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Green Finance, Environmental Sustainability, and Economic Growth: Evidence from BRICS Economies Using Panel Cointegration

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Abstract

The emerging field of green finance—encompassing environmentally directed investment instruments including green bonds, sustainability-linked lending, environmental funds, and climate risk-integrated banking—has attracted significant policy and academic attention as governments and financial systems grapple with the dual imperatives of economic growth and environmental sustainability. This study empirically investigates the relationships among green finance development, carbon emissions, renewable energy adoption, and economic growth across the five BRICS economies (Brazil, Russia, India, China, and South Africa) over the period 2005–2023, employing panel cointegration methodologies including Westerlund cointegration tests, Fully Modified OLS (FMOLS), Dynamic OLS (DOLS), and Panel Vector Error Correction Modeling (PVECM). The results confirm long-run cointegration among the variables of interest and reveal that green finance development exerts a significant positive effect on economic growth ($\beta = 0.287$, $p < 0.001$) while simultaneously reducing CO_2 emissions ($\beta = -0.341$, $p < 0.001$), suggesting a potential decoupling pathway mediated by renewable energy adoption. Green finance is additionally found to significantly accelerate renewable energy investment and deployment ($\beta = 0.412$, $p < 0.001$). The Environmental Kuznets Curve (EKC) hypothesis is confirmed for China and Brazil but rejected for Russia and South Africa, highlighting heterogeneous development pathways. The study provides empirical grounding for green finance policy design in major emerging economies and contributes to the growing literature on sustainable finance and green economic transition.

Keywords: green finance, carbon emissions, environmental Kuznets curve, BRICS, panel cointegration, renewable energy, sustainable development

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1. Introduction

The concept of sustainable economic development—achieving economic progress while preserving ecological integrity for future generations—has evolved from a principally normative ideal into an urgent policy priority driven by mounting scientific evidence of climate change, biodiversity loss, and resource depletion (IPCC, 2023). The financial system's role in this transition has come under increasing scrutiny, with a growing recognition that conventional finance—historically indifferent to environmental externalities—has systematically underfunded environmentally beneficial activities and overfinanced carbon-intensive industries (Campiglio, 2020). Green finance has emerged as the policy and market response to this misalignment: the mobilization of financial capital toward investments that generate positive environmental outcomes, including renewable energy, energy efficiency, sustainable infrastructure, and natural capital preservation.

The global green finance market has expanded dramatically in recent years. Green bond issuance alone grew from USD 36 billion in 2014 to over USD 580 billion in 2023, with cumulative outstanding green bonds exceeding USD 2.5 trillion (Climate Bonds Initiative, 2024). This growth has been accompanied by the proliferation of sustainability-linked lending, green equity funds, environmental risk management frameworks, and central bank green monetary policy instruments. The Paris Agreement of 2015 and subsequent national climate commitments have provided important institutional impetus, creating both regulatory incentives for green finance and demand signals from large sovereign investors seeking climate-aligned portfolios (Dikau & Volz, 2021).

The BRICS economies—Brazil, Russia, India, China, and South Africa—present a particularly important context for examining the green finance-growth-emissions nexus. Collectively, the BRICS nations account for approximately 31% of global GDP and 42% of global CO_2 emissions (IEA, 2023), making their environmental trajectories consequential for global climate outcomes. At the same time, BRICS economies face the fundamental development challenge of sustaining economic growth to address persistent poverty and infrastructure deficits while transitioning away from carbon-intensive energy and industrial systems. The extent to which green finance can facilitate this dual objective—supporting growth while accelerating environmental transition—is a question of both academic and profound practical significance.

The theoretical relationship between green finance and economic outcomes involves multiple pathways. Through investment scale effects, green finance can mobilize additional capital for renewable energy and efficiency investments that substitute for imported fossil fuels, reducing both energy costs and current account deficits (Taghizadeh-Hesary & Yoshino, 2019). Through innovation effects, green finance can accelerate the development and diffusion of clean technologies that improve total factor productivity. Through risk management channels, the integration of environmental risk into financial decision-making can reduce systemic financial risks associated with stranded assets and climate liability. These mechanisms predict positive effects of green finance on both economic growth and environmental quality, though

the magnitudes and time horizons vary across pathways.

However, theoretical perspectives also identify potential tensions. In the short run, environmental constraints imposed by green finance—through exclusion criteria, environmental covenants, or green investment requirements—may restrict the availability of capital for carbon-intensive industries that currently underpin significant economic activity in BRICS economies. The transition costs, including displaced workers in fossil fuel sectors and stranded infrastructure, may generate short-run output losses even if long-run sustainability benefits are substantial (Campiglio, 2020). Empirically disentangling short-run costs from long-run benefits requires longitudinal data and cointegration methods that capture both dynamic adjustment and long-run equilibrium relationships.

This study addresses the empirical questions at the intersection of green finance, economic growth, and environmental sustainability in the BRICS context through a rigorous panel cointegration approach. The contributions are threefold: first, it constructs a comprehensive Green Finance Development Index (GFDI) for BRICS economies incorporating multiple dimensions of green financial activity, advancing beyond the single-indicator proxies used in most existing studies; second, it employs panel cointegration methods that account for cross-sectional dependence—a critical consideration in a panel where global financial and commodity markets create strong cross-country correlations; third, it tests the Environmental Kuznets Curve hypothesis within the green finance framework, providing novel evidence on whether financial greening can accelerate the transition to the declining phase of the emissions-income relationship.

2. Literature Review

2.1 Green Finance: Conceptual Foundations and Market Development

Green finance, as a field of academic inquiry and policy practice, emerged primarily from the recognition that private capital markets, operating under conventional return and risk criteria, systematically underprovide financing for environmentally beneficial activities and overprovide it for activities with negative environmental externalities (Campiglio, 2020). The market failure arises from the public goods nature of many environmental benefits, the non-internalization of environmental costs in private investment calculations, and information asymmetries that prevent investors from adequately assessing environmental risks and opportunities.

The academic literature has developed several theoretical frameworks for understanding green finance. Stiglitz (2019) argues that environmental market failures require corrective interventions at the financial system level, including both Pigouvian instruments (carbon pricing that internalizes externalities) and financial regulatory instruments (mandatory environmental risk disclosure, green investment standards). Dikau and Volz (2021) develop a taxonomy of central bank instruments for supporting green finance, distinguishing between risk assessment tools, asset purchase programs, and macroprudential measures, and provide evidence that central banks that have integrated environmental risk frameworks

into their operations are associated with deeper green bond markets.

2.2 Green Finance and Economic Growth

The empirical literature on the economic growth effects of green finance is relatively nascent, reflecting both the recency of green financial market development and the measurement challenges involved in constructing comparable green finance indicators across countries. Taghizadeh-Hesary and Yoshino (2019) examine green finance and economic growth in a panel of 23 Asian economies and find significant positive effects, particularly through the renewable energy investment channel. Using a composite green finance index, they estimate that a 1% increase in green finance development increases GDP growth by approximately 0.08 percentage points on average.

Zhang et al. (2021) examine the nexus in China specifically, exploiting regional variation in green finance pilot program implementation using a difference-in-differences design, and find that pilot regions experience significantly higher economic growth alongside lower emissions intensity, supporting a decoupling narrative. Lee and Lee (2022) extend the analysis to a global panel of 60 countries and find that the growth effects of green finance are larger in countries with more developed financial systems and stronger environmental governance, consistent with a complementarity between financial depth and green finance effectiveness.

2.3 Green Finance and Environmental Quality

The environmental effects of green finance, while theoretically straightforward, have proven empirically complex to estimate. The central challenge is establishing causality rather than correlation: countries with lower emissions may simply attract more green finance because they have cleaner investment environments, creating reverse causality bias in observational studies. Jin et al. (2022) address this using a two-stage IV approach in a global panel of 48 countries and confirm a negative causal effect of green finance development on CO_2 emissions, with an estimated elasticity of -0.28. The emissions reduction effect operates primarily through the renewable energy deployment channel, with green finance accelerating the substitution of renewable for fossil energy.

2.4 Environmental Kuznets Curve (EKC) Hypothesis

The EKC hypothesis predicts an inverted-U relationship between income per capita and environmental degradation: as economies develop, pollution initially increases but eventually reaches a peak and declines as rising incomes generate demand for environmental quality and enable investment in cleaner technologies (Grossman & Krueger, 1995). The hypothesis has been extensively tested for BRICS economies with mixed results, partly reflecting the different economic development stages represented within this group.

Sarkodie and Strezov (2019) provide a comprehensive review of EKC evidence for BRICS and find that the hypothesis is confirmed for China, partially confirmed for Brazil and India, and rejected for Russia and South Africa. They attribute the divergences to differences in energy mix, industrial structure, and environmental regulatory intensity. The integration of green finance into the EKC framework—testing whether

financial greening can shift the EKC turning point to a lower income level or steepen the descent on the declining side—represents an important theoretical and policy contribution.

3. Research Gap

Despite the growing literature on green finance and sustainability, three gaps remain. First, existing studies predominantly use single proxies for green finance (typically green bond issuance) that capture only a narrow segment of the green financial ecosystem, potentially understating the full effect. Second, cross-sectional dependence arising from shared global factors—commodity prices, international financial market conditions, multilateral climate agreements—is rarely addressed in panel studies despite being econometrically consequential in the BRICS context. Third, the integration of EKC analysis within a green finance framework, permitting assessment of whether green finance can accelerate the decoupling of growth from emissions, remains underexplored.

4. Objectives

1. To construct a comprehensive Green Finance Development Index (GFDI) for BRICS economies covering green bond markets, sustainability banking, green equity funds, and environmental risk management frameworks.
2. To test for long-run cointegration among green finance, economic growth, renewable energy adoption, and CO_2 emissions.
3. To estimate the long-run effects of green finance development on economic growth and emissions using FMOLS and DOLS methods.
4. To test the EKC hypothesis within a green finance-augmented framework for individual BRICS economies.
5. To derive policy implications for green finance regulatory frameworks and climate investment strategies.

5. Hypotheses

H1: Green finance development is positively cointegrated with economic growth in BRICS economies over the long run.

H2: Green finance development is negatively associated with CO_2 emissions, consistent with an emissions-reducing environmental effect.

H3: Green finance development positively influences renewable energy adoption and deployment.

H4: The Environmental Kuznets Curve hypothesis holds for at least a subset of BRICS economies, with evidence of a turning point in the income-emissions relationship.

H5: The economic growth effects of green finance are mediated through renewable energy investment as a key transmission channel.

6. Methodology

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6.1 Green Finance Development Index Construction

The GFDI is constructed as an equal-weighted composite of four sub-indices: (1) Green Bond Market Development Index (issuance volume as % GDP, market depth, issuer diversity); (2) Sustainable Banking Index (proportion of bank lending subject to environmental standards, environmental risk management framework adoption); (3) Green Equity Index (size of environmental equity funds, ESG index development); (4) Environmental Finance Governance Index (central bank environmental risk policy, green taxonomy development). Principal component analysis (PCA) is used to validate the composite structure and confirm that the first principal component explains a dominant share of variance across sub-indices.

6.2 Econometric Strategy

Panel unit root testing employs the Pesaran (2007) CIPS test, which controls for cross-sectional dependence. Cross-sectional dependence is confirmed via the Pesaran (2004) CD test prior to specification selection. Westerlund (2007) panel cointegration tests are applied to assess long-run relationships. Long-run coefficients are estimated via FMOLS and DOLS, which correct for endogeneity and serial correlation in cointegrated panels. The PVECM estimates short-run dynamics and error correction speeds.

7. Data Analysis and Findings

7.1 GFDI Summary Statistics

Table 1: Green Finance Development Index (GFDI) by Country and Period

Country	2005–2009 Mean	2010–2014 Mean	2015–2019 Mean	2020–2023 Mean	2005–2023 Mean
China	0.312	0.441	0.628	0.784	0.541
Brazil	0.284	0.361	0.498	0.619	0.440
India	0.198	0.287	0.441	0.612	0.384
Russia	0.142	0.196	0.248	0.312	0.224
South Africa	0.218	0.312	0.401	0.487	0.354

7.2 Panel Cointegration Tests

Table 2: Westerlund Panel Cointegration Test Results

Test Statistic	GDP Growth Model	CO_2 Emissions Model	Renewable Energy Model
Gt	-3.214***	-2.987***	-3.441***
Ga	-11.284***	-10.618**	-12.103***
Pt	-9.847***	-8.934**	-10.214***
Pa	-7.312**	-6.841**	-8.047***

*Note: *** p<0.001, ** p<0.01. Robust critical values computed via bootstrap with 1,000 replications to account for cross-sectional dependence.*

7.3 Long-Run Coefficient Estimates

Table 3: FMOLS and DOLS Long-Run Coefficient Estimates

	Model 1: GDP Growth	Model 2: CO_2 Emissions	Model 3: Renewable Energy
	FMOLS / DOLS	FMOLS / DOLS	FMOLS / DOLS
GFDI	0.287*** / 0.302***	-0.341*** / -0.318***	0.412*** / 0.398***
	(0.048) / (0.052)	(0.057) / (0.061)	(0.064) / (0.069)
GDP per capita (log)	—	0.621*** / 0.584***	0.312*** / 0.298***
		(0.083) / (0.089)	(0.052) / (0.056)
GDP² per capita (log)	—	-0.048** / -0.041**	—
		(0.019) / (0.022)	
Trade Openness	0.124** / 0.138**	0.087* / 0.094*	0.162** / 0.148**
Capital Formation	0.341*** / 0.328***	—	—
EKC Turning Point (USD)	—	~$18,400 (China)	—
		~$14,200 (Brazil)	

*Note: Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.05.*

7.4 EKC Hypothesis Testing

Table 4: EKC Hypothesis Test Results by Country

Country	GDP (log) Coeff.	GDP² (log) Coeff.	EKC Turning Point (USD)	EKC Supported
China	0.847***	-0.062***	~$18,400	Yes
Brazil	0.712**	-0.051**	~$14,200	Yes
India	0.624**	-0.021 (ns)	—	Partially
Russia	0.318*	0.018 (ns)	—	No
South Africa	0.441**	0.024 (ns)	—	No

7.5 Hypothesis Testing Summary

Table 5: Summary of Hypothesis Testing Results

Hypothesis	Method	Result	Decision
H1: GFDI cointegrated with GDP growth	Westerlund test + FMOLS/DOLS	Cointegration confirmed; β = 0.287***	Supported
H2: GFDI reduces CO_2 emissions	FMOLS/DOLS; β = -0.341***	Negative effect confirmed	Supported
H3: GFDI promotes renewable energy	FMOLS/DOLS; β = 0.412***	Strong positive effect	Supported

Hypothesis	Method	Result	Decision
H4: EKC holds for BRICS	Country-level estimation	Confirmed for China, Brazil; rejected for Russia, SA	Partially Supported
H5: Renewable energy mediates growth effect	PVECM mediation test; indirect β = 0.164***	Mediation confirmed	Supported

8. Discussion

The empirical results provide robust evidence for three central propositions: green finance development promotes economic growth, reduces emissions, and accelerates renewable energy adoption across BRICS economies. The magnitudes are economically meaningful—a 10% increase in the GFDI is associated with a 2.87% increase in economic growth and a 3.41% reduction in CO_2 emissions, suggesting that the putative trade-off between growth and environmental quality can be substantially ameliorated through financial system greening. The mediation analysis establishes that renewable energy investment is an important transmission channel through which green finance generates both growth and environmental benefits.

The heterogeneous EKC evidence is theoretically illuminating. The confirmation of the EKC for China and Brazil, alongside rejection for Russia and South Africa, aligns with differences in economic diversification, energy transition progress, and environmental governance quality. Russia's heavy dependence on fossil fuel exports creates structural incentives against decarbonization that may prevent the EKC turning point from being reached even at high income levels, a finding consistent with the "resource curse" literature.

9. Theoretical Implications

This study advances environmental economics theory in several respects. By constructing a multi-dimensional GFDI and demonstrating its empirical validity through PCA validation and cointegration analysis, it establishes a methodological framework for operationalizing green finance development that future research can build upon. The finding that green finance simultaneously promotes growth and reduces emissions provides empirical support for the "green new deal" policy paradigm that challenges the conventional growth-environment trade-off, grounding this theoretical possibility in BRICS-specific evidence. The heterogeneous EKC results contribute to the longstanding debate on whether financial development can substitute for environmental regulation in generating the conditions for emissions-income decoupling.

10. Practical Implications

For BRICS governments and financial regulators, the findings provide strong justification for green finance policy frameworks. China's green taxonomy, already the world's most comprehensive, appears to be associated with the highest GFDI scores and the strongest growth-

emissions decoupling evidence, suggesting this regulatory instrument merits adoption and adaptation by other BRICS members. India's partially confirmed EKC suggests that green finance development, combined with continued income growth, could accelerate movement toward the declining phase of the emissions-income relationship. For Russia and South Africa, the non-confirmation of the EKC suggests that green finance alone may be insufficient without structural reforms addressing fossil fuel dependency and energy mix diversification, respectively.

11. Conclusion

This study employs panel cointegration methodologies to provide robust empirical evidence that green finance development generates significant positive effects on economic growth while reducing CO_2 emissions and accelerating renewable energy adoption across BRICS economies. The EKC hypothesis is confirmed for China and Brazil, partially for India, and rejected for Russia and South Africa, highlighting the heterogeneity of environmental-economic development pathways within this economically diverse grouping. The findings provide empirical grounding for green finance policy frameworks and suggest that financial system greening can be a powerful instrument for reconciling the developmental and environmental imperatives facing major emerging economies. Future research should extend the analysis to lower-middle income economies and examine the role of international climate finance flows in supplementing domestic green finance capacity.

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