EG, POP, and TRADE increase CO_2 emissions by about 0.87%, 1.08%, and 0.27%, respectively.

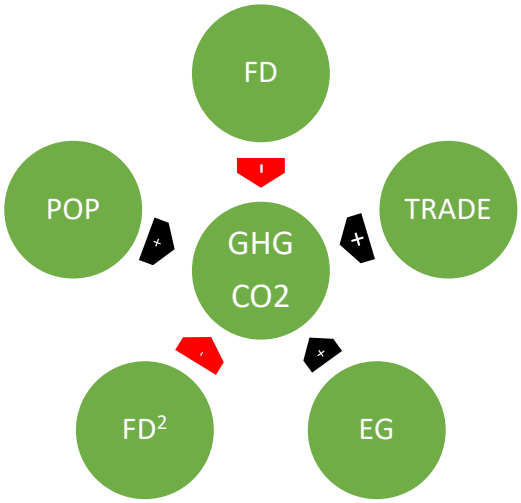


Figure 1. Graphical exhibition of empirical findings.

In addition, the panel causality approach proposed by Dumitrescu and Hurlin [62] is used to examine the causal relationships between variables. Table 8 presents the results of the panel causality test by Dumitrescu and Hurlin [62]. The results of the analysis indicate a one-way causal relationship between GHG emissions and EG at the 5% significance level. The direction of this causal relationship is from EG to GHG. Similarly, the EG is found to significantly influence the CO_2 at the 1% significance level. The result that FD causes the POP is significant at the 10% significance level. No causality is found between FD and GHG, or between FD and CO_2.

Table 8. Results of panel Granger causality.

GHG			CO_2		
Null Hypothesis	**W-Stat.**	***p*-Value**	**Null Hypothesis**	**W-Stat.**	***p*-Value**
GHG → FD	4.401	0.876	CO_2 → FD	4.091	0.736
FD → GHG	4.453	0.900	FD → CO_2	5.117	0.791
GHG → EG	5.709	0.541	CO_2 → EG	5.744	0.527
EG → GHG	8.518 **	0.024	EG → CO_2	9.469 ***	0.005
GHG → POP	1.531 *	0.066	CO_2→ POP	1.573 *	0.069
POP → GHG	5.969	0.445	POP → CO_2	6.497	0.283
GHG → TRADE	7.337	0.117	CO_2 → TRADE	7.063	0.159
TRADE → GHG	6.387	0.313	TRADE → CO_2	6.382	0.314

Note: ***, **, and * signify the 1%, 5%, and 10% significance levels, respectively.

These findings indicate that FD has the potential to be a significant policy instrument in mitigating global climate change. The findings of the study corroborate the hypothesis put out by Shahbaz et al. [21], Paramati et al. [63], Destek and Sarkodie [64], Rafiq et al. [65], Khan et al. [66], and Baloch et al. [67] that increased FD serves as a reliable indicator of CO_2 reduction.

When all analyses conducted in the BRICS-T study are evaluated together, it is found that FD has a statistically significant and nonlinear negative effect on ED. According to the long-term estimation obtained using the ARDL method, FD and FD2 have a negative impact on both GHG emissions and CO_2. However, based on the short-term results, FD has a statistically insignificant positive effect on ED. These findings suggest that FD may not be effective for ED in the short term; however, in the long run, it has a negative impact on ED, or, in other words, a positive effect on EQ. These results are consistent with the results of the fixed effects method. Namely, according to the analysis results obtained using the fixed effects method, both FD and FD2 negatively affect both GHG and CO_2. Overall, the research findings are consistent with some studies that have found a negative impact of FD on ED [6,16,19,21,34,48], but they are not consistent with studies that have found a positive effect of FD on ED [15,27,28,30–32,35,68]. Moreover, the finding that TRADE, POP, and EG included in the models have a positive effect on ED, increasing the significance of the models, is consistent with some studies in the literature. For example, studies by Yang et al. [35] and Farhani and Ozturk [27] also found that EG has a positive effect on ED. Similarly, in their studies, Farhani and Ozturk [27] and Tamazian and Bhaskara Rao [51] found that TRADE was positively effective in ED.

5. Discussion and Policy Recommendations

The study seeks to investigate the impact of FD on ED in consideration of its significance. Initially, a cross-dependence test was conducted to select suitable econometric tests and suitable approaches were used due to the presence of cross-dependence in the variables and models. To achieve this goal, ARDL panel approaches and fixed effects models, as well as panel causality tests, were used to examine the period between 1992 and 2019 for the BRICS-T countries. The estimation results of the panel ARDL and fixed effects model indicate a nonlinear negative effect of FD on ED. Thus, this result indicates that FD has a positive impact on EQ in the long run for BRICS-T countries.

Based on these findings, it is important to develop a series of strategies to improve the environmental impacts of FD for BRICS-T countries. It is clear that FD has significant long-term effects on greenhouse gas (GHG) and carbon dioxide (CO_2) emissions. The negative impact of FD and the square of FD2 on emissions provides an important policy recommendation for governments and regulatory bodies: FD should be aligned with environmental sustainability. Specifically, incentivizing financial systems for green investments and sustainable projects is critical to reducing greenhouse gas emissions. On

the other hand, factors such as economic growth (EG), population growth (POP), and trade (TRADE) have been shown to increase greenhouse gas emissions. This suggests that while achieving growth targets, environmentally friendly policies must also be implemented. Governments should strike a balance between economic growth and environmental sustainability, taking measures to reduce emissions by investing in greener technologies and innovative financial instruments. In this context, policymakers should develop policies that direct FD towards environmentally friendly sectors and strengthen green financing mechanisms. Additionally, to reduce the negative environmental impact of population growth and foreign trade, more sustainable development strategies and environmentally friendly trade policies should be created. These policies will not only improve EQ but also foster sustainable economic growth.

In this context, policymakers should ensure environmental sustainability and mitigate climate change by using financial markets as regulatory tools. It is important to encourage investment in environmentally friendly sectors of the economy. Appropriate credit policies should be implemented to encourage the purchase of equipment that reduces CO_2 emissions. Countries should provide environmentally friendly financial incentives by providing low-cost capital to the renewable energy sector. It is necessary to enhance the framework of capital markets and increase the use of FD in the shift towards a low-carbon economy. Banks should increase support, focusing on the green and low-carbon economies. Green finance mechanisms can increase funding for sustainable development projects. It is essential to develop green technologies and promote green industries. Financial resources should be directed towards clean energy and other environmentally friendly projects. Financial institutions should be interested in investing in green industries. The diversification of financial products is important to facilitate the growth of green lending transactions for renewable energy projects. There is a need to improve energy efficiency and encourage environmentally friendly investments. Regulators must support green investments and monitor their environmental impacts. Financial institutions need to facilitate environmental sustainability initiatives by offering loans with low interest rates. Renewable energy funds should be created to support efforts to combat climate change.

Based on the findings of the study, it is evident that FD plays a crucial role in improving EQ in BRICS-T countries in the long run. Therefore, country-specific policy recommendations should be tailored to align financial systems with sustainability goals. For instance, China and India, due to their high levels of population and rapid industrial growth, should prioritize the expansion of green finance mechanisms and allocate more capital to renewable energy projects. South Africa, facing energy challenges, should promote sustainable energy investments through low-interest loans and incentives for green technology adoption. Russia, with its resource-dependent economy, must diversify its financial markets to channel investments into low-carbon sectors. Brazil, with vast natural resources, should strengthen its environmental regulations and incentivize financial institutions to support forest conservation and sustainable agriculture. Türkiye, as an emerging economy, should enhance its regulatory framework to promote green banking and support environmental, social, and governance (ESG)-oriented financial products. Each country should also adopt financial instruments that encourage investments in clean energy and energy-efficient technologies. Developing green bond markets, implementing targeted credit policies for low-emission equipment, and introducing tax incentives for green innovations can significantly help mitigate climate risks. Furthermore, governments must closely monitor the environmental performance of financed projects to ensure that FD translates into tangible environmental benefits.

While this study offers valuable insights into the long-run relationship between FD and EQ in BRICS-T countries, it is not without limitations. A key limitation is the exclusive

focus on BRICS-T nations, which may restrict the generalizability of the findings to other regions or income groups. Additionally, the current analysis relies on a limited set of variables to represent EQ and resilience, which may not fully capture the multidimensional nature of environmental sustainability. Future research could benefit from expanding the scope to include a broader set of countries—such as OECD, MENA, or developing Asian economies—to enable comparative assessments across different economic and institutional contexts. Moreover, incorporating a wider range of variables (e.g., institutional quality, green innovation, energy structure, and climate vulnerability indices) may offer a more comprehensive understanding of how FD interacts with various dimensions of sustainability. Country-level or region-specific analyses could also provide more granular insights into the policy mechanisms and structural factors that mediate the relationship between FD and environmental outcomes. Such efforts would contribute to a more robust and policy-relevant body of literature on sustainable finance and environmental resilience.

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