Does Green Finance Affect Renewable Energy Development: Evidence from BRICS Countries

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Abstract
The position of sustainable finance is specified in a conversation of clean energy and energy efficiency; it is tough to estimate its suggestions for the growth of inexhaustible energy. This study inspects the impact of green finance on renewable energy development in BRICS nations. The panel root test, panel cointegration test, and panel Granger causality test were used in this work to test the connection between carbon dioxide, green finance, growth of domestic products, renewable energy growth, and oil price. This study uses the conventional first-generation Pedroni and advanced Westerlund (2007) cointegration tests to check the model variables' cointegration relationship. Using the period 1996–2022, The overall results show the critical role of green finance in driving renewable energy development in BRICS nations. However, the findings also reveal significant challenges and opportunities that require tailored strategies. The study's findings provide compelling evidence of green finance's critical role in advancing renewable energy development in BRICS nations. However, the significant variability in results across countries calls for tailored, region-specific strategies. Consequently, to the best of the authors, this will be the best empirical study to explore the impact of green finance on renewable energy growth in BRICS nations.

Keywords: Green Finance, Gross Domestic Product, Renewable Energy, BRICS.

Introduction

Environmental finance, which includes monetary instruments and expenditures created especially to support ecologically friendly enterprises, has become a vital instrument in quickening this shift. With their abundant biodiversity and substantial energy needs, the countries that make up the BRICS—Brazil, Russia, India, China, and South Africa—are among the major actors in environmental finance transition. With the help of developing steady revenue creation while tackling the worldwide environmental catastrophe depends heavily on the rise of clean energy.

Together, these countries account for a sizeable share of the world industry and are in a special position to shape the future of energy produced from renewable sources. It is clear less polluted destiny by looking to see how green finance and the growth of green power in BRICS countries interact, whether creative financial techniques can open the door to a greener. Power protection, environmental mitigation, and equitable growth all depend on the switch to clean energy sources. Research from the BRICS nations shows that expenditures in solar projects, hydropower projects, bio diversity projects, and wind projects have been boosted by

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focused green finance strategies such as green finance loans, loans for renewable energy, and advantageous regulatory structures.

It will take large costs to finance the creation and implementation of renewable power innovations in order to bring about this change. One of the most effective ways to close the lack of funding is through ecological finance, which is defined as money transfers directed toward environmentally friendly ventures. In this regard, the BRICS nations are especially pertinent because of their enormous power needs, wealth of raw assets, and significant economic contributions to the world. It consists of tools that raise both government and commercial funding for environmentally beneficial projects, which include ecological securities, financing for alternative power, & ecological financial money. Collectively, these countries are responsible for a large portion of the earth's carbon energy pollution and more than forty percent of the worldwide populace. This additionally offers fantastic prospects for the advancement of sustainable power, though. For example, China is the world's largest producer of solar panels and power turbines, whereas Brazil makes use of its biomass resources and South Africa is developing its power and photovoltaic modules programs.

Problem Statement

One of its most important worldwide priorities towards reducing environmental impact & attaining ecological growth is switching to green power. The lack of funding for sustainable power tasks continues to be a major obstacle, particularly in developing nations, notably these BRICS (Brazil, Russia, India, China, and South Africa) states. Most countries struggle to raise enough environmental financing for the growth of alternative power, even though they are tactically significant to international power developments and have abundant natural resources. Growth is hampered by weak monetary structures, inconsistent policies, or restricted availability of inexpensive funding. By analyzing all possibilities as well as challenges that define these changes, recent studies aim to answer the crucial issue regarding the way environmentally friendly financing has impacted the growth of green energies in the BRICS countries.

Objectives

Such conversations bring up a crucial query that academics must address: Could BRICS countries' shift to sustainable power get impacted by green finance? This happens because all countries are the greatest nations. Establishing environmentally friendly lending that has expanded considerably, although it hasn't completely switched towards green power currently. Therefore, through analyzing the influence of globalization on the expansion of solar power in BRICS countries between 2003 and 2023, this research aims to provide a statistical response regarding this topic. Further financial, ecological, as well as organizational factors, covering greenhouse gases like carbon dioxide, an increase in gross domestic product, and petroleum cost, were incorporated into the financial evaluating procedure in order to avoid the issues caused by neglected factors.

Research gap

Through an identification of sustainable remedies across more developing regions, plus a comprehensive knowledge of the ways sustainable banking promotes the advancement of solar power within those states, the current study aims to close such imbalance. The majority of studies that are currently available on sustainable financing & renewable technology concentrate on established economies, paying little consideration towards the particular possibilities or difficulties that developing civilizations such as BRICS countries confront. The relationship between worldwide economics, commercial expenditures, and legislation in promoting the growth of clean energy sources in the BRICS economy is also not well studied. A thorough comparative research study that looks at the overall effects of environmental banking throughout the BRICS countries is lacking, despite the existence of specific instance research on sustainable banking projects across those states.

Scope of the Research

Analysis of how sustainable banking affects the growth of clean technology in the BRICS nations is the main goal of this study. It addresses the many aspects. The analysis includes 5 of the BRICS countries. It looks at environmental banking tools like ecological securities, grants, sustainable fuel resources, or foreign expenditures, as well as how they affect sustainable electricity industries like sunlight, breeze, electricity through water, and biomass fuel. The paper mainly examines changes in sustainable power and sustainable financing during the last 30 years, paying particular emphasis to current projects & patterns. Through tackling these topics, the research seeks to offer practical perspectives for decision-makers, banks, and solar electricity participants in the BRICS nations as well as worldwide.

Literature Review

In this research paper we can review 20 research paper related to topic, summaries their findings, objectives and methodology.

Ainou et al. (2023) the study aims to assess Morocco's energy security comprehensively by examining four dimensions: availability, applicability, acceptability, and affordability. Data normalization on a scale of 1–10 to evaluate trends and performance. Visualization through rhombus plotting to represent energy security trends and balance. Their findings were Morocco's affordability performance improved due to the maintenance of energy prices, mainly for butane gas and electricity for low-income households, through subsidies. The proposed set of indicators for Morocco under the 4-As framework provides the country with a holistic paradigm toward achieving its energy security.

Ning et al. (2023) investigate the impact of green bonds on energy efficiency investments and economic growth. This study used DDF Approach to measures efficiency in green financing decisions, GGI approach to Captures renewable energy adoption and sustainability measures and FAHP & FTOPSIS approach for identify and prioritize barriers to green bonds adoption and analyze their solutions. Findings suggest that green bonds help align corporate objectives with sustainability goals, boosting green financing practices. This paper enhancing the ability of firms and investors to channel resources toward green projects. Promoting environmental awareness and responsible investment behavior.

Zhang & Umair (2023) the study explores the role of green bonds in hedging against risks and promoting sustainable development. This research implements a Vector Autoregressive (VAR) and Time-Varying Parameter VAR (TVP-VAR) modeling approach to analyze daily data from January 2010 to December 2020.Found that green bonds are increasingly used to finance decarbonization projects, although their adoption faces challenges, such as limited global standardization and liquidity. The study emphasizes the need to address barriers to investment, particularly in low-income and developing economies, to leverage green finance for sustainable economic growth.

Liu and Xia (2023) examine urbanization and income levels as determinants of carbon emissions in different provinces of China. They used Panel data from 31 Chinese provinces (2010–2019). Dynamic Common Correlated Effects (D-CCE) and Interactive Fixed Effects (IFE) methods to estimate long-term relationships. They found that green finance has a strong negative relationship with carbon emissions, indicating its effectiveness in promoting low-carbon initiatives. The paper recommends that Policymakers must focus on balanced urbanization strategies, leveraging green finance, and advancing green governance to achieve climate goals.

Zhang (2023) examine the impact of green finance and environmental protection on green economic recovery in South Asian economies, with FinTech as a mediating factor. The author uses a panel regression model to assess green growth indices, FinTech innovation, and their impact on sustainable development in India, Bangladesh, and Pakistan. Research paper found that external green finance via FinTech has both positive and negative impacts on GDP, depending on the country and economic conditions. Recommends that government must focus on green investments and leverage FinTech to enhance economic recovery and environmental sustainability.

Nawaz et al. (2021) This study uses a "Difference-in-Differences (DID)' approach. This involves Comparing two groups N-11 (treated) and BRICS (control) countries and applying panel data from 2005 to 2019. The research paper found no significant differences between treated (N-11) and control (BRICS) groups in terms of outcomes. Economic and Policy Implications are essential for mitigating climate change in N-11 and BRICS countries. Policies should encourage FDI, development of bond markets, and private sector participation to drive green financing.

Zhao et al. (2023) explore the mechanisms by which green finance influences energy poverty, focusing on technical innovation and industrial structure adjustment. This research paper used empirical econometric models, including static panel estimation and dynamic panel models using Generalized Method of Moments (GMM) and used provincial sample data from 30 Chinese provinces (2004–2018). Research paper found that green finance has limited effects in high-energy-poverty regions and the western provinces due to weaker financial systems and economic bases. Suggest that strengthening technical progress and optimizing industrial structure are key pathways for green finance to address energy poverty. Volz (2018) examine the role of the financial sector in enabling this "green transformation. "Used qualitative analysis based on policy review and market observations across Asian economies to review the state of green finance in Asia, including policies, barriers, and market innovations, and provide recommendations for sustainable development. Study found that green finance in Asia is still a niche market but growing rapidly. Barriers to green investment include insufficient ESG integration, lack of trained professionals, and poor disclosure practices. Recommends that Capacity building, transparent ESG disclosures, and new financial instruments like green bonds are crucial for scaling green finance.

Akomea-Frimpong et al. (2022) Provide insights into the trends and contributions of different regions, institutions, and researchers to green finance literature. Using Scopus as the primary search engine a systemic literature review from 1990 to 2019. Found a significant increase in publications on green finance since 2017 key green finance products include loans, bonds, and carbon finance, while determinants such as regulations, environmental policies, and internal practices play crucial roles. The study highlights the need for standardized global regulations, better risk management frameworks, and comprehensive performance metrics for green finance. Rasoulinezhad & Taghizadeh (2022) examine the relationship between green finance, CO_2 emissions, green energy consumption, and energy efficiency in the top 10 countries. The study uses Stochastic Impact by Regression on Population, Affluence, and Technology model from 2002 to 2018 for 10 economies (Canada, Denmark, Hong Kong, Japan, New Zealand, Norway, Sweden, Switzerland, the UK, and the USA). Found that no immediate causal link between green finance tools (like green bonds) and CO_2 reduction. Encourage private sector investment in green projects. Fu et al. (2023) explore the role of regulatory frameworks, institutional investors, and financial instruments in promoting green finance. The study analyzed various scholarly articles, reports, and research papers to synthesize key findings. Found positive influence on decarbonization and sustainable economic growth. Increasing need for standardized data, robust policies, and addressing implementation barriers. Future research should focus on emerging markets, innovative financial tools, and the role of technology in advancing green finance. Muchiri et al. (2022) analyzing academic trends related to green finance, such as publication patterns, dominant themes, and geographic contributions. The study used a bibliometric approach using statistical and visualization tools from 2015 till 2022 Found that publications on green finance remain more frequent in climate policy journals than in mainstream finance journals, revealing a gap in economic research. There is a need to expand empirical studies on green financial instruments for their practical application and global harmonization. Lin et al. (2023) The primary aim of the study is to evaluate how green finance can facilitate the low-carbon transformation of China's power generation sector. Specifically, the research focuses on reducing thermal power generation. A provincial panel dataset from 30 Chinese regions 2007 till 2019 used a Generalized Method of Moments and Difference-in-Differences method. Found that green finance significantly reduces the share of coal-fired power generation, indicating its role in promoting low-carbon transformation. Recommend that strengthening green financial systems to allocate resources efficiently and promoting high-quality urbanization and R&D investments. Bhattacharyya (2022) examine the historical evolution and concepts of green finance.

The research adopts a review-based methodology by synthesizing information from academic and grey literature on green finance mechanisms and their applications. Found that green finance has gained significant traction globally, particularly after the Paris Agreement (2015). Instruments like green bonds and carbon pricing mechanisms are widely adopted to mobilize funds for climate-positive projects. Suggested that promoting innovative financing mechanisms to ensure inclusive, sustainable growth. Zhang et al. (2022) evaluate the role of energy financing in facilitating energy retrofits during the COVID-19 pandemic. Methodology used to combination of empirical techniques, including the Kalman technique and the Malmquist index to estimate energy efficiency improvements and the impact of financing tools. Found that green bonds significantly contribute to energy retrofit financing in E7 economies, promoting low-carbon development. Policy recommendations include developing long-term energy financing systems, incentivizing private sector participation, and regional collaboration for energy retrofits. Taghizadeh & Yoshino (2020) address the challenges of green financing and investment in renewable energy projects. Used of case studies to illustrate the effectiveness of proposed financing mechanisms (e.g., Australia's Powering Australian Renewables Fund). Found that proposed solutions like green credit guarantee schemes and spillover tax mechanisms can significantly mitigate risks and enhance returns. Research paper suggested that further development of institutional capacities and risk mitigation frameworks is necessary for sustainable green energy growth.

Xie et al. (2024) this study aims to provide insights into their interplay and influence using advanced modeling techniques. Models used to dual machine learning models, spatial econometric models, and panel threshold effect models from 266 Chinese cities spanning 2009-2021. Found that interaction between green finance and financial technology amplifies innovation impacts and financial technology plays a critical role in mitigating underperformance in regions with low green finance development. Policymakers should emphasize integrating advanced financial technologies with green financing mechanisms to amplify innovation benefits and minimize regional disparities. Klioutchnikov, I., & Kliuchnikov, O. (2021) explore the role of green finance in addressing environmental threats posed by climate change and its impact on economic recovery post-COVID-19. Methodology employs a review of existing literature, analysis of financial and environmental data, and policy documents related to green finance, climate change, and the pandemic. Found that COVID-19 pandemic has shifted public and investor focus toward sustainability and resilience, highlighting the interconnection between health, environment, and finance. Proposed that A balanced approach combining technological innovation, policy support, and lifestyle changes is imperative for achieving long-term environmental and economic stability.

Sun et al. (2023) To analyze the impact of green finance and renewable energy deployment on reducing carbon dioxide emissions in China. The method employs the STIRPAT theoretical framework and uses a system generalized method of moments to evaluate panel data from 25 Chinese provinces 2010 till 2021. Found that labor force and income per capita positively influence emissions in central and western regions, while green finance shows a stronger impact in developed eastern provinces. Indorse that policymakers should adopt region-specific strategies, including incentive policies for developed areas and supportive measures for less developed regions, to ensure equitable and sustainable progress. Yu et al. (2021) examine how financing constraints affect green innovation in Chinese enterprises and evaluate the effectiveness of green finance policies in mitigating these constraints. The study utilizes a panel dataset of Chinese listed industrial firms from 2001 till 2017. Found that financing constraints negatively impact green innovation capabilities, reducing both patent quantity and quality. This study recommended that policymakers should ensure equitable allocation of green funds to foster innovation across all enterprise types, contributing to China's carbon neutrality goals by 2060.

Methodology

Data Sources

This study attempts to evaluate the impact of Green finance on renewable energy transition. In this research the data used were annual statistics for the period of 1996–2022. Table 1 provides details of independent and dependent variables in terms of sources of data and description**.**

Table 1: Description of variables

Acronyms	Variables	Measurement Unit	Source
Y	GDP (Growth domestic product)	Growth annual %	https://databank.worldbank.org
RE	REG- Renewable energy growth	% of total electricity output	https://databank.worldbank.org
OP	OILPrice	consumer price index (2010=100)	https://databank.worldbank.org
GF	Green Finance	Green finance index	https://databank.worldbank.org
RL	Rule of law	number of sources	https://databank.worldbank.org
CO2	CO2 emissions	From fugitive emission (energy) (Mt CO2e)	https://databank.worldbank.org

Source: Author’s Estimations

The table provides an essential foundation by defining the variables central to the study. GDP (Y) measures economic growth, reflecting how economic activities influence renewable energy adoption. Renewable energy growth (RE) is a critical dependent variable, capturing the shift toward sustainable energy. Variables like oil prices (OP) and CO2 emissions (C02) are crucial because energy markets and pollution levels often directly influence policy and financing decisions. Green Finance Index (GF) serves as a proxy for green finance, while the rule of law (RL) highlights the governance environment in each country. The inclusion of diverse and interconnected variables supports the study's objective of analyzing green finance's role in transitioning to renewable energy in economies with unique energy and environmental challenges. Data on these variables are collected from World Development Indicators.

Theoretical Underpinning and Model Construction

The study follows the following model:

$$RE_{it} = f(Y_{it}, OP_{it}, GF_{it}, RL_{it}, CO2_{it}) \quad (1)$$

Here all symbols show the variables as stated in the previous section. The intercept term is α, β shows the variable's parameters, ε is the error term, whereas i and t are cross-sections and periods. The regression equations of models 1 can be formulated as follows:

$$RE_{it} = \alpha_{it} + \beta_1 Y_{it} + \beta_2 OP_{it} + \beta_3 GF_{it} + \beta_4 RL_{it} + \beta_5 CO2_{it} + \varepsilon_{it} \quad (2)$$

Cross-section dependency and slope heterogeneity

At the initial stage, the study ascertains cross-section dependency (CSD) for robust findings. Unexpected factors or shocks, such as the COVID-19 pandemic, the Russian invasion war, global financial crises, and shocks in oil prices, influence all economies and may cause the CSD problem among countries. In this aspect, we utilize Pesaran (2007) to overcome this problem, and it can be written mathematically as:

$$\text{CSD}=\sqrt{\frac{2t}{n(n-1)}}\left(\sum_{j=0}^{n-1} \sum_{i=j+1}^{n} \rho_{ij}\right) \quad (3)$$

Where CSD=1,2,3…,n and p-values will reject the assumption of no CSD for EF, CBE, DT, TD, NR, IVA, and GDP in the MINT nations at the 1% level of significance and asymptotically follows a standard normal distribution.

In the second step, the Hashem Pesaran & Yamagata (2008) test is adopted to determine the sample countries' slope heterogeneity (SH). The confirmation of SH is tested under two specifications, which are expressed as follows:

$$\tilde{\Delta}_{slope\ homogeneity}= n^{\frac{1}{2}}(2m)^{-\frac{1}{2}} + \left(\frac{1}{n}\tilde{s} - k\right) \quad (4)$$

$$\tilde{\Delta}_{adjusted\ slope\ homogeneity}= n^{\frac{1}{2}}\left(\frac{2m(t-m-1)}{t+1}\right)^{-1/2} + \left(\frac{1}{n}\tilde{s} - 2k\right) \quad (5)$$

Panel Unit Root Tests

It is a prerequisite to assess stationary properties of model variables using unit root analysis. The traditional unit root test of cross-section augmented dickey fuller (CADF) is applied. However, this test does not encounter CSD and heterogeneity concerns. For this purpose, advanced cross-section Im Pesaran Shin (CIPS) testing addresses this issue. The application of both conventional and sophisticated unit root methods produces comparable and unbiased outcomes for appropriate econometric methodology. The CIPS test equation can be denoted as follows:

$$\Delta W_{i,t} = \varphi_i + \varphi_i Z_{i,t-1} + \varphi_i \underline{W}_{t-1} + \sum_{l=0}^{p} \varphi_{il}\Delta \underline{W_{t-1}} + \sum_{l=1}^{p} \varphi_{il}\Delta W_{i,t-1} + u_t \quad (6)$$

Where the cross-section averages are indicated by W as follows:

$$W^{i\prime t} = \varphi^1\underline{TD^{i,t}} + \varphi^2\underline{DT^{i,t}} + \varphi^3\underline{NR^{i,t}} + \varphi^4\underline{IVA^{i,t}} + \varphi^5\underline{GDP^{i,t}} \quad (7)$$

The statistic of the CIPS test is specified as follows:

$$\widehat{CIPS} = N^{-1}\sum_{l=1}^{n} \quad CDF_i \quad (8)$$

Where CDF represents cross-section dickey fuller in equation above.

Panel Cointegration

This study uses the conventional first-generation Pedroni and advanced Westerlund (2007) cointegration tests to check the model variables' cointegration relationship. The Westurlund test assumes "no cointegration," which is tested against the four statistics, i.e., mean group statistics (Gt and Ga) and panel statistics (Pt and Pa). The significant statistics reject the proposition, which can be indicated as follows:

$$\alpha i(L)\Delta yit = \gamma 1i + \gamma 2it + \beta i(yit - 1 - \acute{a}ixit - 1) + \gamma i(L)'vit + \eta i \quad (9)$$

Where $\delta 1i = \beta i(1)\vartheta^{\wedge}{}_{2i} - \beta_i\lambda_{1i} + \beta_i\vartheta^{\wedge}{}_{2i}$ and $\gamma_{2i} = -\beta_i\,\lambda_{2i}$ (10)

Equation 11 shows the cointegration vector among covariates. The acronym βi represents the parameter of the error correction term, and statistics are denoted in the below equations:

$$G_t = \frac{1}{N}\sum_{i=1}^{N} \quad \frac{\acute{a}i}{SE(\acute{a}i)} \quad (11)$$

$$G_a = \frac{1}{N}\sum_{i=1}^{N} \quad \frac{T\acute{a}i}{\acute{a}i(1)} \quad (12)$$

$$P_T = \frac{\acute{a}}{SE(\acute{a})} \quad (13)$$

$$P_a = T\acute{a} \quad (14)$$

Panel Granger Causality

The Panel Granger Causality Test is a statistical method used to determine the direction and existence of causality between two or more variables in panel data. It extends the traditional Granger causality test, which is typically used in time-series analysis, to accommodate data from multiple entities over time, such as the BRICS countries in this study.

In essence, the Panel Granger Causality Test assesses whether past values of one variable help predict future values of another variable, indicating a causal relationship. The null hypothesis typically states that "X does not Granger-cause Y," meaning past values of X do not provide significant information for predicting Y.

For panel data, this test is adapted to account for the heterogeneity across individual entities (countries, in this case). It uses a combination of cross-sectional and time-series dimensions, which allows for a more robust examination of causal relationships across different entities. The test typically includes lags of variables, so that one can determine if, for example, green finance (GF) influences renewable energy growth (RE) or vice versa.

Findings and Discussion

The findings of this study are explained in this section. . It begins with Table 2 comprises of several insights as follows:

Table 2: Descriptive Statistics

Variable	Mean	Median	Maximum	Minimum	Jarque-Bera	Probability
Y	4.372593	4.5	14.2	-7.8	5.60288	0.060723
RE	268.1034	173.3945	1321.709	0.624	170.4882	0
OP	102.2588	96.1	205.3	9.4	5.070571	0.079239
GF	8.485704	8	18.1	0.27	8.044169	0.017916
RL	-0.28777	-0.2235	0.34808	-1.19659	9.068912	0.010733
C02	160.7215	79.6	731.9	21.6	104.91	0

The table shows that RE 268.1 shows significant adoption expressed through mean, but the wide range reflects uneven progress among BRICS nations. A high mean of CO2 indicates substantial pollution, underscoring the urgent need for clean energy transitions. The Green Finance Index averages at 8.49, indicating a moderate level of green finance development across BRICS countries. The index likely reflects the extent to which financial markets are supporting sustainable or green energy initiatives. The wide range indicates substantial disparities in green finance activities within the BRICS countries. For example, China might have a higher score due to its well-developed green bond market, while countries like Russia or South Africa may lag behind due to less developed green finance structures. Significant p-values of the JB test for RL and GF suggest non-normal distributions, indicating potential outliers or heterogeneity. The high variability in renewable energy and emissions reflects the diverse energy profiles and environmental challenges of the BRICS countries, which should be addressed through tailored green finance policies.

Table 3: Cross-Section Dependence Test

Variable	CD-test	p-value
Y	5.55	0.00
RE	8.17	0.00
OP	16.26	0.00
GF	6.72	0.00
RL	-0.72	0.473
C02	9.55	0.00

Note: Under the null hypothesis of cross-section independence CD ~ N(0,1)

The CD-test results show significant cross-sectional dependence for most variables ($p < 0.05$), except RL ($p = 0.473$). This implies that variables like GDP, renewable energy growth, and emissions are interlinked across the BRICS nations. Economic and environmental developments in one country may influence others due to shared policies, markets, or geographic proximity. Strong cross-sectional dependence highlights the need for coordinated policy frameworks among BRICS countries to ensure the success of green finance initiatives.

Table 4: Slope homogeneity test

	Statistics	P-values
Delta	13.153	0.000
Adj. Delta	14.914	0.000

Note: H0: slope coefficients are homogenous. Source: Author's estimation

The rejection of the null hypothesis confirms slope heterogeneity, indicating that the impact of green finance on renewable energy varies across BRICS nations. For instance, China, with its large-scale green finance initiatives, may exhibit stronger effects compared to South Africa, where financing systems are less developed. Slope heterogeneity shows the importance of country-specific strategies for implementing green finance to maximize its impact on renewable energy growth.

Table 5: Panel Unit Root Tests

Variables	CADF		CIPS	
	I(0)	I(1)	I(0)	I(1)
Y	0.012	0.00	-3.998	-6.190
RE	0.423	0.00	-2.655	-5.638
OP	0.784	0.457	-0.924	-2.063
GF	0.775	0.116	-1.087	-2.633
RL	0.808	0.012	-1.182	-3.935
C02	0.954	0.014	-2.924	-6.484

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

The results show non-stationarity for most variables but stationarity after first differencing. This indicates that the variables exhibit trends over time and require differencing to avoid spurious regressions.

Table 6: Westerlund cointegration test

Statistics		Values	P-values
Gt	-3.582	-1.769	0.038
Ga	-9.471	2.042	0.979
Pt	-9.455	-3.582	0
Pa	-11.083	0.729	0.767

Source: Author's estimation

Significant results for the Gt and Pt statistics suggest a long-term relationship between green finance and renewable energy growth. The lack of significance in Ga and Pa indicates potential variability in cointegration strength across countries. Cointegration confirms that green finance and renewable energy are intrinsically linked in the long run. Policymakers must view green finance not just as a short-term measure but as a sustainable mechanism for driving renewable energy transitions.

Table 7: Panel Causality Test

Null hypothesis	Z-bar statistics	P-values
GF ⇏ Y	1.2474	0.2122
Y ⇏ GF	4.7344	0.000
GF ⇏ RE	4.8303	0.000
RE ⇏ GF	5.8217	0.000
GF ⇏ OP	4.0482	0.0001
OP ⇏ GF	20.6488	0.000
GF ⇏ RL	-0.0362	0.9711
RL ⇏ GF	0.8847	0.3763

Source: Author's estimation

We found bidirectional causality between green finance and renewable energy.: Green finance initiatives directly promote renewable energy adoption, while the growth in renewable energy reinforces the need for further green finance investments. The table also shows that Economic growth supports green finance, but the reverse relationship is insignificant, suggesting limited direct contributions of green finance to GDP growth in the short term. Strong causality reflects the sensitivity of green finance to fluctuations in traditional energy markets. No significant causality between RL and GF. Governance quality, while important, does not directly drive green finance, indicating that green finance initiatives may operate independently of institutional quality. The bidirectional causality between green finance and renewable energy highlights a virtuous cycle where investments in sustainability create demand for further green financial products. The sensitivity to oil prices underscores the importance of insulating green finance mechanisms from traditional energy market volatilities.

The overall results show the critical role of green finance in driving renewable energy development in BRICS nations. However, the findings also reveal significant challenges and opportunities that require tailored strategies.

The variability in renewable energy growth and the green finance-renewable energy relationship highlights the need for region-specific approaches. For instance:

- China: With its advanced green finance ecosystem, China can focus on scaling innovative financing tools and exporting these models to other BRICS countries.
- India: As a rapidly growing economy with high energy demands, India should prioritize expanding its renewable energy capacity through blended finance models.
- Brazil: Leveraging its abundant natural resources, Brazil can focus on diversifying its renewable energy mix beyond hydropower.
- Russia and South Africa: These countries need foundational reforms in governance and financial systems to attract green investments and overcome infrastructural and policy barriers.

The confirmed cointegration between green finance and renewable energy emphasizes the need for sustained policy support. BRICS nations must establish stable regulatory frameworks, such as tax incentives, green bond standards, and renewable energy mandates, to attract long-term investments. The feedback loop between green finance and renewable energy development presents an opportunity to align environmental and economic goals. Policies should focus on integrating green finance with broader economic development plans, such as job creation in renewable energy sectors and support for clean technology innovation. The sensitivity of green finance to oil prices underscores the need for diversification. BRICS nations should develop resilient green finance mechanisms that are less dependent on traditional energy market dynamics. Examples include expanding carbon markets, establishing sovereign green bonds, and promoting international climate finance. While governance does not directly influence green finance, improving institutional quality can enhance its effectiveness. BRICS countries should strengthen legal and regulatory frameworks, improve transparency, and build capacity for implementing green finance initiatives.

Conclusion and Recommendations

In light of the findings, the study recommends that BRICS nations should create a platform for sharing best practices, technologies, and financing models to accelerate renewable energy transitions collectively. Promoting Innovation and R&D: Investments in research and development for clean energy technologies should be prioritized to improve cost-efficiency and scalability. Expand the use of green bonds, climate funds, and carbon markets, ensuring that these instruments are accessible and affordable. Build robust governance structures and regulatory frameworks to enhance transparency, accountability, and efficiency in implementing green finance. Implement policies to gradually phase out fossil fuel subsidies and redirect these funds to renewable energy projects. Establish clear metrics and benchmarks for tracking the impact of green finance on renewable energy development and environmental outcomes.

The study's findings provide compelling evidence of green finance's critical role in advancing renewable energy development in BRICS nations. However, the significant variability in results across countries calls for tailored, region-specific strategies. Policymakers must focus on sustaining long-term investments, addressing regional disparities, and mitigating energy market risks while leveraging the positive feedback loop between green finance and renewable energy growth. By addressing these challenges and opportunities, BRICS nations can position themselves as global leaders in sustainable energy transitions, contributing to global environmental goals and fostering inclusive economic growth.

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