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Green Finance, Financial Development, and CO_2 Emissions Mitigation in BICS Economies: Evidence from Advanced Panel Estimation

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ABSTRACT

The crucial role of finance in addressing environmental challenges has become increasingly important. The COVID-19 outbreak has further magnified the significance of green finance (GF) in promoting sustainable development, improving quality of life and environmental protection. In the present study, we analyze the role of financial development (FD) and GF in CO2 emissions (CEM) in Brazil, China, India and South Africa (BICS) economies during 2000–2022 using the Driscoll-Kraay Standard Error estimation approach. Our findings demonstrate that GF plays a significant role in mitigating CEM but FD enhances it. Moreover the results of Dumetriscu and Hurlin Panel Causality test show that both GF and FD do not cause CEM in BICS countries. Based on the findings of the study, governments of BICS economies are recommended to implement fiscal policy tools and green financing measures to encourage green investment, which can create new opportunities for sustained growth and help to mitigate the dangers of climate change, particularly during a post-pandemic economic recovery. The study contributes to the energy-environment literature by explaining how green financial flows can support low-carbon development in high-emitting emerging economies.

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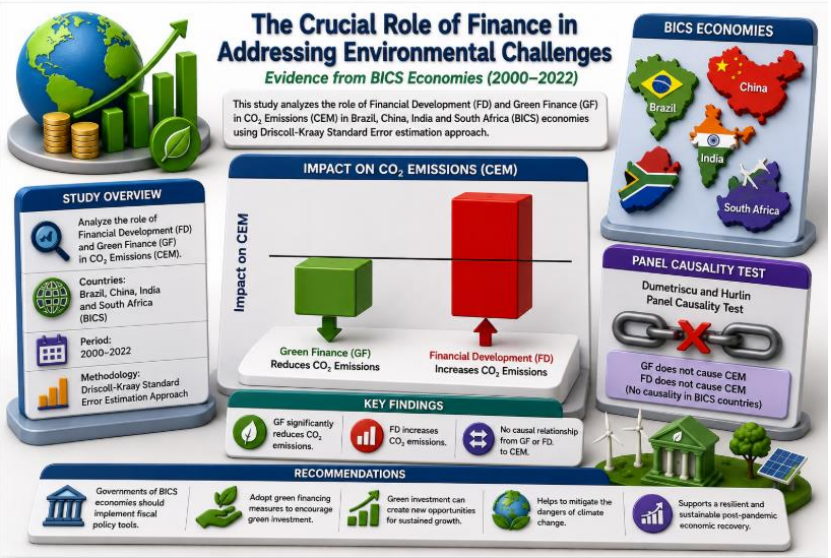

Graphical Abstract

1. Introduction

Greenhouse gas emissions (GHG), especially CEM, have become a great global concern. The concentration of CO_2 has been increased to over 400 ppm which is significantly higher than pre-industrial levels of 280 ppm, leading to severe environmental and ecological health impacts. Industrial development's current state is further aggravating this issue. In this regard, achieving the targets set at the Paris Climate Conference (2015) necessitates a joint response involving various environmental and economic solutions, with the role of financial markets being critical. The financial sector had been fundamental to growth of an economy since the Industrial Revolution. In the existing literature, financial development (FD) has been considered as a crucial factor for the improvement in environmental quality, as it lowers the intermediation cost, advances risk diversification and facilitates both public and private sector investors to invest in green energy projects (Khan et al., 2021). However, investors often fund ecologically harmful ventures, particularly those that accelerate anthropogenic climate change, which may ultimately collapse the financial system. While finance is critical in anthropogenic studies, ecological concerns are often overlooked in financial studies (Meo & Abd Karim, 2021; Scholtens, 2017).

In this regard, the financial sector has started to pay close attention to green investments and promoting long-term prosperity (Falcone et al., 2018). GF gained popularity in the 1980s and continues to draw interest all around the world. GF refers to "financing investments that positively impact the environment." It describes how corporate objectives can be met while considering environmental benefits. Financial markets and institutions have developed financial instruments such as green home mortgages, bonds, loans for sustainable buildings, auto loans, environment home equity initiatives, and climate credit cards. Unlike traditional financial transactions, GF focuses on projects that prevent environmental damage. Empirical evidence of environmental changes shows that world must take actions now to avoid catastrophic costs. Therefore, GF is a crucial tool for addressing the fundamental challenges of climate change. Financial regulators and central banks have debated climate change-related threats to the financial sector's stability in recent years, and many researchers have concentrated on estimating green finance's role in improving environmental quality.

However, most studies examining the performance of GF have focused on developed economies, while emerging markets contribute significantly to climate change (Wang et al., 2020). Brazil, India, China and South Africa occupy the position among the four most polluted countries globally (Yang et al., 2021). These countries have experienced continuous increase in CEM over the past two decades as shown in Figure 1, showing that the countries have experienced significant economic growth, but this has come at the expense of societal concerns and conservation challenges (Li et al., 2022). China and India, the two primary contributors to increased carbon emissions, face enormous pressure to reduce their CEM while addressing poverty by increasing urbanization and industrialization (Wang et al., 2018). In today's world, emerging economies are facing the daunting challenge of preserving the environment with limited resources at their disposal. We must conduct thorough research into the operations of the financial sector in developing countries and their environmental impact to find effective solutions (Rafique et al., 2020). One potential solution is establishing an efficient financial system with effective regulations, which can act as intermediaries for obtaining capital and leveraging financial resources. Such a system could stimulate economic growth by improving the performance of stock markets and encouraging investors to buy energy-conserving technology at minimal prices, thereby promoting long-term environmental efficiency (Yao et al., 2021). Over the past few years, many governments of emerging economies have taken initiatives for GF development to limit pollution levels and promote high-quality development. For instance, the Chinese government has announced several rules in the context of green investment aimed at mitigating environmental damage derived by the operations of high firms and channeling financial assets to more environmentally friendly fields of production (Zhang et al., 2021). Similarly, various commercial and governmental banks and non-banking financial organizations in India have committed approximately $2570 million to finance green policies (Jha & Bakhshi, 2019).

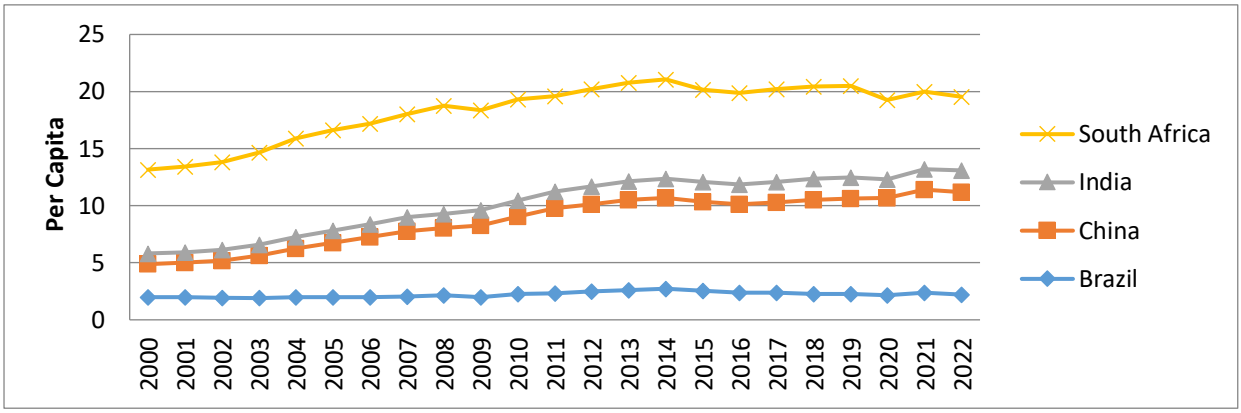

Figure 1: Trend of CO_2 Emissions in BICS Countries (2000-2022)

Against this backdrop, our research aims to estimate the efficiency of finance in reducing CEM in BICS economies from 2000 to 2020. Earlier studies documented the impact of FD on CEM (Charfeddine & Kahia, 2019; Haseeb et al., 2018; Javid & Sharif, 2016; Solarin et al., 2017). However, very few researches have investigated the effectiveness of GF in fighting climate change in selected countries (Le et al., 2020). For example, Scholtens (2009) explored the nexus between financial institution performance and social responsibility. According to Li and Jia (2017), green or sustainable finance is one of the valuable strategies to lessen ecological damage. GF promotes investment in innovative technology and developments such as renewable energy, which can help address climate change concerns (Meo & Abd Karim, 2022). Moreover, as global economies are seriously impacted by the COVID-19 pandemic, leading to financial and economic uncertainties that have made it increasingly difficult to obtain green funding. This has resulted in a decline in investments in renewable energy, energy efficiency, and green projects during 2020–2021 (Singh & Mishra, 2022). As a result, investor's interest in renewable fuels has diminished, posing a threat to the Sustainable Development Goals as well as Paris Climate Agreement (Taghizadeh-Hesary et al., 2021). Therefore, it is crucial to focus on green finance and improve its efficiency to reinforce its role in post-pandemic economic recovery, which will have enormous benefits and make society more resilient to shocks in the long run (Klioutchnikov & Kliuchnikov, 2021).

Our study is a significant and unique contribution to the literature by analyzing the role of finance in climate prevention in BICS economies. Unlike prior research that primarily focused on the FD and environmental protection relationship, our study places a special emphasis on GF. Furthermore, previous studies have employed various methodologies, such as nonlinear ARDL (Li et al., 2022), quantile regression (Wang & Ma, 2022), dynamic seemingly unrelated regression (Haseeb et al., 2018), augmented mean group (AMG) (Rafique et al., 2020) , fully modified least square (FMOLS) (Zakarya et al., 2015), generalized methods of moments (GMM) (Yao et al., 2021), and panel threshold model (Ganda, 2021) to analyze the effect of finance or GF on the environment. However, to our knowledge, there are only a few studies using second-generation estimation methods such as DK-SE model, in the literature on BICS economies. Therefore, we employed second-generation panel estimations, including the cross-sectional dependence test (CSD), (Pesaran, 2007) stationarity or unit root tests, cointegration tests by (Westerlund & Edgerton, 2008), DK-SE for coefficient estimation, and Dumitrescu and Hurlin (2012) panel causality analysis. In these aspects, our study also provides a novel addition to the literature on GF, specifically in the context of BICS countries, in methodological terms.

In the upcoming sections, we provide comprehensive review of the previous literature on GF, FD, and their environmental impact in Section 2. We then elaborate on our study's model specifications, data sources, and empirical estimations in Section 3. Results are presented and discussed in detail in Section 4. Finally, we conclude the study in Section 5 and highlight the policy implications for governments.

2. Literature Review and Theoretical background

2.1. FD and Climate Change Mitigation

The role of the financial sector in providing firms with necessary financial resources has been extensively studied (Ji et al., 2021). However, traditional finance sources are known to affect environmental quality negatively, underscoring the importance of increasing the use of GF (Kim et al., 2020). As investors and businesses become aware of the importance of clean energy for the protection of environment, GF is gaining popularity (Gagnon et al., 2020). Furthermore, sustainable economic models with lower profit volatility have been shown to reduce credit risk, making green financing an effective means of achieving environmental objectives (Naqvi et al., 2021). This, in turn, benefits lenders by reducing loan loss and capital needs. Recent research has demonstrated that green financial resources exceed non-green financial assets (Ji et al., 2021). However, it is essential to note that there have been disincentives for investors seeking green alternatives (Afzal et al., 2022). The previous literature gives sufficient confirmation about the role of finance in determining ecological quality, with some studies showing a positive impact and others indicating a negative impact.

For instance, Javid and Sharif (2016) used the ARDL technique to estimate the impact of GDP, squared GDP, energy consumption, and FD on the CEM. It was found that increased FD, GDP and energy consumption led to increased emissions in Pakistan. However, CEM decreased after a certain level, validating the EKC hypothesis[1]. Solarin et al. (2017) concluded the similar findings in the context of Ghana. Charfeddine and Kahia (2019) analyzed the role of FD and renewable energy on CO_2 emissions and economic growth in MENA economies for 1980–2015 using the panel vector auto-regression (VAR) model. The authors concluded that both variables possessed a slight impact and only explained a small portion of economic growth and CEM.

More recently, Lv and Li (2021) applied spatial econometric techniques to estimate the nexus between FD and CEM in 97 economies. The results indicated a spatial correlation in CEM between the economies for the studied period. The authors that concluded the FD of neighboring economies could also impact the CEM of any country. Wang et al. (2022) estimated the relevance of globalization, FD, and green energy in N11 countries[2]. The estimation findings of CS-ARDL and causality analysis indicated that FD and globalization positively affected CEM, while clean energy helped to improve it.

Conversely, Saud et al. (2019) estimated the FD and ecological deterioration nexus in Belt and Road Initiative economies for 1980–2016. The authors controlled for trade openness, electricity use and economic growth, and found that FD positively affects the environmental quality. This finding contradicts Nazir et al. (2018) study, which analyzed the role of the financial sector in CEM in Kyoto Annex countries from the 1970- 2016 using GMM estimation. Their results showed a negative association between FD and CEM. Similarly, Saidi and Mbarek (2017) investigated the impact of FD on CEM by taking a panel of emerging economies from 1990 to 2013, controlling for income, urbanization and trade openness. The authors concluded that FD hurt CEM.

Overall, the literature presents mixed findings regarding the relationship of FD with environmental degradation. Some researchers indicate a positive relationship, whereas others indicate a negative one. This inconsistency could be due to differences in the economies studied, the periods covered, and the methodologies employed. Nonetheless, the increasing awareness about the importance of green energy and ecological protection is the cause of the rise of green finance, which is expected to play a crucial role in achieving

[1] The EKC hypothesis states that as countries develop economically, there is an increase in environmental degradation initially, followed by a decrease after a specific income level. This association is believed to be inverted U-shaped. However, this hypothesis has faced criticism and its validity is debated in the literature.

[2] "Next Eleven" (N11) refers to a bloc of 11 countries having the potential to become some of the largest economies of the world in the twenty first century. Bangladesh, Indonesia, Egypt, Mexico, Iran, Nigeria, the Philippines, Pakistan, South Korea, Turkey, and Vietnam are the members of this bloc.

sustainable economic development. As such, further research is necessary to identify the most effective ways to incentivize investors to pursue green alternatives and to develop policies that can promote the growth of GF.

2.2. GF and Climate Change Mitigation

The field of GF and its relationship to environmental sustainability has got considerable attention from researchers in a couple of years. Several studies have focused on defining and establishing a GF framework and emphasizing its critical role in achieving environmental sustainability (Agyekum et al., 2021; Guild, 2020; Tolliver et al., 2019; Zhang et al., 2021). Other researchers have proposed using environmental financing to reduce environmental degradation, promoting investment in clean energy technology, and fostering innovations in green technologies (Jinzhou, 2011; Sandberg et al., 2019).

While GF has been studied for its role in promoting environmental sustainability, the nexus between GF and CEM has not been extensively researched. However, recent studies have shed light on this topic. According to Meo and Abd Karim (2022), GF negatively influenced CEM, suggesting it is a viable financial strategy for reducing carbon emissions. Other studies, such as those by Wang et al. (2021) and Ren et al. (2020), have shown GF can have a significant adverse effect on CEM severity and contribute to reducing carbon intensity.

In addition to investigating the GF and CEM nexus, researchers have also explored the factors that promote green financing in different countries. Nawaz et al. (2021) found that determinants such as renewable energy consumption, population, CO_2, foreign direct investment (FDI), grants for technical cooperation, inflation, FD, and R&D have a major role in promoting green financing in the BRICS and N11 economies. Similarly, Afzal et al. (2021) concluded that FD helped in environmental quality improvement across 40 European economies, while institutional quality and FDI worsened it.

Furthermore, study by Zhou et al. (2020) have estimated the impact of GF on economic growth and environmental quality. Zhou et al. (2020) found that green finance positively impacted both economic growth and environmental quality, and its effect on the environment varied with varying levels of economic development. Similarly, Wu et al. (2021) utilized FMOLS and VECM estimations to show that GF policies improved the environment by reducing pollution levels, ultimately benefiting economic growth. Overall, research into GF and its relationship with climate change mitigation has highlighted the importance of promoting investment in non-fossil energy technology and fostering innovation to reduce environmental degradation. Furthermore, the factors that promote GF and the role of GF policies in environmental protection and economic growth have also been explored.

In conclusion, the study of green finance and its relationship to climate change mitigation has garnered significant attention from scholars in recent years. While some researchers have focused on establishing a framework and definition of GF, others have analyzed its impact on environmental sustainability, particularly in reducing pollution emissions. Recent studies have indicated that GF can exert a considerable adverse effect on CEM severity and can be an effective strategy for reducing carbon emissions, depending on the circumstances of GF markets in different economies. Additionally, studies have shown that FD and R&D are essential in promoting green financing in different countries. As policymakers continue to explore the potential of GF to mitigate climate change, more research will be necessary to understand its mechanisms and limitations better. Ultimately, a better understanding of GF and its relationship to climate change mitigation will be crucial in developing more effective and sustainable policies and strategies for addressing the global climate crisis.

2.3. Literature Gap

The existing studies on the role of finance in climate change or carbon emissions have overlooked the significance of GF in BICS economies. This is a critical gap in the literature

and as such the current study contributes by examining the role of GF in CEM in BICS economies. Specifically, we seek to estimate the effect of finance on CEM in these economies by examining the relationship between FD, GF, economic growth, globalization and CEM.

3. Data, variable description, and methods

3.1. Model Specification and Data

As this study analyzes the finance and CEM relationship in BICS countries from 2000 to 2022, the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) Framework proposed by Dietz et al. (2007) provides basis for the model specification. This model assumes that environmental impacts result from three factors: affluence, population and technology. Several earlier studies have used the STIRPAT framework to investigate factors which affect environmental degradation (Amer et al., 2024; Hanif & Nawaz, 2024). Equation (1) is the basic formulation of the STIRPAT model:

$$I_i = \alpha P_{it}^{\beta} A_{it}^{\gamma} T_{it}^{\delta} \varepsilon_{it} \quad (1)$$

Where, I shows environmental impacts, P denotes population, A represents affluence, and T shows technology. β, δ and γ denote coefficients and ε shows error term. STIRPAT model has the flexibility to integrate additional variables that affect environmental quality. Therefore, taking the theoretical foundations of this framework, the basic model of the study is specified as follow:

$$\text{CEM} = f\ (\text{GF, FD, GLOB, TI, EG, POP}) \quad (2)$$

Where, GF shows green finance, TI shows technological innovations, FD shows financial development, CEM represents carbon dioxide emissions, POP shows total population, EG represents economic growth and GLOB represents globalization. Affluence, population and technology components of STIRPAT framework are measured by economic growth, total population and technology innovations, respectively, and following the studies of Chin et al. (2024), Sadiq et al. (2024), Saadaoui et al. (2024), Wang et al. (2024) and Haq et al. (2024), GF, FD and globalization are added to the model to analyze their impacts on CEM in BICS countries. The econometric form of the model is given by the equation (3):

$$\text{CEM}_{it} = \alpha_o + \beta_1 \text{GF}_{it} + \beta_2 \text{FD}_{it} + \beta_3 \text{EG}_{it} + \beta_4 \text{GLOB}_{it} + \beta_5 \text{POP}_{it} + \beta_6\, \text{TI}_{it} + \epsilon_{it} \quad (3)$$

Where, α_o is the intercept, and β_1, β_2, β_3, β_4, β_5 and β_6 represent parameters indicating the impact of GF, FD, EG, GLOB, POP and TI on CEM, respectively. CO_2, measured in per capita, serve as the dependent variable. FD is measured by domestic credit to private sector (percent of GDP), while GF is measured by financial flows to developing countries for renewable energy development. GDP, measured in per capita constant dollars (2015), is taken as proxy for economic growth, and the KOF index measures globalization. Total population is taken as a proxy for population variable and number of patents (residents) measures technological innovations in the present study. We assessed the data for the globalization index from the KOF Swiss Economic Institute, while all remaining variables data have been extracted from the World Development Indicators and Our World in Data database.

3.2. Applied Estimation Techniques

To examine the long-run and short-run determinants of CO_2 emissions across high-emitting countries, we adopt a multi-step panel econometric approach that accounts for cross-sectional dependence (CSD), slope heterogeneity, and non-stationarity.

3.2.1. Cross Sectional Dependence (CSD) Test

To panel data analysis, one of the most important tests is the CSD test because this issue exists due to economic interdependencies among countries. Without considering the CSD issue, the econometric analysis can result in inconsistent and biased results Sun et al.

(2025). For this purpose, we use the CSD test developed by Pesaran (2004). The basic equation of this test is shown in the following equation.

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}\right) \sim N(0,1) i,j \quad (4)$$

In above equation, CD shows cross sectional dependence, N shows cross sections and T denotes time. $\hat{\rho}_{ij}$ shows evaluated cross-sectional correlation between j and i units.

3.2.2. Slope Heterogeneity test

After CSD, it is also essential to check slope heterogeneity in data. For this purpose, the slope heterogeneity test proposed by Pesaran and Yamagata (2008) is used and the statistics for this test are given in the following equations:

$$\tilde{\Delta}_{SH=} (N)^{\frac{1}{2}} (2K)^{-1/2} \left(\frac{1}{N} \tilde{S}\text{-k}\right) \quad (5)$$

$$\tilde{\Delta}_{ASH=} (N)^{\frac{1}{2}} \left(\frac{2k(T-k-1)}{T+1}\right)^{-\frac{1}{2}} \left(\frac{1}{N} \widetilde{S} - k\right) \quad (6)$$

Where, delta and adjusted delta tilde are represented by $\tilde{\Delta}_{SH}$ and $\tilde{\Delta}_{ASH}$, respectively. $\widetilde{S} - k$ denotes the average weighted slope coefficients of all cross-sectional units and the number of regressors is denoted by k (Pesaran & Yamagata, 2008).

3.2.3. Unit Root or Stationarity Tests

After performing the necessary CSD and slope heterogeneity tests, it is necessary to check the stationarity properties of the variables (Hanif, Nawaz, Hussain, et al., 2022). To accomplish this, the second generation Cross-sectionally Augmented Im Pesaran–Shin (CIPS) and Cross-sectional Augmented Dickey-Fuller (CADF) proposed by Pesaran (2007) are used because the first generation unit root tests do not provide efficient outcomes when CSD and slope heterogeneity issues exist (Hanif & Nawaz, 2024) . The equation for CIPS estimation is given in equation (7).

$$\text{CIPS} = \frac{1}{N} \sum_{i=1}^{N} CADF_i \quad (7)$$

Where, the ADF test statistic for ith cross section is denoted by CADF in the above equation. Moreover, the CADF test statistics is given in the following equation (8):

$$\Delta y_{it} = \alpha_i + \delta_i^* y_{it-1} + \gamma_0 \bar{y}_{t-1} + \sum_{j=0}^{\gamma} \alpha_{j+1} \overline{\Delta y}_{t-j} + \sum_{k=1}^{\gamma} c_k \Delta y_{it-k} + \varepsilon_{it} \quad (8)$$

3.2.4. Driscoll-Kraay Standard Error Approach

In the context of the present study that analyzes the relationship between GF, FD and CEM in BICS, the Driscoll Kraay Standard Error (DKSE) approach proposed by is justified to be used as this approach addresses the issues of CSD, heteroscedasticity and serial correlation which are often observed in panel data (Chen et al., 2025). The presence of CSD, serial correlation and heteroscedasticity can lead to inefficient standard errors and biased estimates if not properly handled. DKSE approach is robust to all these issues and provides reliable estimates in the presence of correlation, CSD and heteroscedasticity (Afolabi et al., 2024; Shah et al., 2021).

3.2.5. Dumitrescu and Hurlin (2012) Panel Causality Test

The last step of the econometric analysis involves estimating the causal association among variables under study. For this purpose, Dumitrescu and Hurlin (2012) (D-H) causality test is applied to assess the causal relationship among variables. This approach efficiently addresses the issues of the CSD and heterogeneity, which, the conventional causality

estimators do not account for. The foundations of D-H technique are provided by W and Z-bar statistics. According to this test, there are three possible ways to understand the effects of two variables: a bidirectional relationship, a unidirectional relationship, or no causal association at all. According to the null hypothesis of this test, no causal association exists between two variables and the alternative hypothesis assumes that causality is present between variables (Sadekin, 2025). Graphical illustration of the empirical analysis is given in Figure 2.

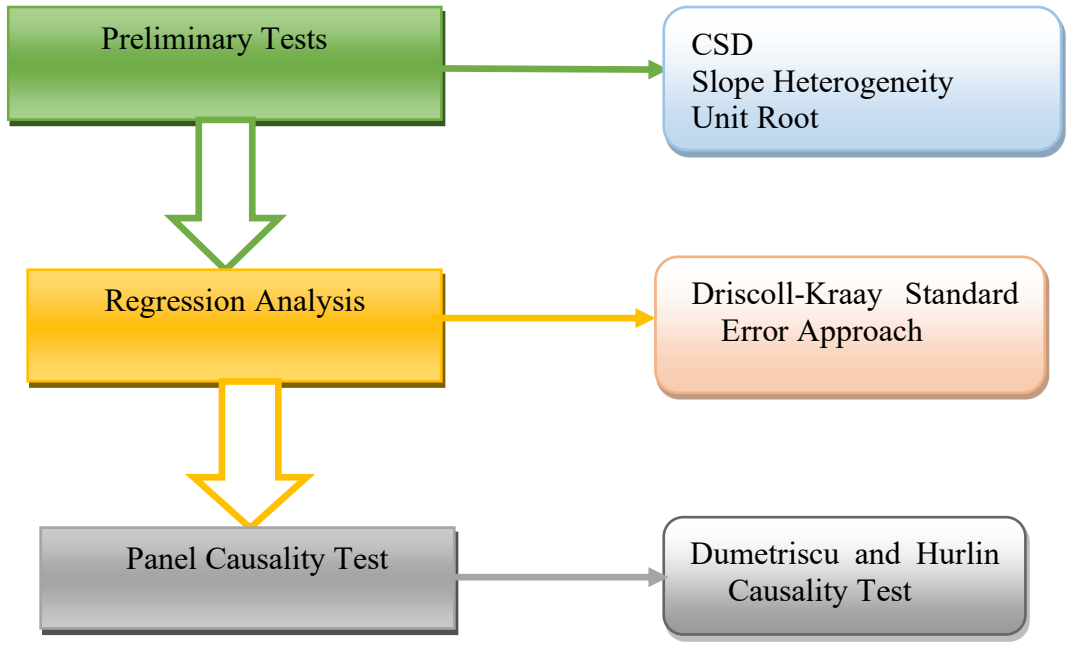

Figure 2: Methods of Analysis Step by Step Procedure

4. Findings and Discussion

As noted by several researchers, it is imperative to check for CSD to avoid erroneous conclusions. Table 1 illustrates the results of CSD testing, which reveals that test statistics for all variables except TI are significant, thereby supporting H1 or dependence among the data series.

Table 1
Findings of the CSD test

Variable	t-Stat / prob values
CO_2	4.034*** (0.000)
GF	3.991*** (0.000)
FD	2.262** (0.024)
GLOB	11.293*** (0.000)
TI	1.035 (0.301)
POP	11.636***(0.000)
EG	9.354***(0.000)

*** and ** are 1 and 5% significance levels and parentheses enclosing P-values.

We also conducted a slope homogeneity analysis using the advance form of Swamy (1970) slope homogeneity test developed by (Pesaran & Yamagata, 2008). This test aimed to determine the homogeneity or heterogeneity of slope coefficients. The results of this analysis, as presented in Table 2, show that we reject the null hypothesis of homogeneity in both delta and delta tilde, indicating that slope heterogeneity is present in data.

To further assess the stationarity of the variables, we conducted CIPS and CADF tests developed by (Pesaran, 2007). These tests are particularly effective when heterogeneity and CSD are present. Table 3 presents the corresponding results, which indicate that Pesaran

test identifies that except GF, the CIPS levels for variables such as CEM, FD, GLOB, POP and EG as significant at first difference level, indicating that series have first order integration. However, the CADF output is significant for all variables at first difference, indicating that they are not level stationary in this test. Therefore, all series become stationary at first difference as indicated by the results.

Table 2
Slope Heterogeneity Test Findings

Regressend: CEM **Test Statistics**	**Test value and Prob-values**
D-tilde	4.863*** (0.000)
Adj D- tilde	6.022*** (0.000)

*** is a 1 percent significance level; parentheses enclose P-values. D-tilde denotes delta tilde and Adj D-tilde shows adjusted delta tilde.

Table 3
Findings of the CIPS and CADF Tests

Variables	**CIPS**		**CADF**	
	Level	**1st difference**	**Level**	**1st difference**
CEM	-0.962	-2.934***	-1.282	-3.475***
GF	-3.937***	--------	-2.323	-5.458***
FD	-0.164	-4.023***	-0.434	-2.973**
GLOB	-2.117	-4.918***	-2.067	-2.530*
EG	-1.085	-2.488***	-2.057	-3.299**
POP	-0.585	-4.082***	-1.267	-3.792***
TI	-2.096	-3.979***	-1.455	-3.321**

Where, *** and ** are 1 and 5% significance levels.

This study utilized DK-SE estimation method to explore the association between dependent and independent variables. Estimation results presented in Table 4 indicate that, except GLOB, all of the variables had a statistically significant negative or positive impact on CEM. In particular, analysis shows that GF impacts CEM negatively, indicating that it mitigates environmental pollution by enhancing the financial facilities of small and medium enterprises to deal with the issue of rising CEM, and enhancing environmentally friendly business operations, leading to long-term sustainable development. This finding aligns with earlier studies of Sadiq et al. (2024), Tran (2022), Meo and Abd Karim (2022) and (Wang et al., 2022). This finding implies that policymakers should prioritize developing the financial sector to enhance the availability and accessibility of GF for individuals and businesses, which might help reduce carbon emissions worldwide.

Table 4
Findings of Driscoll-Kraay Standard Error Estimation

Variables	**Coefficient**	**Driscoll-Kraay Std.error**	**t-stat**	**Prob-value**
GF	-2.201*	1.151	-1.91	0.070
GLOB	-0.0202	0.023	0.86	0.400
FD	0.0080	0.0019	4.18	0.000
TI	0.0066**	0.0029	2.23	0.037
POP	2.980**	8.451	3.53	0.002
GDP	0.0006***	0.00045	14.14	0.000

Where, ***, ** &* reveals 1, 5 and 10 percent significance level.

Secondly, the research finds that increasing FD has an increasing impact on CEM. The finding implies that the financial deepening through markets and institutions can encourage climate change by creating scale effect and loan provision to increase economic activities. in many developing countries, financial sectors are not targeting environment friendly and energy efficient projects, and unplanned and unrestricted capitalization by FD enhances climate change (Batool et al., 2022). This finding is in line with Shoaib et al. (2020), Rafique et al. (2020) and Batool et al. (2022).

Third, the study finds that GLOB negatively affects CEM in BICS economies but the concerned coefficient is statistically insignificant. This finding is theoretically supported as GLOB promotes the development of green and energy efficient technologies and advance manufacturing processes which improve energy efficiency and reduce environmental pollution. New investments by international capitalists provide energy efficient production processes and cutting-edge techniques which improve energy efficiency and contribute to economic progress in host country (Bilal et al., 2021). These results are analogous to the outcomes of (Islam et al., 2021). The negative effect of GLOB on CEM is in line with Islam et al. (2021) and Sharif et al. (2020) and the insignificant impact of GLOB on CEM in BICS countries is analogous to the finding of (Haseeb et al., 2018).

Among control variables, TI has significant and positive impact on CEM consistent with Churchill et al. (2019) and (Dauda et al., 2019). This finding is counter intuitive but can be justified in the light of the fact that TI can increase CEM through the scale effect of economic growth. Moreover, according to the Jevons Paradox, although TI enhances resource efficiency, the higher economic growth driven by TI need more use of energy and natural resources which induces high CEM (Kocak et al., 2024). The study also found that GDP and POP positively impact CEM in the studied economies. This positive effect stems from the dependence of economic activities on conventional energy sources to produce goods and services in the targeted economies. Consequently, the release of additional CO_2 gas into the atmosphere occurs due to these energy sources. This outcome is strongly supported by Hanif, Nawaz, Hussain, et al. (2022) and Hanif, Nawaz, Fazal, et al. (2022). Likewise, our finding about POP is in line with many studies as it is found to be associated with rise CEM in BICS countries. This finding is in-line with the studies of Namahoro et al. (2021) and Islam et al. (2021) who argued that increase in POP is associated with increase in demand for energy and, therefore, contribute to higher proportion of CEM.

Lastly, the assessment of the causal association among variables given in Table 5 finds that GF, FD and TI have unidirectional causal association with CEM. POP and GDP have bidirectional causal association with CEM, whereas GLOB has no causal association with CEM. The direction of causal association among variables is given graphically in Figure 3.

Table 5
Findings of D-H Causality Analysis

Null hypothesis	Zbar-Stat	P-value
GF has no causal association with CEM	-0.829	0.407
CEM has no causal association with GD	2.284**	0.022
FD has no causal association with CEM	1.390	0.164
CEM has no causal association with FD	3.451***	0.000
GLOB has no causal association with CEM	0.711	0.476
CEM has no causal association with GLOB	-0.131	0.892
TI has no causal association with CEM	0.058	0.953
CEM has no causal association with TI	3.451***	0.000
POP has no causal association with CEM	2.768**	0.005
CEM has no causal association with POP	4.224***	0.000
GDP has no causal association with CEM	2.596**	0.009
CEM has no causal association with GDP	3.801***	0.000

Where, ***, ** &* reveals 1, 5 and 10 percent significance level.

5. Conclusion

5.1. Concluding Remarks and Policy Recommendations

As we conclude our analysis of the role of finance, specifically GF in CEM in BICS economies from 2000 to 2022, we must emphasize the importance of our findings. These economies are among the top polluting and green finance-consuming countries globally. Our study utilized second-generation panel estimation methods such as DK-SE for coefficient estimation and D-H causality test for causality analysis. Our findings demonstrate that GF plays significant role in climate prevention in the studied economies, while FD, economic growth and population have substantial roles in climate deterioration.

The implications of our study for policymakers are significant, especially in light of the COVID-19 outbreak. This pandemic presents financial sector with an opportunity to reevaluate and strengthen its long-term position. It is a reasonable time for financial institutions to incorporate environmental, structural, and social considerations into their long-term strategies. A robust and efficient financial sector can support investment decisions by issuing loans to firms committed to reducing CEM. The governments of these countries should employ fiscal measures to encourage the use of GF and increase the utilization of fiscal funds to direct social capital and credit financing towards green credit, green investment, and green securities. Improvements in green finance structures and prioritization of green operations are necessary. Additionally, governments and policymakers should simplify the approval and operation processes for sectors focused on ecological, green, and low-carbon initiatives. Moreover, in impoverished regions, the government needs to implement the strategy of GF and decrease the issue and selling limits for green bonds and securities.

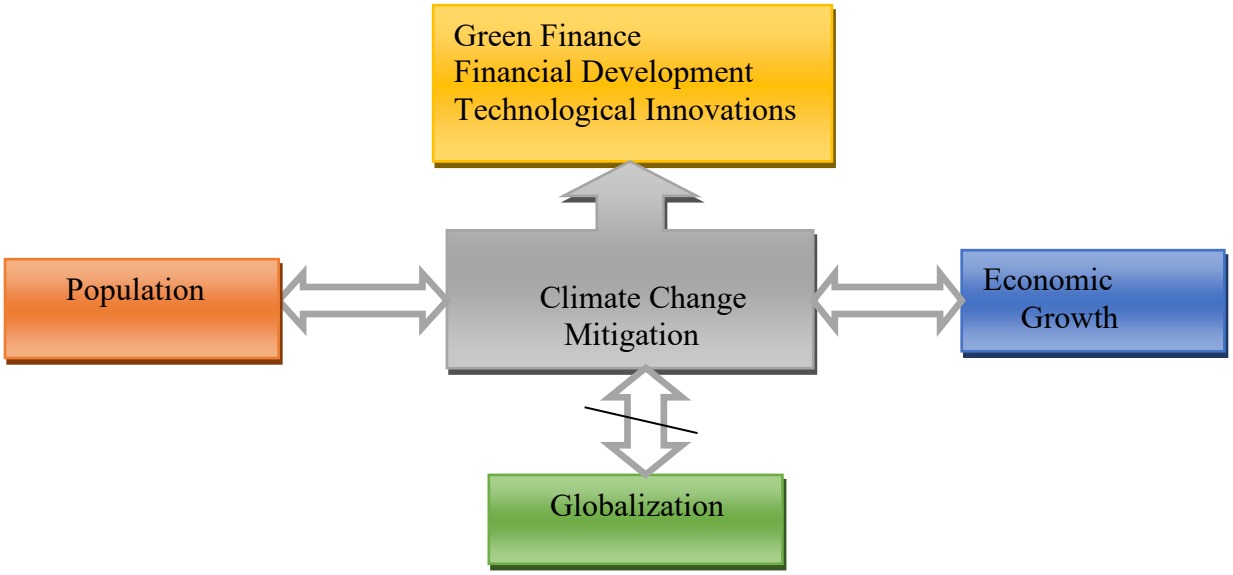

Figure 3: Graphical Illustration of Causal Association among Variables

We hope that during the post-pandemic economic recovery, the emphasis on GF in financial systems will open up new opportunities for sustained growth, reduce the risks of climate change to the community, and generate millions of new jobs in the coming decades. We must consider that GF can boost growth at the country level and provide the necessary drive for a worldwide green revival after COVID-19 outbreak. In conclusion, we must continue prioritizing research on the impact of finance on climate change and work collaboratively to implement policies that promote green finance and contribute to sustainable economic growth.

5.2. Study Limitations and Directions for Future Research

On the basis of our estimation of the impact of finance on CEM in BICS economies, several limitations and directions for future studies need to be considered. Firstly, the present study only analyzed the role of GF and FD on CEM while controlling for globalization,

technological innovations, population and economic growth. Other important determinant, such as energy consumption, environmental policies and institutional quality are not included in the present study. Therefore, future research can explore the role of these factors in CEM in BICS countries. Secondly, time period of the study spans over 2000 to 2022. Future research can extend the time frame of the analysis to analyze the long-term impact of GF and FD on CEM. Third, this study only considered BICS economies to analyze the impact of finance on CEM. Future research can expand the scope of analysis to include other emerging economies to compare and contrast the effect of finance on emissions. Lastly, it is worth noting that the results of the study are based on the assumption that FD and GF positively impact CEM. Future research can explore the possibility of reverse causality, where low CEM lead to higher FD and GF. This would provide a more nuanced understanding of the association between finance and CEM.

Authors Contribution

Sobia Hanif: contributed to conceptualization, data collection, methodology, analysis, and initial drafting

Muhammad Atif Nawaz: supervised the study, refined the methodology, reviewed the manuscript, and approved the final version.

Conflict of Interests/Disclosures

The authors declared no potential conflicts of interest w.r.t the research, authorship and/or publication of this article.

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