

The Impact of Financial Development, Political Stability and Foreign Direct Investment on Greenhouse Gas Emissions in BRICS Countries

Eda Dineri

Department of Economics,
Hasan Kalyoncu University, Gaziantep, Turkey.
E-mail: eda.dineri@hku.edu.tr
ORCID: <https://orcid.org/0000-0002-5637-594X>

Yunus Kilic

Department of Insurance,
Akdeniz University, Antalya, Turkey.
Corresponding author: yunuskilic@akdeniz.edu.tr
ORCID: <https://orcid.org/0000-0002-9758-5118>

Pelin Aliyev

Department of Political Science and International Relations,
Hasan Kalyoncu University, Gaziantep, Turkey.
E-mail: pepin.aliyev@hku.edu.tr
ORCID: <https://orcid.org/0000-0003-2466-2132>

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Abstract

This study examines the effects of financial development, political stability, renewable energy, foreign direct investment, and national income on greenhouse gas emissions in the BRICS countries by employing the Augmented Mean Group (AMG) estimation method over the period 2002–2021. The BRICS countries have become an important focus of environmental economics research due to their remarkable economic growth performance and the environmental challenges associated with their intensive industrialization processes. Although previous studies have extensively explored the relationship between economic growth and environmental degradation in these countries, limited empirical evidence exists regarding the environmental implications of the interaction between financial development and political stability. The empirical findings indicate that financial development, political stability, and national income contribute to higher GHG emissions, whereas renewable energy and foreign direct investment have mitigating effects on GHG emissions. Furthermore, unlike the findings reported in earlier studies, the interaction between financial development and political stability is found to increase GHG emissions. Considering these findings, the study suggests that BRICS countries should develop renewable energy policies that support economic growth while simultaneously reducing emissions in order to alleviate the adverse environmental consequences associated with economic expansion.

Keywords- Environmental degradation, Foreign direct investments, Political stability, Greenhouse gas emissions, Sustainable development.

1. Introduction

Achieving a balance between economic growth and environmental sustainability has emerged as one of the major challenges confronting countries worldwide in the current global context (Jahanger et al., 2022). Rising global energy consumption has led to increased emissions of harmful greenhouse gases into the atmosphere and has further exacerbated the challenges associated with climate change (He et al., 2022; Liu et al., 2019; Sarkodie et al., 2020). In 2023, global average CO₂ concentrations reached 420.0 ppm, methane 1.934 billion ppb, and nitrous oxide 336.9 ppb; these values correspond to 151%, 265%, and 125% of pre-

industrial levels, respectively (World Meteorological Organization, 2024). Thus, climate change has become one of the most significant global challenges, with greenhouse gas (GHG) emissions having far-reaching impacts on both the natural environment and human societies (Yang et al., 2017). WMO Secretary-General Celeste Saulo emphasizes the seriousness of the situation, stating, “*This should set alarm bells ringing among decision makers*” (World Meteorological Organization, 2024).

Climate change affects soil fauna, biodiversity and microbial activity, potentially leading to significant alterations in the composition and productivity of cropping systems. Over the next 50 years, rising temperatures, increased water stress and more frequent extreme weather events are expected to reduce agricultural productivity in many regions around the world (Smith et al., 2013). Furthermore, air pollution is a major contributor to several health conditions, including cardiovascular diseases, stroke, lung cancer, and respiratory disorders (Khan et al., 2019). Moreover, as noted by the Monetary Authority (2020), climate change poses a significant risk of amplifying economic uncertainty and exacerbating financial instability (Wei et al., 2022). As noted by Adeyemi et al. (2025), climate disasters weaken the financial system by causing liquidity problems; they increase credit risks due to job and asset losses; and reduce credit supply. Furthermore, rising insurance claims stemming from climate and extreme weather events, coupled with trends in household savings, leads to a reduction in available credit funds. Collectively, all these factors disrupt the functioning and stability of the financial system.

To address these challenges, various national and international efforts have been undertaken to reduce GHG emissions, which have multi-dimensional effects. With growing concern over global warming, increasing attention has been devoted to determining and examining the factors influencing GHG emissions (Liu and Liang, 2017; Liu et al., 2019) in order to design effective policies. A substantial body of literature have examined the relationships between GHG emissions and variables such as financial development (He et al., 2022; Zaidi et al., 2019; Ziolo et al., 2019), foreign direct investment (Abbas et al., 2021; Kim, 2020; Liobikienė and Butkus, 2019; Sarkodie and Strezov, 2019), political stability (Ayhan et al., 2023; Han et al., 2024), renewable energy (Amponsah et al., 2014; Khan et al., 2019; Liobikienė and Butkus, 2019) and national income (Hamit-Haggar, 2012; Liobikienė and Butkus, 2019; Wahab et al., 2024). Moreover, recent studies in environmental economics have particularly focused on developing or emerging economies. This is mainly because rapid economic growth and industrialization in these countries are often accompanied by environmental degradation. However, this situation directly contradicts the goals of sustainable development.

Within this framework, this study investigates the effects of financial development, foreign direct investment, political stability, renewable energy, and national income on GHG emissions in the BRICS countries (Brazil, Russia, India, China, and South Africa) by employing the AMG (Augmented Mean Group) estimation method. The application of this approach enables a more comprehensive assessment of the long-term effects of these factors on GHG emissions. BRICS represents a group of countries that have established cooperation mechanisms to strengthen their economic and political influence at the global level (Mashamaite, 2025). Due to their rapid economic expansion and the environmental pressures associated with intensive industrialization processes, these countries have received increasing attention in the environmental economics literature (Hamid et al., 2022). As emerging economies with substantial production capacity, BRICS countries account for approximately 42% of global carbon emissions, highlighting their critical role in addressing environmental sustainability challenges (Erkiliç et al., 2025).

Accordingly, the empirical analysis focuses on the effects of financial development, political stability, renewable energy, foreign direct investment, and national income on GHG emissions in BRICS countries over the period 2002–2021. Furthermore, the study extends the analysis by investigating whether the

interaction between political stability and financial development has a significant impact on GHG emissions in these countries.

The existing literature provides limited empirical examination of this relationship. Political stability enhances countries' credibility in financial markets, facilitates individuals' participation in the financial system, supports institutional development, and enables the effective implementation of reforms (Chletsos and Sintos, 2024; Levine, 1999). In this context, increased financial incentives alongside financial development can contribute to reducing carbon emissions by encouraging companies to engage in green investments. Therefore, political stability can have an indirect effect on reducing emissions through financial development. However, empirical research examining the environmental consequences of this interaction remains highly limited. To date, only Al-Zubairi et al. (2024) have investigated the relationship between financial stability and political stability in relation to environmental degradation by analyzing their effects on CO₂ emissions in Arab countries. Despite this contribution, the impact of financial development, economic growth, foreign direct investment, political stability, renewable energy consumption, and the interaction between financial development and political stability on GHG emissions in BRICS countries has not been sufficiently explored. Therefore, this study addresses this research gap by empirically examining these relationships within the BRICS framework. Moreover, the inclusion of foreign direct investment in the model enables an assessment of whether FDI affects emissions through production activities and technology transfer channels. In this respect, the study provides additional evidence to the environmental economics literature by extending the existing discussions on the determinants of GHG emissions.

The remainder of the paper is organized as follows. Section 2 reviews the existing literature on the relationship between environmental degradation and the key determinants considered in this study, including financial development, political stability, foreign direct investment, renewable energy, and economic growth. Section 3 describes the data set, model specification, methodology, and empirical results. The final section concludes the study by presenting the main findings, policy recommendations, and limitations.

2. Literature Review

This section reviews the current literature on (1) financial development and climate change, and (2) political stability and climate change, (3) foreign direct investment and climate change, (4) economic growth and climate change, and (5) renewable energy and climate change in sequence.

2.1 Financial Development and Climate Change

Financial development is widely recognized as an important driver of economic growth and development; however, its environmental implications have also attracted increasing attention due to its close relationship with financial activities and foreign direct investment. The expansion of foreign direct investment facilitated through financial markets can stimulate production activities, which may increase energy consumption and subsequently contribute to higher carbon dioxide emissions (Asif et al., 2024b). Similarly, the economic expansion supported by financial development may intensify CO₂ emissions, thereby accelerating global warming and its associated environmental consequences (Halaç et al., 2025). Halaç et al. (2025) further argue that financial development may alter energy consumption patterns. As financial systems become more developed, increasing economic activity may generate higher energy demand, particularly when such demand is satisfied through fossil fuel-based energy sources, resulting in additional emission pressures.

Empirical studies have provided evidence supporting the adverse environmental effects of financial development. Using panel data from 162 countries between 2000 and 2019, He et al. (2022) investigated the relationship between financial development and GHG emissions and reported that sustainable financial development contributes to higher GHG emissions. Similarly, Xing et al. (2017) found that financial development negatively affects environmental quality in both the short and long run. Examining 12 West African countries, Tsaurai (2019) showed that financial sector credit is positively and significantly associated with carbon emissions. In a broader analysis covering 155 countries, Jiang and Ma (2019) demonstrated that the emission-increasing effect of financial development exists globally and is more pronounced in developing and emerging economies. Therefore, although a developed financial sector improves access to financial resources and reduces investment constraints, it may also generate environmental costs alongside its contribution to economic growth (Halaç et al., 2025).

Conversely, a considerable strand of the literature indicates that financial development may contribute to reducing GHG emissions (Saidi and Mbarek, 2017; Shi et al., 2019; Zaidi et al., 2019). Zaidi et al. (2019) investigated the dynamic relationship between financial development and carbon emissions in APEC countries over the period 1990-2016. Employing the Westerlund cointegration technique to examine long-run relationships along with the CUP-BC and CUP-FM estimation methods, they reported that financial development significantly decreases carbon emissions. Similarly, Salahuddin et al. (2015) analyzed the Gulf Cooperation Council countries during the period 1980-2012 and concluded that financial development has a reducing effect on carbon emissions. Wang et al. (2019) provided further evidence by showing that financial development contributes to lower carbon emissions in OECD countries.

In another study, Saidi and Mbarek (2017) examined the effects of financial development, income, trade openness, and urbanization on CO₂ emissions in 19 emerging countries between 1990 and 2013 using the GMM estimator approach. Their findings revealed that financial development has a negative long-term effect on carbon dioxide emissions. More recently, Halaç et al. (2025) explored the effect of financial market development on environmental quality using panel data from 21 emerging countries covering the period 2001-2023 and found that financial development improves environmental quality. In contrast, Asif et al. (2024b) employed a fixed effects model within a panel data framework and demonstrated that financial development increases CO₂ emissions through trade openness in BRICS countries during the period 2004-2023. The study emphasized that integrating the environmentally friendly industrial technological knowledge and experience of industrialized economies into the BRICS countries could contribute to sustainable development through investments in renewable energy.

Investigating BRICS countries over the period 1990-2021, Apeaning and Labaran (2025) employed a fixed effects regression method and provided evidence that stronger financial systems significantly contribute to the reduction of carbon dioxide emissions. Their findings further indicated that the interaction between financial development and climate change mitigation technologies plays an important role in decreasing CO₂ emissions. In this regard, financial development may support environmental sustainability by facilitating the transition toward sustainable energy sources and encouraging investments in environmentally friendly projects. Consistent with this perspective, Kirikkaleli et al. (2022) demonstrated that financial development and green energy consumption reduce emissions in Chile.

The environmental benefits of financial development are also associated with the capacity of advanced financial systems to improve access to financing opportunities, particularly for environmental investments. A developed financial sector can enhance environmental performance by providing lower-cost financial resources for projects aimed at improving environmental quality (Tamazian et al., 2009). Through the integration of clean energy technologies and green financing instruments, financial systems can support the

reduction of carbon emissions and facilitate the transition toward a low-carbon economic structure consistent with sustainable development goals (Apeaning and Labaran, 2025).

Tamazian et al. (2009) examined the relationship between economic growth, financial development, and environmental quality in BRIC countries and identified financial development as an important determinant of carbon emission reductions. Likewise, Tamazian and Rao (2010) showed that financial development has significant implications for carbon emissions in transition economies. Using AMG and RCCE methods, Degirmenci et al. (2025) found that financial development improves environmental quality in Russia and India among E-7 countries during the period 1991-2019. The authors attributed this result to increased financial support and incentives directed toward environmentally friendly projects in these countries. Furthermore, Zhang et al. (2022), analyzing 49 countries that issued green bonds between 2007 and 2019 through a dynamic panel approach, revealed that green finance contributes positively to addressing environmental and climate-related challenges.

China represents an important case in discussions on the relationship between economic development and environmental sustainability, as it has achieved rapid economic growth and become the world's second-largest economy by nominal GDP after the United States. Nevertheless, this remarkable economic expansion has been accompanied by increasing energy demand, largely driven by fossil fuel sources such as coal and oil, which has generated considerable environmental pressures (Dong et al., 2024). Focusing on 30 Chinese provinces over the period 2005-2021, Dong et al. (2024) highlighted that financial development plays a crucial role in facilitating energy investments and financing mechanisms required for sustainable development and carbon dioxide emission reductions. Based on the P-VAR model, their findings confirmed the significant contribution of financial development to sustainability-oriented outcomes and emission mitigation. However, contrary evidence has also been reported in the literature, suggesting that the environmental effects of financial development may vary across different contexts (Charfeddine and Kahia, 2019; He et al., 2022).

In contrast to the aforementioned findings, some studies have reported an insignificant relationship between financial development and environmental degradation. For instance, Sahu and Kumar (2020) investigated the relationship between financial development and CO₂ emissions within the framework of the Environmental Kuznets Curve hypothesis by applying the ARDL approach for the period 1971-2014. Their empirical results indicated that financial development does not exert a statistically significant effect on carbon emissions.

2.2 Political Stability and Climate Change

Political stability represents an important institutional factor influencing the formulation and implementation of environmental policies. Stable political conditions enable governments to maintain consistent policy frameworks and pursue long-term strategic objectives, which are fundamental for promoting sustainable development and supporting the transition toward a net-zero emissions economy (Han et al., 2024; Rout and Gochhayat, 2024). Democratic governance, good governance practices, and well-developed institutional structures in a country attract foreign direct investment, while the presence of political stability serves as a crucial complementary factor in facilitating these investments (Kirikkaleli and Osmanlı, 2023). Politically stable countries offer low-risk environments and reliable business conditions, making them attractive destinations for foreign investors (Uddin et al., 2023).

In contrast, political instability creates an atmosphere of uncertainty, which can negatively influence corporate investment decisions. It may also lead to regulatory institutions losing their ability to control and incentivize industries in line with sustainable development goals, causing firms to adopt risk-averse

behaviors and withdraw from environmentally friendly investments (Hacıımanoğlu and Sungur, 2024). As a global public issue, environmental problems require international solutions, and at the same time, countries adopt decisions internally to implement these solutions and manage the process effectively. Government instability heightens political risk, generating multifaceted effects on the economy, energy demand, and the environment. Such instability may hinder the implementation of energy policies, thereby deteriorating environmental quality (Ahmed et al., 2025).

Empirical evidence regarding the relationship between political stability and environmental outcomes remains mixed across different countries and methodological approaches. Focusing on sub-Saharan African countries, Abid (2016) reported that economic growth increases CO₂ emissions, whereas political stability contributes to emission reductions. Similarly, Sell (2019) identified a negative relationship between political stability and carbon emissions in ASEAN countries. Examining South Asian countries, Pata et al. (2022) found that political stability and renewable energy reduce environmental degradation, while financial development has an adverse environmental effect.

The role of political stability in reducing emissions has also been supported by more recent studies. Han et al. (2024) investigated the long-term relationship between natural resources, government debt, political stability, and net-zero carbon emissions in China, India, Pakistan, and Kazakhstan over the period 2001-2021 by employing the Westerlund panel cointegration test and Iterated Generalized Least Squares analysis. Their results revealed a negative and statistically significant association between political stability and CO₂ emissions. Using CS-ARDL and AMG methods, Behera et al. (2024) analyzed seven OECD countries during 2000-2019 and found that political stability and renewable energy contribute to lower CO₂ emissions.

Similarly, Hacıımanoğlu and Sungur (2024) examined the effects of economic growth, renewable energy consumption, and financial stability on CO₂ emissions in the United States for the period 1984-2017 through the FARDL method. Their findings indicated that renewable energy and political stability have statistically significant emission-reducing effects in both the short and long run. Rout and Gochhayat (2024) also provided evidence that political stability reduces GHG emissions in India between 1996 and 2021 using the ARDL method.

However, the environmental consequences of political stability may differ depending on country-specific conditions. Ridwan et al. (2025) analyzed Bangladesh during the period 1990-2022 using the ARDL method and examined the effects of economic growth, foreign direct investment, and financial stability. Their findings showed that economic growth, foreign direct investment, and population growth increase CO₂ emissions, whereas political stability supported by good governance helps reduce environmental pressures. In Pakistan, Sohail et al. (2022) investigated the impact of political instability on environmental quality between 1990 and 2019 using the non-linear ARDL method and found that political instability decreases clean energy consumption and deteriorates environmental quality in the long run. Conversely, Asif et al. (2024a) reported that political instability has a negative impact on the carbon footprint in South Asian countries during 1996-2019 by using carbon footprint as an indicator of environmental degradation.

2.3 Foreign Direct Investment and Climate Change

The relationship between foreign direct investment (FDI) and environmental degradation has also been examined in different country contexts, with empirical findings indicating both positive and negative environmental effects. Salahuddin et al. (2018) analyzed Kuwait over the period 1980-2013 by applying the ARDL bounds testing approach and found that economic growth, energy consumption, and foreign direct investment contribute to higher CO₂ emissions.

Using panel data from 147 countries, Liobikienė and Butkus (2019) investigated the effects of GDP, trade, foreign direct investment, urbanization, industrialization, renewable energy consumption, and energy efficiency on GHG emissions through the system GMM estimator. Their empirical results showed that GDP has a positive effect on GHG emissions, whereas foreign direct investment and urbanization do not generate a scale effect on GHG emissions.

Similarly, Abbas et al. (2021) explored the relationship between regulatory quality, energy consumption per capita, foreign direct investment, and GHG emissions in 27 Asian countries during the period 2001-2018 by employing the GMM approach. Their findings indicated that energy consumption negatively affects GHG emissions, while improvements in regulatory quality contribute to emission reductions. In addition, foreign direct investment was found to play an integrative role by supporting clean energy use and improving energy consumption efficiency through sufficient FDI inflows.

Focusing on Korea, Kim (2020) investigated the effects of foreign direct investment, industrial structure, renewable and nuclear energy, economic growth, and urbanization on GHG emissions using the ARDL bounds test. The findings revealed that urbanization and economic growth increase GHG emissions, whereas the share of manufacturing industry, renewable energy, and nuclear energy contribute to emission reductions. Although foreign direct investment inflows were also associated with higher GHG emissions, the estimated coefficient was found to be relatively small.

FDI inflows represent an important source of external financing, particularly for developing countries. Nevertheless, the environmental consequences of FDI remain ambiguous. The relocation of carbon-intensive and energy-intensive industries from countries with stringent environmental regulations to countries with relatively weaker regulatory frameworks may lead to the emergence of pollution havens (Sarkodie and Strezov, 2019). However, an alternative perspective suggests that FDI can also generate positive environmental outcomes through technology transfer, efficiency improvements, and knowledge diffusion.

Supporting this view, Uddin et al. (2023) examined BRICS countries over the period 1990-2018 by employing ARDL, FMOLS, and Dynamic Ordinary Least Squares (DOLS) methods and reported that FDI has a long-term mitigating effect on CO₂ emissions. Similarly, Apergis et al. (2023) investigated the environmental effects of foreign direct investments originating from Germany, France, and Italy and found that these investments contributed to emission reductions in BRICS countries during the period 1993-2012. Using the GMM method, Limazie and Woni (2024) also provided evidence that FDI reduces environmental damage in ECOWAS countries between 2005 and 2016.

The emission-reducing role of FDI can be explained through several channels, including the transfer of clean technologies, technology diffusion, human capital development, and improvements in corporate social responsibility practices in host countries. In line with this argument, Mert and Bölük (2016), applying the PMG estimation method to data from 21 countries that signed the Kyoto Protocol, concluded that renewable energy and foreign direct investment have long-term reducing effects on CO₂ emissions. Overall, previous studies indicate that FDI inflows may enhance energy efficiency and environmental quality in recipient countries. However, FDI may also increase environmental pressures by stimulating production activities and energy consumption, particularly when the additional energy demand is satisfied through fossil fuel sources. Therefore, the environmental impact of foreign direct investment depends on the prevailing economic structure, technological capacity, and regulatory conditions of host countries.

2.4 Economic Growth and Climate Change

Since GHG emissions are largely associated with fossil fuel combustion, energy production and consumption remain among the fundamental factors shaping discussions on climate change (Bölük and Mert, 2014). Accordingly, the relationship between energy consumption, economic development, and environmental pollution has received considerable attention in the environmental economics literature over the last three decades (Huang et al., 2008). Moreover, climate change is expected to impose significant constraints on existing development strategies and economic growth policies by creating additional environmental and economic challenges (Adzawla et al., 2019).

Empirical studies have extensively investigated the relationship between economic growth and environmental degradation. Yusuf et al. (2020) analyzed African OPEC countries over the period 1970-2016 by examining the relationship between GHG emissions, energy consumption, and economic growth through the PARDL approach estimated using MG and PMG methods. Their results indicated that economic growth increases both CO₂ and methane emissions in the long run, while its positive effect on methane emissions remains significant in the short run. Similarly, Wahab et al. (2024) explored the effects of economic growth, trade, resources, and institutional quality on GHG emissions in OECD countries during the period 1990-2022 using the Method of Moments Quantile Regression. Their findings revealed a positive and statistically significant relationship between economic growth and GHG emissions, emphasizing the necessity of sustainable strategies that incorporate environmental considerations into economic development processes.

Focusing on Vietnam, Nguyen et al. (2022) examined the relationship between GHG emissions, economic growth, fossil fuel consumption, renewable energy, and trade openness over the period 1980-2018 by employing a panel ARDL approach. The results showed that GDP was the most influential factor affecting GHG emissions and that economic growth has a positive impact on emissions.

Beyond the direct relationship between economic growth and environmental degradation, several studies have also incorporated financial development and foreign direct investment into this framework. Nasir et al. (2019) investigated the ecological consequences of economic growth, FDI, and financial development in selected ASEAN-5 economies using data covering the period 1982-2014. Applying DOLS and FMOLS techniques within a panel data framework, they found a statistically significant long run cointegration relationship between financial development, economic development, FDI, and environmental degradation (CO₂ emissions). Their findings indicated that economic growth, financial development, and FDI contribute to higher environmental degradation in ASEAN-5 countries.

However, the relationship between economic growth and emissions is not universally consistent. In contrast to these findings, Lapinskienė et al. (2017) examined the relationship between economic growth, GHG emissions, and other relevant factors using panel data from 22 EU countries and suggested that CO₂ emissions may decline significantly as GDP increases in the future.

2.5 Renewable Energy and Climate Change

Meeting the increasing energy demand caused by population growth with fossil fuel resources necessitates a transition to alternative energy sources due to the limited nature of these resources and their contribution to environmental degradation. Renewable energy sources play an important role in preventing global warming due to their unlimited nature and low carbon emissions (Rafiq et al., 2014; Shahzad, 2012). The objective is to make renewable energy sources more accessible and affordable through subsidies, tax incentives, and infrastructure investment support, thereby increasing their use and preventing global warming (Sohag et al., 2024). With the increased use of renewable energy sources, countries will contribute

to sustainable development goals by reducing energy costs, improving payment balances, ensuring energy supply security, and reducing pressure on the environment (Agrawal and Soni, 2021; Erdogan et al., 2023). Many organizations, including the European Union, are developing various strategies and policies to increase interest in renewable energy sources such as solar, wind, biomass, and tidal energy (Marks-Bielska et al., 2020).

Bölük and Mert (2014) investigated the EKC hypothesis by examining the relationship between carbon emissions, income, and energy consumption in 16 European Union countries during the period 1990-2008. Their empirical findings demonstrated that renewable energy consumption generates considerably lower carbon emissions compared to fossil fuel-based energy consumption. In particular, the environmental burden associated with renewable energy was found to be substantially lower than that of fossil fuels, indicating that transforming the energy consumption structure toward renewable energy sources may provide an effective mechanism for reducing GHG emissions.

Consistent with this perspective, Shafiei and Salim (2014) showed that renewable energy consumption contributes significantly to emission reductions in OECD countries over the period 1980-2011. Furthermore, Khan et al. (2019) examined the relationship among relevant variables using panel data covering 34 high-income countries across Asia, Europe, and America between 1995 and 2017. By applying Dumitrescu and Hurlin's causality test and the Augmented Mean Group estimator, they found that financial development (in Asia and America), renewable energy (in Europe and America), and trade openness (in Europe) contribute to reductions in GHG emissions. At the country level, bidirectional relationships were identified between GHG emissions and financial development in 11 countries, renewable energy in 22 countries, trade openness in 5 countries, and tourism in 12 countries.

Ulucak and Khan (2020) investigated the relationship between real income, economic growth, natural resource rent, urbanization, and ecological footprint in BRICS countries, which have attracted considerable attention due to their rapid economic expansion and increasing energy demand. Employing FMOLS and DOLS estimation methods, they found that renewable energy, urbanization, and natural resource rent contribute positively to environmental quality over the period 1992-2016. Similarly, Erdogan et al. (2023) explored the role of renewable energy investments and technologies in achieving carbon neutrality targets in G7 countries by applying a second-generation panel data approach. Their findings indicated that both renewable energy investments and technologies have a mitigating effect on carbon emissions.

Leitão (2024) examined the effects of foreign direct investment, renewable energy, and human development on CO₂ emissions in G7 countries during the period 1990-2019. Using the PMG-ARDL method, the study demonstrated that renewable energy improves air quality in both the short and long run, whereas the positive environmental contribution of foreign direct investment emerges only in the long run. In addition, foreign direct investment was found to have a negative effect on CO₂ emissions in the short term. Focusing on South Caucasus countries, Dilanchiev et al. (2024) analyzed the causal relationship between renewable energy, economic growth, and CO₂ emissions and identified a unidirectional causality running from CO₂ emissions to renewable energy. Their results also showed that positive shocks in renewable energy reduce CO₂ emissions. Furthermore, Sohag et al. (2024) investigated OECD countries using the CS-ARDL approach and reported that environmental policies reduce ecological footprint through the renewable energy channel during the period 1990–2018.

Overall, the existing literature provides extensive empirical and theoretical evidence regarding the interactions between greenhouse gas emissions and various macroeconomic, financial, energy-related, and institutional determinants. The findings reported in previous studies reveal that GHG emissions are shaped

by multiple factors, including economic growth, financial development, foreign direct investment, renewable energy, and institutional conditions. Based on this comprehensive review, the present study establishes its conceptual foundation by considering how the major variables included in the research model have been addressed in the existing literature. The theoretical relationships among these variables and their expected effects are illustrated in **Figure 1**, which presents the conceptual framework of the study.

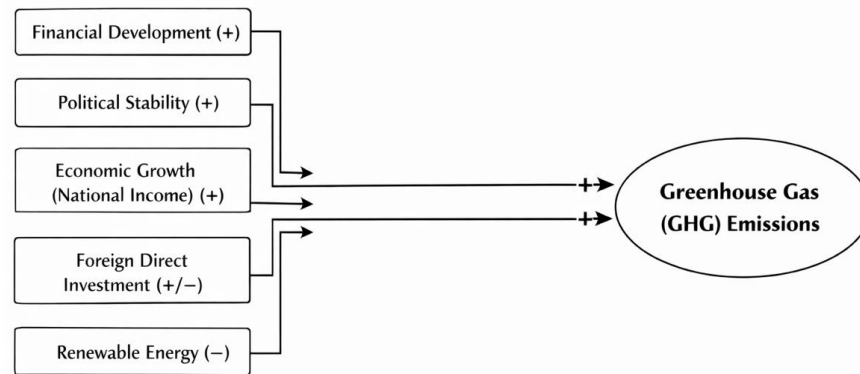


Figure 1. Conceptual framework of the study.

On the basis of the above framework, the current methodology section undertakes a comprehensive review of the variables of interest and the empirical approach adopted in the current research in a panel data approach.

3. Research Methodology

3.1 Data and Model

The study investigates the impact of national income, renewable energy, foreign direct investments, financial development and political stability on emissions in BRICS countries for the period of 2002-2021. The natural logarithms of all variables except political stability variables are taken. In this research model, the study developed by Al-Zubairi et al. (2024) is utilized. Al-Zubairi et al. (2024) examined the effect of the interaction of financial stability and political stability on CO₂ emissions in their study. The econometric model is given below:

$$\ln ghg_{i,t} = \alpha_0 + \alpha_1 \ln gdp_{i,t} + \alpha_2 \ln ren_{i,t} + \alpha_3 \ln fdi + \alpha_4 \ln fd_{i,t} + \alpha_5 ps_{i,t} + \alpha_6 \ln fd * ps_{i,t} + \varepsilon_i \quad (1)$$

where, “*i*” represents the country, “*t*” denotes time, “ ε ” denotes error term. $\alpha_0, \alpha_1, \alpha_2 \dots$ denotes slope coefficients. The variables, description and database are given **Table 1**.

Table 1. Information of variables.

Variables	Abbreviations	Description	Database
Greenhouse gas emissions	lnghg	Metric tons per capita.	https://data.worldbank.org/
Gross domestic product	lngdp	Per capita constant 2015 US\$.	https://data.worldbank.org/
Renewable energy consumption	lnren	% of total final energy consumption.	https://data.worldbank.org/
Foreign direct investment	lnfdi	Foreign direct investment, net inflows (% of GDP).	Basic Dataset University of Gothenburg (https://www.gu.se/en/quality-government)
Financial development	lnfd	Financial Development Index.	https://data.imf.org/
Political stability	ps	Political Stability and Absence of Violence/Terrorism Index.	Basic Dataset University of Gothenburg (https://www.gu.se/en/quality-government)

The BRICS countries are experiencing rapid growth accompanied by increases in production, industrialization, and energy consumption. Meeting energy demand primarily through fossil fuel sources leads to increased environmental degradation. Indeed, the BRICS Policy Center (2024) highlights that BRICS countries are among the largest GHG emitters. Therefore, economic growth is expected to have a positive impact on GHG emissions. The existence of political stability is important in terms of attracting investment to the country by expressing confidence in the country. The arrival of technology in the country through foreign direct investment is necessary to ensure economic growth (Le et al., 2023). As economic growth becomes the driving force behind investments, GHG emissions are expected to increase. The effect of foreign direct investment on GHG emissions may be either positive or negative depending on the scale, composition, and technological characteristics of investment flows. On the other hand, the transfer and diffusion of environmentally friendly technologies to the host country can reduce GHG emissions. Therefore, in BRICS countries as host nations, foreign direct investment may also have a negative impact on GHG emissions.

The relationship between financial development and GHG emissions remains theoretically inconclusive, as previous studies provide competing arguments regarding the direction of this effect. From one perspective, financial development is expected to contribute to emission reductions by improving access to financial resources and encouraging investments in environmentally friendly projects. The expansion of financial sectors may facilitate the financing of environmental initiatives and support improvements in environmental quality (Abid, 2016; Safi et al., 2021). Accordingly, the expected sign of financial development is negative. Empirical evidence supporting this argument has been provided by Liu et al. (2023) for Belt and Road Initiative (BRI) countries and Shahbaz et al. (2013) for Malaysia. As emphasized by Abid (2016), Liu et al. (2023) and Shahbaz et al. (2013), financial development can contribute to preventing environmental degradation by enabling lower-cost financing opportunities for environmental investment projects.

Conversely, financial development may also exert a positive effect on GHG emissions through alternative economic channels. A more developed financial system can attract foreign direct investment (FDI), stimulate economic activities, and consequently increase energy demand (Mahalik et al., 2017; Le and Öztürk, 2020). Mahalik et al. (2017) demonstrated that financial development increases energy demand through the consumer-business-wealth effect. When the additional energy demand generated by economic expansion is primarily satisfied through fossil fuel resources, higher levels of GHG emissions are expected. Therefore, the positive impact of financial development on GHG emissions can also be theoretically justified. Considering these two opposing mechanisms, the effect of financial development on GHG emissions remains an empirical issue, and this study does not impose a predetermined direction by allowing both positive and negative effects to be considered.

The expected relationship between political stability and GHG emissions is negative, implying that greater political stability may contribute to emission reductions. With political stability, countries' environmental laws and green technology practices help to reduce pollution, while instability reduces laws and practices (Purcel, 2019).

The relationship between renewable energy and GHG emissions is expected to be negative. The rapid economic expansion experienced by BRICS countries has increased energy requirements, which may intensify GHG emissions when energy demand is primarily satisfied through conventional fossil fuel sources. However, greater reliance on renewable energy sources, which represent a cleaner alternative in the energy mix, is expected to mitigate environmental pressures by reducing GHG emissions.

3.2 Methodology

The AMG estimator is utilized in this study due to its ability to consider cross-sectional dependence and accommodate heterogeneous slope coefficients in the estimation of long-run coefficients. The AMG method is preferred because it can be applied to non-stationary series and does not require strict assumptions regarding the cointegration condition (Eberhardt, 2012).

The systematic process followed in the study based on panel data analysis is shown below (**Figure 2**).

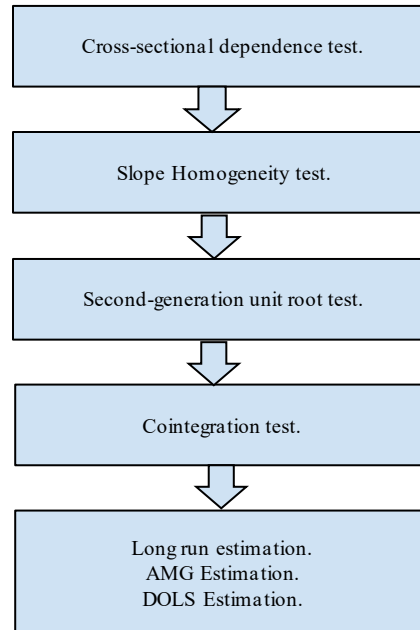


Figure 2. Analytical framework of the study.

3.2.1 Cross-Sectional Dependence Test

The empirical analysis initially investigates cross-sectional dependence and slope homogeneity properties of the panel data. The cross-sectional dependence tests are conducted to determine whether shocks or movements in one country affect other countries within the panel. For this purpose, the presence of cross-sectional dependence is examined through the Breusch-Pagan (1980) LM, Pesaran (2004) Scaled LM, and Pesaran (2004) CD tests. The formulation of the Breusch-Pagan LM (1980) test, used in models with small N and large T , is as follows:

$$LM = \sum_{i=1}^{N-1} \sum_{j=i+1}^N T \hat{p}_{ij}^2.$$

The Pesaran (2004) Scaled LM test is appropriate for panels with medium to large N , whereas the Pesaran (2004) CD test is used for panels with large N .

$$LM_{scaled} = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^N (T \hat{p}_{ij}^2 - 1) \quad LM_{scaled} \sim N(0,1),$$

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

where, T denotes the time dimension, N represents the number of cross-sectional units, and $\hat{\rho}_{ij}$ denotes the error correlation between units i and j .

The hypotheses for the tests in use are the following:

H_0 : There is no cross-sectional dependence.

H_1 : There is a cross-sectional dependence.

If the null hypothesis is not rejected, indicating the absence of cross-sectional dependence, the analysis may proceed by applying conventional unit root tests that do not account for cross-sectional dependence. Therefore, conducting cross-sectional dependence tests is a necessary step for determining the appropriate unit root testing procedure.

3.2.2 Slope Homogeneity Test

Following the horizontal section dependence, the homogeneity of the slope coefficients in the model is examined using the slope homogeneity test developed by Pesaran and Yamagata (2008). The calculation of the slope homogeneity test statistic, based on Swamy's (1970) homogeneity test, is as follows:

$$\hat{\Delta} = \sqrt{N} \left(\frac{N^{-1} \sum_{i=1}^N \frac{S_{-k}}{\sqrt{2k}} \right) \quad \Delta \sim N(0,1).$$

For small samples, the $\hat{\Delta}$ test is adjusted by correcting its mean and variance under the normal distribution, and its adjusted version is formulated as follows (Hsueh et al., 2013):

$$\hat{\Delta}_{adj} = \sqrt{N} \left(\frac{N^{-1} \sum_{i=1}^N \frac{S-E(Z_{iT})}{\sqrt{Var(Z_{iT})}} \right) \quad \Delta \sim N(0,1),$$

where, $E(\hat{Z}_{iT}) = k$, $Var(\hat{Z}_{iT}) = 2k(T - k - 1)/(T + 1)$.

Based on tests $\hat{\Delta}$ and $\hat{\Delta}_{adj}$, the null and alternative hypotheses are formulated.

H_0 : $\beta_1 = \beta_2 = \dots \beta_N$ (for all i) slope coefficients are homogeneous.

H_1 : $\beta_i \neq \beta_j$ (for a non-zero fraction of pair-wise slopes for $i \neq j$) (Pesaran and Yamagata, 2008).

3.2.3 Panel Unit Root Test

The stationarity characteristics of the variables are investigated through panel unit root analysis. Considering the presence of cross-sectional dependence and heterogeneity across countries, the second-generation CIPS unit root test proposed by Pesaran (2007) is employed. Unlike the Augmented Dickey-Fuller (ADF) unit root test, which evaluates each series separately, the CIPS approach incorporates cross-sectional information by including the first differences of cross-sectional averages together with individual lagged terms. The regressions developed within this framework are referred to as the CADF (Cross-Sectionally ADF) regressions (Pesaran and Yamagata, 2008). The equation associated with the CADF test statistic is presented below:

$$\Delta Y_{it} = \alpha_{it} + \beta_i Y_{i,t-1} + c_i \bar{Y}_{t-1} + d_i \Delta \bar{Y}_t + \epsilon_{i,t},$$

where, p denotes the lag length, $Y_{i,t}$ represents the variable under investigation, and Δ denotes the first-difference operator. The CIPS test statistic is obtained as the average of the individual CADF test statistics.

$$CIPS = \frac{1}{N} \sum_{i=1}^N CADF_i.$$

3.2.4 Panel Cointegration Test

Based on the equations presented above, the null hypothesis of the test assumes that the variables contain a unit root, whereas the alternative hypothesis suggests that at least one cross-sectional unit in the panel is stationary. After determining the stationarity properties of the variables, the existence of a long-run relationship among the variables is examined by employing Westerlund's (2007) cointegration test. This test provides four different statistics, namely the group statistics (Gt and Ga) and the panel statistics (Pa and Pt). While the group statistics evaluate whether cointegration exists for at least one cross-sectional unit, the panel statistics assess the existence of a cointegration relationship for the panel as a whole. Once a long-run relationship is confirmed, the analysis proceeds with the estimation of long-run coefficients (Westerlund, 2007).

3.2.5 AMG Estimation Method

For heterogeneous panel data structures, the AMG estimator introduced by Bond and Eberhardt (2013) and Eberhardt and Teal (2010) is employed to obtain long-run coefficient estimates. This estimator is particularly suitable for cases involving cross-sectional dependence and heterogeneous slope coefficients among panel units. Unlike conventional estimators, the AMG approach incorporates both the time-series characteristics of the data and the differences arising from observable and unobservable factors across panel groups (Eberhardt and Bond, 2009). In this framework, the influence of unobserved common factors is captured within the estimation procedure. Similar to the Common Correlated Effects Mean Group (CCEMG) estimator, the AMG approach incorporates cross-sectional averages of the variables and requires the variables to exhibit a cointegrated relationship (Güney and Üstündağ, 2022). The estimation procedure of the AMG estimator is implemented in two stages. In the first stage, the first-differenced form of the model is estimated using the Ordinary Least Squares (OLS) method.

$$\text{The first stage } \Delta Y_{it} = \beta^I \Delta X_{it} + c_t \Delta D_{it} \Rightarrow \hat{c}_t + \hat{\mu}_t,$$

where, $i = 1 \dots N$; $t = 1 \dots T$; ΔY_{it} denotes the first difference of the dependent variable, ΔX_{it} denotes the first difference of the independent variable; ΔD_{it} represents the first difference of the time dummy variables, and c_t denotes the coefficients of the time dummies.

$$\text{The second stage } Y_{it} = \alpha_i + \beta^I X_{it} + c_{it} \Delta D_{it} + \hat{\mu}_t + \varepsilon_{it} \Rightarrow \hat{b}_{AMG} = N^{-1} \sum_i b_i,$$

where, $\hat{\mu}_t$ represents a common and unobservable process shared by all units in the panel. It is assumed that the effect of this process is identical across units. The $\hat{b}_{AMG}$ estimator is obtained as the average of the individual b_i estimates following the approach of Pesaran and Smith (1995) (Bond and Eberhardt, 2013).

3.3 Empirical Analysis Findings

This section presents empirical analysis findings in a systematic manner, following the methodological framework of the study. Prior to discussing the econometric estimation results, **Table 2** reports the descriptive statistics of the variables included in the analysis, providing an overview of the main characteristics of the data set.

Table 2. Descriptive statistics.

Variables	Mean	Median	Maximum	Minimum	Standard deviation
lnghg	0.711262	0.752530	1.245583	0.237609	0.337386
lngdp	12.18404	12.15425	13.20006	11.37310	0.466945
lnren	1.177575	1.139776	1.698970	0.505150	0.419749
lnfdi	0.656868	0.732356	2.288486	-1.560648	0.674322
lnfd	-0.588532	-0.629186	-0.226607	-0.950286	0.198840
ps	-0.562400	-0.510000	0.330000	-1.510000	0.421724
lnfd*ps	0.154449	0.080732	0.548263	-0.125563	0.150712

Table 2 presents the summary descriptive statistics of the variables. Among the variables, the one with the highest positive values is the lngdp variable, followed by lnren, lnghg, and lnfdi, respectively. The variables lnfd and ps have negative average values. **Table 3** reports the results of the cross-sectional dependence tests, which are conducted to determine whether shocks and common factors affecting one panel unit may also influence the other units in the panel.

Table 3. The cross-sectional dependence test results.

Name of the test	Test statistics	Probability
Breusch- Pagan LM	49.30626	0.0014*
Pesaran Scaled LM	7.671114	0.0021*
Pesaran CD	1.874802	0.0608***

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

The presence of cross-sectional dependence among the countries included in the panel was examined using the Breusch-Pagan LM (1980), Pesaran (2004) Scaled LM, and Pesaran (2004) CD tests. The results of all three tests indicate that the probability values are below the 0.10 significance level; therefore, the null hypothesis of no cross-sectional dependence is rejected. Accordingly, the alternative hypothesis suggesting the existence of cross-sectional dependence among panel units is supported. These findings imply that a shock occurring in one country may transmit to other countries, indicating the presence of interdependence among the countries in the panel. Therefore, subsequent estimations are conducted using econometric techniques that account for cross-sectional dependence.

Given the presence of cross-sectional dependence, the analysis is further extended by employing a second-generation unit root test. Following this procedure, the slope homogeneity test proposed by Pesaran and Yamagata (2008) is applied, with the obtained results presented in **Table 4**.

Table 4. Slope homogeneity test results.

Name of the test	Model	
	Test statistics	Probability
Delta Tilde	4.291*	0.000
Delta Tilde Adjusted	5.539*	0.000

Note: * indicates the statistical significance at 1% level.

The results of the slope homogeneity test indicate that the null hypothesis is rejected at the 1% significance level, suggesting that the slope coefficients are not homogeneous across BRICS countries. This finding implies that the effects of changes in the explanatory variables on GHG emissions differ among countries, confirming the heterogeneous structure of the BRICS panel. Considering the findings of the cross-sectional dependence and slope homogeneity tests, the analysis proceeds with the second-generation CIPS unit root

test to examine the stationarity properties of the variables. The results of the Pesaran (2007) CIPS unit root test are presented in **Table 5**.

Table 5. Cips unit root test results.

Variables	Lag length	Level	First difference
lnghg	2	-1.105	-2.863*
lngdp	2	-1.612	-2.905*
lnren	2	-2.441**	-3.252*
lnfdi	2	-2.369**	-5.684*
lnfd	2	-2.822	-5.285*
ps	2	-1.775	-4.879*
lnfd*ps	2	-2.003	-4.916*

Note: *, ** and *** indicate statistical significance at the 1%, 5% and 10% levels.

The CIPS unit root test results, which account for cross-sectional dependence, reveal that the variables exhibit different orders of stationarity. At the level form, the dependent variable lnghg and the independent variables lngdp, ps, and lnfd*ps are found to contain a unit root, whereas lnren, lnfdi, and lnfd are stationary at the 5% significance level. However, after taking the first differences, all variables become stationary at the 1% significance level. These findings indicate that the variables are integrated at different orders, which allows for further investigation of the long-run relationship among the variables.

Therefore, the Westerlund cointegration test is employed to examine whether a long-term relationship exists among the variables, and the corresponding results are reported in **Table 6**.

Table 6. Cointegration test result.

Statistics	Statistics	Bootstrap P- value
Gt	5.222	0.480
Ga	3.985	0.510
Pt	-2.970***	0.060
Pa	-2.970*	0.000

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

The presence of a long-run relationship among the variables is examined through the cointegration test. As reported in **Table 6**, the Westerlund cointegration test results confirm the existence of a long-term relationship both across the panel as a whole and among the variables included in the model. Following the confirmation of cointegration, the long-run coefficient estimates are presented in **Table 7**.

Furthermore, the DOLS method is employed as a robustness check alongside the AMG estimator to evaluate the effects of the explanatory variables on GHG emissions using an alternative econometric approach.

The AMG estimation results show that the effect of the increase in economic growth in BRICS countries on GHG emissions is statistically significant and positive, which is consistent with the expected effect in the research. In this case, it can be argued that economic growth causes environmental degradation by increasing greenhouse gas emissions. While BRICS countries experience economic growth, environmental sustainability is being neglected. They need to implement policies to reduce GHG emissions for sustainable development. These findings are consistent with the literature examining BRICS countries. Indeed, Li et al. (2023), Naseem et al. (2022), Oprea et al. (2024) and Xu et al. (2025) have found that economic growth

increases CO₂ emissions.

Table 7. Long- short run estimation analysis results.

Variables	(Dependent variable:lnghg)	(Dependent variable:lnghg)
	AMG	DOLS estimation
lngdp	0.33351* (0.0759)	0.12079* (0.0050)
lnren	-0.31922* (0.10607)	-0.43229* (0.04058)
lnfdi	-0.00527* (0.00952)	-0.01373* (0.00793)
lnfd	0.41225*** (0.22317)	0.34417* (0.13549)
ps	0.17027* (0.06531)	0.24881* (0.08192)
lnfd*ps	0.75657** (0.36090)	1.30008* (0.60946)
Constant	-2.76835* (0.9583)	-
Wald chi ²	73.58 (0.000)	-

Note: The value in parentheses (.) represents the standard errors. *, ** and *** indicate statistical significance at the 1%, 5% and 10% levels.

In addition to the AMG test, the DOLS test is applied in the study, and according to the results obtained, it was determined that the variables other than renewable energy and foreign direct investment have a statistically significant and positive effect on greenhouse gas emissions. The findings show that these variables cause environmental degradation. On the other hand, it shows that renewable energy and foreign direct investment have a positive effect on improving environmental quality.

It has been found that renewable energy consumption reduces GHG emissions as expected in other literature studies. For example, Ulucak and Khan (2020), who examined the same sample group, found that renewable energy reduces CO₂ emissions. Dogan and Seker (2016) found that renewable energy, which are among the variables, have a reducing effect on emissions in top renewable energy countries. Studies conducted by Dilanchiev et al. (2024), Erdogan et al. (2023) and Sohag et al. (2024) have also revealed similar results. Increasing investment in renewable energy sources to reduce dependence on fossil fuels in the energy demand of the rapidly growing BRICS countries, along with the development of policies that reduce costs and encourage innovation and research and development activities, will enable environmental sustainability.

Financial development has a statistically significant and positive effect on greenhouse gas emissions. The results obtained regarding the impact of financial development on emissions are consistent with those obtained by Asif et al. (2024b), He et al. (2022), Jiang and Ma (2019) and Le and Öztürk (2020). The development of financial resources directed largely toward carbon-intensive sectors in BRICS countries contributes to an increase in greenhouse gas emissions. Therefore, policies and practices should be developed within the financial system to encourage green finance.

Emerging economies constitute a significant share of the global population and make substantial contributions to global carbon emissions, GDP, CO₂ emissions, and financial development (FD). The rising trend in CO₂ emissions poses a major challenge for these countries. To address this issue, it is necessary to implement various economic and financial policies that promote economic growth (GDP) while protecting the environment (Halaç et al., 2025). As also emphasized by Kirikkaleli et al. (2022), policymakers need to

dynamically encourage research and development in low-carbon technologies and investments in renewable energy, while developing policies targeting energy-intensive and consumption-based sectors that increase CO₂ emissions. As noted by Cai et al. (2018), clean energy sources are expected to play a crucial role in maintaining the balance between economic growth and environmental protection in developing countries. As stated by Shafiei and Salim (2014), for stable and sustainable growth, governments should develop and implement policies that encourage investment in renewable energy technologies.

There is a negative relationship between foreign direct investment (FDI) and GHG emissions in BRICS countries. This situation can be interpreted to mean that FDI flows could contribute to reducing emissions in BRICS countries, thereby helping to mitigate environmental degradation through mechanisms such as the transfer of environmentally friendly and energy-efficient technologies and production methods, and ultimately leading to positive outcomes in terms of environmental quality. Similarly, Apergis et al. (2023), Limazie and Woni (2024) and Mert and Bölük (2016) have demonstrated its emission-reducing effect in their studies.

Political stability, on the other hand, has an increasing effect on emissions. This is similar to the studies conducted by Asif et al. (2024a) and Sohail et al. (2022). This situation could be interpreted to mean that environmental issues are not among the political priorities in these countries. However, it is essential that environmental issues be placed on the political agenda in order to mitigate their negative impacts.

The interaction between financial development and political stability has also a statistically significant and positive effect on GHG emissions. Financial development promotes economic growth, but we can say that GHG emissions have increased due to insufficient investment in renewable energy and environmentally friendly technologies. Contrary to the effect obtained in this study, Al-Zubairi et al. (2024), in their study on Arab economies, found that the interaction between financial development and political stability has a statistically significant and negative effect on CO₂ emissions for the 2000-2020 period.

4. Conclusion and Recommendations

4.1 Conclusion

This research examined the relationship between greenhouse gas emissions and financial development, political stability, foreign direct investment, economic growth, renewable energy, and the interaction between political stability and financial development for the period 2002–2021 using the AMG method. The most distinctive feature of this study is that it is the first to examine the impact of four variables—financial development, economic growth, foreign direct investment, and political stability—as well as the interaction between financial development and political stability, on CO₂ emissions in the context of BRICS countries.

The findings show that the increase in economic growth in BRICS countries has a statistically significant and positive effect on greenhouse gas (GHG) emissions. In other words, economic growth leads to environmental degradation in these countries. Another finding reveals that renewable energy consumption reduces greenhouse gas (GHG) emissions in this group of countries. It is understood that environmental degradation is lower in these countries when they prefer renewable energy sources. The study found a negative relationship between foreign direct investment and greenhouse gas (GHG) emissions. Accordingly, as foreign direct investment increases, environmental degradation decreases. Another finding indicates that financial development in BRICS countries has a statistically significant and positive effect on greenhouse gas (GHG) emissions. The study found that political stability has an emissions-increasing effect. In sum, the findings suggest that while political stability, financial development, and national income tend to increase GHG emissions, renewable energy adoption and foreign direct investment plays a critical

role in reducing them. The most important finding of the study is that the interaction between political stability and financial development has an emissions-increasing effect.

The fact that the interaction between political stability and financial development has an emission-increasing effect may indicate that economic activities are not yet supported by clean energy and sustainable investments. Political stability reduces uncertainty and encourages investment. Financial development also facilitates access to credit, encourages investment, accelerates industrialization, and increases production and employment, which in turn boosts energy demand. If energy is based on fossil fuels, emissions increase. Therefore, in the absence of clean technology, a rise in emissions occurs. Financial development does not always lead to green investment. Indeed, the positive relationship found in our analysis between FD and emissions can be interpreted as indicating that foreign investments are not environmentally friendly. On the other hand, even if there is political stability, if a growth-oriented economic model is pursued and issues such as environmental regulations and carbon pricing do not find a place on governments' agendas, emissions may increase.

4.2 Recommendations

To achieve a balance between growth and the environment, BRICS countries need to rapidly implement green development policies. To ensure the effective implementation of these policies, it is necessary to develop and promote a green finance system within the financial sector by increasing incentives. This involves decoupling energy consumption from output through energy efficiency standards, low-carbon industrial policies, and incentives for the adoption of clean technologies. Growth-oriented policies should be supported by environmental safeguards to prevent locking in carbon-intensive pathways. Although renewable energy has a mitigating effect on GHG emissions, BRICS countries are still significant contributors to global emissions, as reported in recent assessments. This indicates that renewable energy investments are insufficient and contribute only marginally to preventing environmental degradation. Therefore, countries need to develop and implement more comprehensive strategies and policies to increase renewable energy investments, especially by actively utilizing incentive-based policies targeting investments. In particular, measures aimed at reducing the high costs of renewable energy investments will contribute to the widespread adoption of these resources and the achievement of Sustainable Development Goal 7 (SDG7).

To reduce the impact of financial development in BRICS countries on environmental degradation, it is important to direct financial investments towards environmental projects and increase incentives, develop sustainable financial instruments aimed at improving environmental quality, primarily green bonds, and provide incentives and tax breaks to sectors to increase green investments. Regulations and incentives for financial institutions related to environmentally friendly projects and clean energy use will contribute to reducing emissions. In particular, tax reductions and incentives should be applied to promote clean energy practices in high-emission industries.

The mitigating effect of direct foreign investment in BRICS countries on greenhouse gas emissions; political stability, financial development, and the effectiveness of green finance mechanisms in attracting clean technologies to the country will contribute to the achievement of sustainable growth targets and the improvement of environmental quality. To prevent BRICS countries from becoming pollution havens, they must enforce effective and stringent environmental policies. In addition to environmental regulations, strategies should be devised to attract environmentally friendly foreign direct investments by making these investments more appealing.

Political stability has a positive impact on environmental degradation. The presence of political stability means that capital flows are secured. In such an environment, the expectation is the use of clean technology and renewable energy sources. This is because environmental degradation is prevented in this case. When political stability is high, long-term environmental policies become more feasible. Financial markets have a stronger potential to shift towards environmentally friendly projects. The likelihood of environmental regulations being implemented is higher. The expected effect of political stability is negative. However, political stability has a positive effect on environmental degradation. This may be attributed to the fact that policymakers in BRICS countries tend to overlook environmental sustainability policies while focusing primarily on economic growth.

The interaction between political stability and financial development is expected to have an emission-reducing effect. Indeed, Al-Zubairi et al. (2024) have obtained such a result. However, unlike this study and contrary to expectations, we found that this interaction has an emission-increasing effect. The interaction between financial development and political stability further highlights the potential challenges associated with environmentally unfriendly investments driven by financial growth. The most important reason for this can be argued to be the carbon-intensive economic activities of the BRICS countries. At this point, it can be argued that economic growth is prioritized in BRICS countries, environmental concerns are pushed to the background, and sustainable growth is not a consideration. To mitigate the detrimental effects of economic growth on the environment, it is crucial for BRICS countries to implement renewable energy policies that simultaneously promote economic growth and reduce emissions. By focusing on sustainable development, these countries can navigate the dual challenges of fostering economic progress while addressing the global threat of climate change. This research underscores the need for a comprehensive approach that balances financial growth with environmental sustainability to ensure a cleaner, more resilient future.

The study's data range covers the period 2002-2021. The BRIC (Brazil-Russia-India-China) concept was introduced by Jim O'Neill, an economist at Goldman Sachs, based on economic growth performance and future political implications (Chatterjee and Naka, 2022). The concept was later expanded to BRICS with the inclusion of South Africa. Taking this definition into account, the data set begins in 2001. Periods after 2001 were excluded from the analysis due to the lack of data for these countries. Also, this study is limited by its focus on BRICS countries, which may restrict the generalizability of the findings to other country groups. However, this sample was intentionally selected due to the comparable economic structures, rapid growth and similar environmental challenges observed among BRICS economies.

It is important to conduct studies by categorizing countries according to income groups to observe how outcomes may differ across these groups. Including the technological innovation variable, which has been frequently discussed in the literature in recent years, in the model will enable more comprehensive results to be obtained regarding the effects of environmentally friendly technologies on environmental degradation. In recent years, including the issuance volume of green bonds as a variable is believed to contribute to understanding the role of financial development in achieving sustainability.

Future studies could broaden the scope of this research by including structural breaks and country-specific heterogeneity in the analysis.

Conflicts of Interest

The authors declare that there is no conflict of interest.

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AI Disclosure

During the preparation of this work the authors used AI for English language editing. After using AI, the author's reviewed, edited and take full responsibility for the content of the published article.

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