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The Impact of Green Finance, Energy and Sustainable Development Policies in BRICS Indonesia: A Robust Panel Data Econometric Modeling

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ABSTRACT

Environmental change is reshaping the global economy. This study examines the relationship between green finance, sustainable development, and eco-friendly policies in BRICS countries and Indonesia from 1990 to 2023. We use panel data methods, including Driscoll-Kraay standard errors, FMOLS, DOLS, and Method of Moments Quantile Regression (MMQR), to assess the impacts of clean energy financing, environmental taxes, and renewable energy use on the Green finance index (GFI). Clean energy financing consistently drives green financial development across all models. Environmental taxation has mixed effects: It limits growth in less developed green markets (lower GFI quantiles), but its impact is less pronounced in more advanced markets. This study uniquely reveals non-linear, quantile-specific patterns, showing that the connection between finance, policy, and sustainability depends on a country's stage of green market development. These results suggest that strategies should be tailored to individual needs. Focus on direct investment, and adjust fiscal tools based on market readiness to support a sustainable financial transition.

Keywords: Green Finance, Sustainable Development, BRICS-Indonesia, Panel Data, Quantile Regression, Environmental Taxation
JEL Classification: G18, Q44,Q55

1. INTRODUCTION

The world economy stands at a crossroads (Khan et al., 2022), as climate change and the ongoing deterioration of natural resources in our ecosystems (Amin et al., 2025) continue to escalate. The concept of sustainable development has emerged as one of the primary principles guiding international policy in addressing climate change and the degradation of natural resources (Dong et al., 2023). Sustainable development goals are to promote balanced economic growth with environmental protection and social justice (Chen et al., 2024). In this context, the shift to a low-carbon, resource-efficient economy implies unprecedented rates of investment, which triggers the development of green finance as a catalytic determinant tool (Amin et al., 2025). Green finance (GF) refers to financial investments in sustainable development projects and initiatives. GF is a collection of instruments such as green bonds, sustainability-linked loans, and environmental, social, and governance (ESG) investing that is aimed at contributing to the mitigation of climate change, the control of pollution, and the preservation of biodiversity (Arzova and Şahin, 2024).

The BRICS countries (Brazil, Russia, India, China, and South Africa) provide a convincing context to investigate the dynamics of green finance (Xing et al., 2024). Indonesia's inclusion in the BRICS bloc is highly significant and strategic, as it offers a critical comparative perspective. As the largest economy in Southeast Asia, Indonesia faces similar urgent challenges as a major emerging market, being both resource-rich and highly vulnerable to the effects of climate change, thus confronting the same developmental issues as its BRICS counterparts. These countries collectively account for over 40% of the global population and nearly a quarter of the world's GDP (Ping and Shah, 2023), and are responsible for a significant proportion of global greenhouse gas emissions (Kanwal et al., 2023). Their rapid industrialization and economic growth have often come at a substantial environmental cost, yet their immense scale and strategic influence also position them as indispensable actors in the global pursuit of sustainability (Sahoo et al., 2024). The developmental trajectories of the BRICS economies are thus characterized by a complex and urgent tension: the imperative to sustain economic growth and alleviate poverty, set against the pressing need to decouple this growth from environmental depletion (Zhou et al., 2020). Navigating this tension requires a fundamental reorientation of their financial systems towards sustainable ends, making the efficacy of green finance within these contexts a subject of paramount importance.

Although the prospect of green finance is often recognized as a theoretical one, its practical effect, especially in the specific and diversified economy of the BRICS and Indonesia is an open and debatable field of academic investigation. Available resources indicate that green finance can contribute to a sustainable development through reallocation of capital to projects in the renewable energy industry (Chen et al., 2024), energy efficiency renovations, and circular economy structures, which creates a green innovation and new markets (Nawaz et al., 2021). The benefits are however not automatic to be realized. According to the scholars, green finance can only succeed when the regulatory environment is strong and conducive (Liang and Nasruddin, 2024). The eco-friendly policies carbon pricing mechanisms, renewable energy subsidies and strict environment are theorized to establish the required market signals and de-risk sustainable investments to increase the power of financial mechanisms (Udeagha and Muchapondwa, 2023). In the absence of these policies, the initiatives on green finance may remain isolated, weak, or unable to transform the entire system (Zhang et al., 2021).

With the increase in the body of research, there are still significant gaps in knowledge. To begin with, the majority of investigations use methodological solutions that do not consider panel data characteristics like cross-sectional dependence and heteroscedasticity, which can result in inefficient and biased estimations (Tsaurai, 2020). Second, available empirical data regarding the nexus of green finance, favorable policies and actual sustainable development outcomes in the BRICS plus are frequently disjointed with very limited literature providing a multivariate econometric evaluation of the interaction between financial, fiscal and regulatory factors. The unique and changing statuses of the variables, e.g., sustainable development spending, taxes that are collected through the eco-sectors, or financing of clean energy, in a single analytical framework and their interactions are to be explored further (Nguyen and Khominich, 2023).

In light of these gaps, this study examines the impact of green finance on sustainable development in the BRICS and Indonesia from 1990 to 2023. We use a comprehensive panel data model that integrates the green finance index (GFI) with determinants such as CEG (clean energy generation), green development efficiency (GDE), taxation revenue from eco-sectors (TRE), Eco-policy effectiveness (EPE), clean energy financing (CEF), and the environmental performance index (EPI). Methodologically, this research stands out by using Driscoll-Kraay standard errors. This robust technique yields consistent estimates even in the presence of cross-sectional dependence, heteroscedasticity, and autocorrelation. To test the robustness of our findings, we also apply fully modified OLS (FMOLS), dynamic OLS (DOLS), and method of moments quantile regression (MMQR).

The contribution of this paper is threefold. First, it offers a new and comprehensive examination of the relationship between green finance and sustainable development, with a focus on an important yet underexplored context. Second, it employs solid methods by applying advanced panel data tools that address common statistical issues identified in earlier work. Third, the findings offer practical, fact-based guidance for policymakers in BRICS countries and beyond, demonstrating how financial innovation and effective regulation can support the achievement of the sustainable development goals (SDGs). By explaining how green finance and eco-friendly policies help sustainable progress, this study aims to guide smart choices and support a stronger, fairer global future.

2. LITERATURE REVIEW

2.1. The Conceptual and Operational Evolution of Green Finance

There has been a significant shift in the concept of green finance, transitioning from a marginal issue to a central axis of the global financial system (Udeagha and Muchapondwa, 2023). It is officially considered financial intermediation, which explicitly takes into account environmental criteria and emphasizes investments that produce both positive ecological yield and economic profit (Kwilinski et al., 2023). It represents a conceptual shift that is the next step in moving beyond traditional finance and aims to correct a systematic market failure: the under-pricing of environmental risks and the failure to internalize negative externalities, such as pollution and biodiversity loss (Ali et al., 2023). The conceptual basis of the paradigm is the concept of sustainable development, which aims to align the distribution of capital with the planet's sustainable interests, as outlined in international treaties such as the Paris Accord (Ping and Shah, 2023).

This evolution has been operationally characterized by a high rate of development and diversification of specific financial instruments and mechanisms (Chakravarty and Mandal, 2016). It has already evolved into a complex set of instruments in the market, including green bonds, sustainability-linked loans, green credit, and environmental, social, and governance (ESG) integrated investment funds (Yuan et al., 2024). The tools have a tailored direction of capital investment into sustainable projects in the areas of renewable energy, energy efficiency, circular economy models, and pollution control (Liang and Yang, 2024). Green finance success is, however, increasingly realized to lie in areas beyond the amount of capital deployed. According to Ali et al. (2023), scholars view it as a governance mechanism, stating that the key aspect of its success is its ability to influence corporate behaviour and encourage green innovation by establishing strict disclosure standards, special financing conditions, and systematically incorporating climate-related risks into financial decisions.

2.2. Theoretical Nexus between Green Finance and Sustainable Development

The theoretical basis of the role of green finance in promoting sustainable development lies in several economic frameworks (Hussain et al., 2024). Firstly, it highlights a severe market failure, namely a negative environmental externality that is not reflected in conventional financial decision-making (Nile et al., 2024). Green finance enables a more optimal allocation of capital by internalizing these externalities, leading to changes in capital allocation and shifting investments toward more sustainable options, rather than brown industries, which aligns with the principles of ecological economics (Oanh, 2024). Moreover, the concept of the so-called green Solow model suggests that long-term economic growth can be achieved in conjunction with the long-term sustainability of investment in clean technology and environmental protection, which is not contingent upon resource exhaustion (Annu and Tripathi, 2024). This aligns with the triple bottom line (TBL) approach, which emphasizes that performance should be evaluated in terms of social, environmental, and financial aspects the balance that green finance is explicitly aimed at achieving (Ali et al., 2025).

2.3. Empirical Evidence from the BRICS and the Indonesian Context

Based on empirical studies on green finance in emerging economies, a complex and context-specific picture emerges (Lee et al., 2025; Mahmood et al., 2024). Within the BRICS bloc, there have been mixed results regarding economic systems and policy settings. The development of green finance in China has been positively correlated with a decrease in carbon emissions intensity, as established by various studies. The research conducted by Liu et al. (2023) revealed that green credit policies have a significant impact on reducing industrial pollution, limiting the financing of companies associated with high emissions levels, and stimulating the development of green technologies.

Likewise, studies in India have also identified green finance as a crucial tool for increasing the use of solar energy, linking it to both reduced emissions and enhanced energy security (Armia, 2025). The evidence, however, is not uniformly positive. According to some of the analyses, green finance may be neutralized without complementary factors. Notably, in Russia and South Africa, where fossil fuel dependencies are deeply rooted, the effectiveness of green financial instruments has been shown to be less efficient without parallel structural changes and increased regulatory pressure (Setiawan, 2025).

A critical comparative view is offered by the case of Indonesia, an important emerging economy that is not part of the BRICS but faces similar developmental issues (Al Putra et al., 2025). Indonesia serves as an example for other countries, being both rich in natural resources and vulnerable to the effects of climate change. According to Maulana and Azis (2025), the issuance of sovereign green sukuk (Islamic bonds) has been an innovative move, which has achieved success in financing renewable energy and climate resilience projects. Nonetheless, research also indicates that the major challenges include a financial sector that remains highly vulnerable to the energy sector, which operates coal-fueled, as well as deforestation-prone sectors (Haryono et al., 2024). Green finance in Indonesia heavily relies on the implementation of its forestry moratorium and its overall energy transition policy, implying that, like other BRICS countries, finance is insufficient without transformative sectoral policies (Al Putra et al., 2025). The potential of green finance is considerable; however, its impact is constrained by existing economic structures and the effectiveness of policy frameworks in emerging economies.

2.4. Green Policies and Regulatory Frameworks

There is a strong consensus in the literature that the success of green finance is closely tied to the quality and rigidity of the policy ecosystem surrounding it (Yadav et al., 2025). The policy instruments that are market-based, including carbon taxes and emissions trading schemes, provide a direct financial incentive for decarbonization, thereby increasing the appeal of green investments (Mady et al., 2024). Command-and-control regulations are also crucial, as they establish clear environmental standards and provide recommendations for green technologies (Udodiugwu et al., 2025). Here, the resonance with the Porter Hypothesis, which proposes that innovation and competitiveness can be stimulated with the help of well-designed environmental regulations, resonates (Haryono et al., 2024).

Financial measures, such as subsidies for renewable energy and environmental taxes on pollution, play a crucial role in de-risking green projects and enhancing their bankability. Another example is offered by the Indonesian situation, where the government policy of feed-in-tariff on both geothermal and solar power has been stated as one of the most influential factors in attracting the geothermal and solar power investment by the private sector, although issues related to the implementation are still common (Akramova et al., 2024). In addition, the design is not the only policy attribute that determines its effectiveness; implementation and stability of policies are also important factors. Furthermore, policy uncertainty is a significant impediment to long-term green investment in both BRICS and ASEAN settings (Maulana and Azis, 2025). Thus, the interaction between a supply-side measure, such as green finance, and a demand-side and regulatory one, such as eco-policy, is essential to a successful sustainability transition in all major emerging economies.

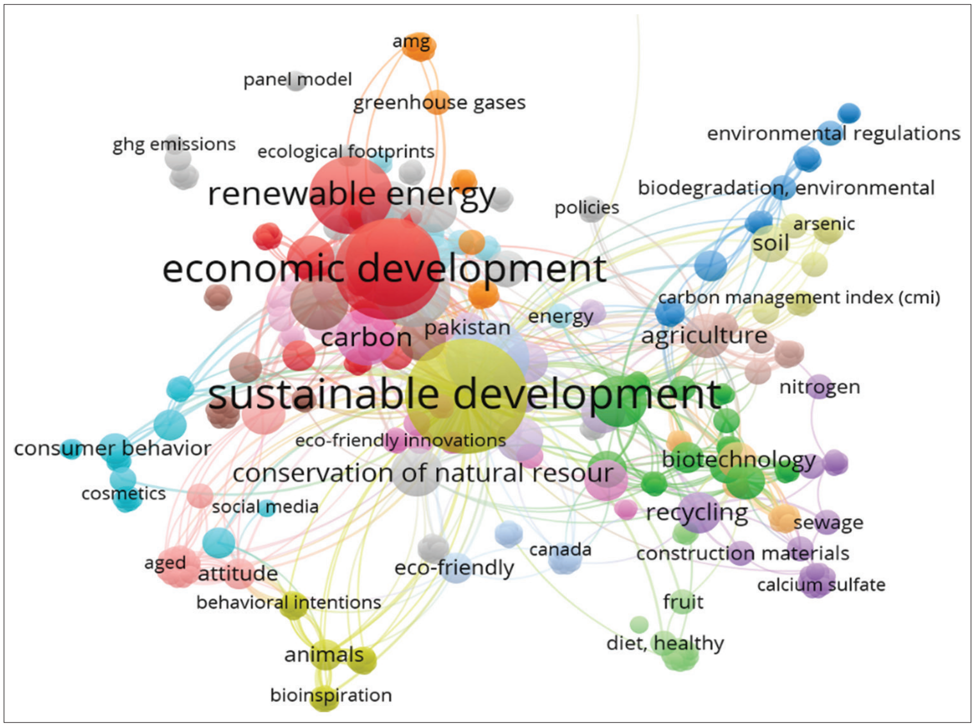
Lastly, Figure 1 illustrates the visualization network of the literature through biblimetric analysis, indicating that sustainable development, followed by economic development and renewable energy, forms the central cluster, exhibiting a strong relationship, while less co-occurring clusters are also shown in the Figure 1.

3. RESEARCH METHODOLOGY

3.1. Theoretical Framework and Econometric Strategy

The development of an effective econometric strategy is depending upon a clear theoretical framework. Thus, this research paper is based on the endogenous growth theory (Romer, 1994) and the theory of environmental Kuznets curves which suggest that specific financial processes may trigger the development of a sustainable economy by reallocating capital to green innovations and effectively utilizing resources. Theorizing green finance suggests that it serves not only as a funding mechanism but also as

Figure 1: Visualization network of the literature through bibliometric analysis



an indicator that alters the incentive-based structures of firms and policymakers, thereby accelerating the decoupling of economic growth from environmental degradation.

Therefore, we have tested the hypothesis in our empirical model that green finance, when complemented by complementary fiscal policies and effective regulation, has a significant impact on a set of sustainable development indicators. The methodology extends beyond traditional financial analysis to explore the synergistic nature of public expenditure, tax transfers, and investment in clean energy, aiming to mediate the relationship between finance and sustainability.

3.2. Econometric Model Specification

To empirically examine the proposed relationships, a multivariate linear panel data model is specified. The baseline model is presented as follow in Equation [1].

$$\ln(GFI)_{it} = \beta_0 + \beta_1 \ln(SDE)_{it} + \beta_2 \ln(GDE)_{it} + \beta_3 \ln(TRE)_{it} + \beta_4 \ln(EPE)_{it} + \beta_5 \ln(CEF)_{it} + \beta_6 \ln(EPI)_{it} + \varepsilon_{it}$$

Where

"i" denotes the country (i = 1,..., N = 6 (Brazil, Russia, India, China, South Africa, and Indonesia) are used.

"t" denotes the year (t = 1990,..., 2023)

ln denotes the natural logarithm

GFI (green finance index) is the dependent variable.

SDG (sustainable development expenditure), GDE (green development efficiency), TRE (taxation revenue from eco-sectors), EPE (eco-policy effectiveness), CEF (clean energy financing), and EPI (environmental performance index) are the independent variables.

A logarithmic transformation is applied to all variables to allow interpretation of the coefficients as resistances and to reduce potential heteroscedasticity in the error term εit (Wooldridge, 2010). This specification enables estimation of the percentage change in the Green Finance Index associated with a 1% change in each explanatory variable, while holding all other variables constant. The model is further refined to address the complex panel data structure using the econometric procedures described below.

3.3. Variable Construction and Data Sources

The empirical analysis relies on a balanced annual panel dataset for the BRICS and Indonesia (n = 6) from 1990 to 2023. Including Indonesia (I) extends the analytical scope to a major emerging economy with significant green policy ambitions. This enhances the cross-sectional heterogeneity of the sample. All data were sourced from internationally recognized databases to ensure consistency, comparability, and reproducibility.

The variables are constructed with careful attention to their theoretical definitions and standard measurement practices in the literature. To ensure methodological rigor and construct validity, this study uses carefully selected variables from internationally recognized sources. The dependent variable is the Green Finance Index (GFI). It is a composite measure based on green bond issuance, sustainable fund assets, and bank green credit as a percentage of total credit. Data come from the OECD Green Finance Indicators and the Global Sustainable Investment Alliance. The explanatory variables cover key dimensions of the sustainability transition. CEG (clean energy generation) is measured as the percentage of electricity generated from non-fossil fuel sources, including nuclear and renewables.

This data is sourced from the World Development Indicators. Green development efficiency (GDE) is defined as GDP per unit of energy use, representing economic energy efficiency. Taxation revenue from eco-sectors (TRE) is calculated as environmentally related tax revenue as a percentage of GDP using OECD Green Growth Indicators. Eco-Policy effectiveness (EPE) is operationalized as total renewable energy consumption in terajoules, as reported by the International Energy Agency, serving as a tangible measure of policy effectiveness. Clean energy financing (CEF) is represented by per-capita investment in renewables and energy efficiency in constant US dollars, as reported by the International Renewable Energy Agency. The environmental performance index (EPI) is a comprehensive score that captures performance across climate, health, and ecosystem vitality, as measured by Yale.

3.4. Econometric Analysis Procedure

The empirical procedure is meticulously designed to address the specific challenges of macro-panel data, including cross-sectional dependence, non-stationarity, and heterogeneity. First, we test for cross-sectional dependence (CSD) using the Pesaran (2021) CD test. The high degree of economic and financial integration among BRICS and Indonesia economies makes them susceptible to common global shocks, violating the assumption of cross-sectional independence. The presence of CSD renders first-generation panel unit root tests invalid. Therefore, we proceed with second-generation unit root tests that are robust to CSD. We employ the Cross-sectional Augmented Dickey-Fuller (CADF).

Upon establishing that the variables are integrated of order one, I(1), we test for a long-run cointegrating relationship using the Westerlund (2007) error-correction-based cointegration test. This test is preferred for its robustness to CSD and heterogeneity in the cointegrating vectors across panel units. For the estimation of long-run parameters, our primary estimator is the pooled ordinary least squares (POLS) method, with standard errors as proposed by Driscoll and Kraay (1998). This non-parametric technique produces heteroscedasticity - and autocorrelation-consistent standard errors that are also robust to general forms of cross-sectional dependence, making it highly suitable for our macro-panel context.

To strengthen our results and overcome potential endogeneity issues, we employ two additional estimators the fully modified OLS (FMOLS) and the dynamic OLS (DOLS). FMOLS controls serial correlation and endogeneity of the regressors, whereas DOLS includes leads and lags of the differenced regressors to control possible simultaneity bias (Kao and Chiang, 2001).

Lastly, to test for possible distributional heterogeneity and asymmetry in the relationships, we employ the method of Moments Quantile regression (MMQR) of Machado and Santos Silva (2019). This will enable us to test whether the effect of the explanatory variables on the Green Finance Index differs across various quantiles of its conditional distribution. The empirical analysis will conclude with the panel causality test, which examines the direction of causal relations between the variables. This test is particularly suitable for heterogeneous panels.

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistics

Table 1 presents the results of the descriptive analysis, indicating that the BRICS and Indonesia panel data comprise 163 observations. The Green finance index (GFI) shows a mean of 7.7931 and a median of 7.7925, indicating a balanced distribution. Clean Energy Generation (CEG) and Clean Energy Financing (CEF) exhibit moderate variability, with standard deviations of 0.4801 and 0.4578, respectively. This suggests relatively consistent effort across countries with some variation. In contrast, green development efficiency (GDE) and taxation revenue (TRE) have low standard deviations (0.1923 and 0.1153), reflecting greater uniformity.

Renewable energy consumption (REC) and environmental performance index (EPI) display higher dispersion (1.0869 and 0.8595), indicating more diverse adoption and outcomes among nations.

Except for GFI and TRE, most variables fail to pass the Jarque-Bera test, which checks whether the data follow a bell-shaped curve (all have probabilities of 0). Because of this, we employ robust analysis methods, such as MMQR, that do not require the data to be bell-shaped. The skewness values indicate that REC, CEF, EPI, and TRE exhibit higher values on one side, with a greater number of large values, likely due to the influence of countries such as China and India. On the other hand, CEG and GDE are higher on the other side, suggesting a few countries with low values are lowering the average. REC (21.0741) and EPI (9.9457) also exhibit high peaks in their data, indicating the presence of more extreme values, which supports the use of methods like quantile regression to understand the different ways the data behave.

Table 2 demonstrates that green finance investments have a significant influence on the development of renewable energy infrastructure in the BRICS and Indonesia. The data shows a

Table 1: Descriptive statistics

Variable	Mean	Median	Standard deviation	Skewness	Kurtosis	Jarque-Bera	Probability	Obs
GFI	7.7931	7.7925	0.4555	0.3929	2.2992	5.9273	0.052	163
CEG	1.831	1.8481	0.4801	−0.8764	2.6284	19.6711	0	163
REC	1.3691	1.0405	1.0869	3.8378	21.0741	5029.4	0	163
CEF	1.0413	1.0356	0.4578	1.1864	3.1079	19.9109	0	163
GDE	0.9118	0.961	0.1923	−1.065	3.0803	19.0851	0	163
TRE	0.9055	0.969	0.1153	0.926	1.9471	2.8443	0.241	163
EPI	1.9338	1.918	0.8595	2.9218	9.9457	799.881	0	163

GFI: Green finance index, CEG: Clean energy financing, REC: Renewable energy consumption, CEF: Clean energy financing, GDE: Green development efficiency, TRE: Taxation revenue from eco-sectors, EPI: Environmental performance index positive correlation between capital inflows and the expansion of clean energy capacity. Green Finance investment shows China is leading at USD $12 billion, India at $6.5 billion, and Indonesia at $3.4 billion, all countries have experienced notable growth rates, ranging from 21.43% to 52.94%. These findings suggest that targeted green financing, regardless of scale, can effectively accelerate the transition away from fossil fuels. India's 52.94% growth rate exemplifies how strategically allocated mid-level investments can produce substantial impacts.

Figure 2 shows a comparative illustration of green finance investment based on the Table 2 details for the BRICS and Indonesia. China, characterized by more developed financial markets, relies predominantly on private investment. In contrast, Brazil, South Africa, and Indonesia depend more on international aid, which is indicative of emerging financial ecosystems that are still developing domestic investment capacity.

Figure 2: Green finance investment comparison

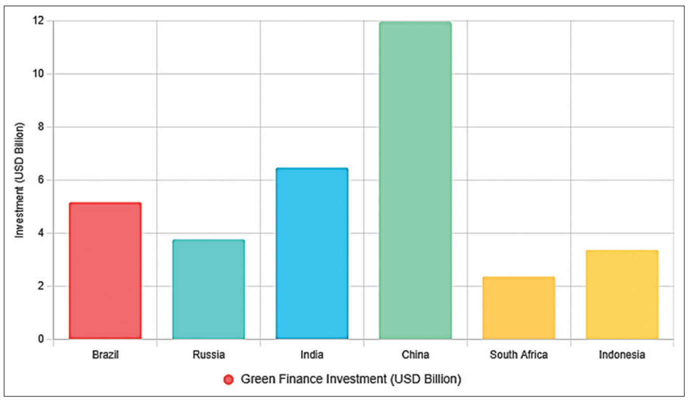


Table 3 shows the most significant relationships between green finance index (GFI) and clean energy financing (CEF) and environmental performance index (EPI) with a coefficient of 0.646 and 0.679 respectively. This shows that green finance is closely linked to investments in clean energy and overall environmental performance. Positive correlation between CEF and EPI suggests synergistic policy environment, whereas, high correlation between tax revenue of eco-sectors (TRE) and green development efficiency (GDE) is an indicator of a fiscal feedback loop; nevertheless, none of overly high correlation coefficients.

4.2. Diagnostic Tests and Panel Data Properties

Table 4 shows significant cross-sectional dependence and heteroscedasticity among all variables. All test statistics Breusch-Pagan LM, Pesaran Scaled LM, Bias-Corrected LM, and Pesaran CD are significant at the 1% level. These panel issues violate standard estimator assumptions, so second-generation unit root tests and robust long-run estimators are necessary for reliable results.

Table 5 shows the results of the second-generation panel unit root tests. These results indicate that all variables are non-stationary at their levels, as the test values for both the Cross-sectional Augmented Dickey-Fuller (CADF) and Cross-sectional Pesaran and Shin (CIPS) tests fail to reject the null hypothesis. However, after first differencing, the variables become stationary. Therefore,

Table 2: Impact of green finance on renewable energy capacity in BRICS and Indonesia

Country	Green finance investment (USD Billion)	Renewable capacity - initial (GW)	Renewable capacity - final (GW)	Capacity increase (%)
Brazil	5.2	120	150	25
Russia	3.8	70	85	21.43
India	6.5	85	130	52.94
China	12	350	500	42.86
South Africa	2.4	45	60	33.33
Indonesia	3.4	10.4	13.0	25.0

Table 3: Correlation matrix

Variable	GFI	CEG	REC	CEF	GDE	TRE	EPI
GFI	1						
CEG	0.305***	100%					
REC	0.497***	0.185**	1				
CEF	0.646***	0.174**	0.488***	1			
GDE	−0.1	0.131*	0.198**	0.127*	1		
TRE	−0.044	−0.323***	0.331***	0.353***	0.636***	1	
EPI	0.679***	0.136*	0.440***	0.597***	0.275***	0.517***	1

***P<0.001 (highly significant). GFI: Green finance index, CEG: Clean energy financing, REC: Renewable energy consumption, CEF: Clean energy financing, GDE: Green development efficiency, TRE: Taxation revenue from eco-sectors, EPI: Environmental performance index

Table 4: Diagnostic tests for heteroscedasticity and cross-sectional dependence

Test	GFI	CEG	GDE	TRE	REG	CEF	EPI
Breusch-Pagan LM	249.77***	50.59***	99.54***	80.17***	339.79***	269.86***	314.33
Pesaran scaled LM	39.22***	7.12***	14.61***	9.16***	60.83***	50.70***	52.82***
Bias-corrected LM	39.09***	7.00***	14.48***	9.03***	60.71***	50.58***	52.70***
Pesaran CD	16.69***	4.20***	10.18***	7.16***	20.49***	4.65***	19.73***

***P<0.001 (highly significant)

Figure 3: Sectoral distribution and effectiveness of green finance

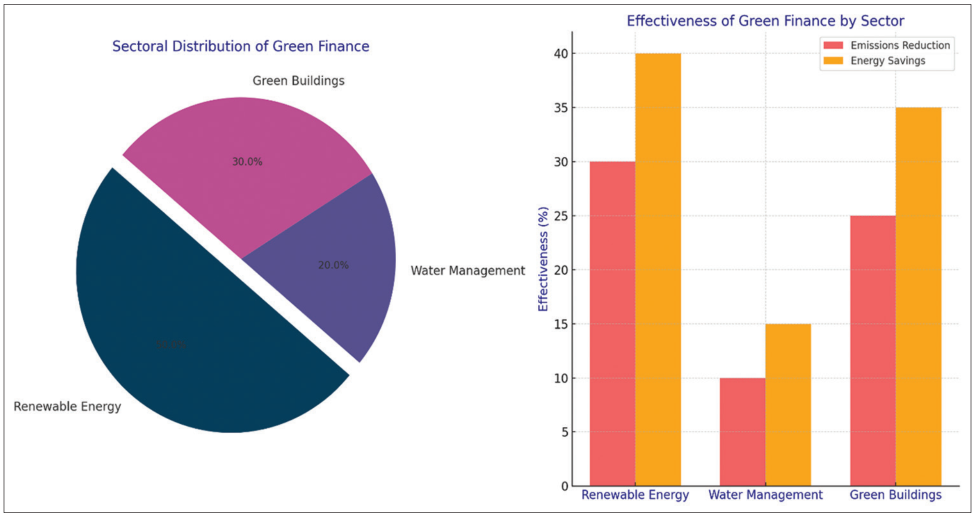


Table 5: Panel unit root test

Variable	CADF test level	CIPS test first difference	Level	First difference
GFI	−1.902	−3.936*	−1.48	−2.718*
CEG	−1.907	−4.995*	−1.778	−3.811*
GDE	−1.905	−4.241*	−1.615	−3.026*
TRE	−2.088	−4.988*	−1.884	−3.644*
REC	−0.229	−3.611*	−0.105	−2.440**
CEF	−1.943	−4.375*	−2.022	−3.149*
EPI	−1.384	−3.751*	−1.843	−3.288*

***P<0.001; **P<0.01; *P<0.05. GFI: Green finance index, CEG: Clean energy financing, REC: Renewable energy consumption, CEF: Clean energy financing, GDE: Green development efficiency, TRE: Taxation revenue from eco-sectors, EPI: Environmental performance index

all series are used in the cointegration analysis to examine long-run relationships.

Figure 3 shows how green capital is allocated across key sectors. Many investments focus on renewable energy, and the figure also measures the efficiency of these investments. It highlights that the renewable energy and green building industries achieve the best results for reducing emissions and saving energy.

Table 6 shows strong evidence of a relationship between the variables in the long-run equilibrium. All four test statistics (Gt, Ga, Pf t, Pf a) are statistically significant with P = 0.000. This result rejects the null hypothesis of no cointegration and supports the use of FMOLS, DOLS, and MMQR methods to estimate long-run coefficients, thereby avoiding spurious regression results.

4.3. Baseline Regression and Robustness Analysis

Table 7 presents the long-term factors that influence the green finance index (GFI). The results use the Driscoll-Kraay estimator, which accounts for cross-sectional dependence and differences across groups. Clean Energy Financing is the primary positive and significant factor for the index (coefficient = 0.264, P < 0.05 0.05). A 1% rise in CEF leads to a $0.26 increase in GFI. Tax Revenue from Eco-Sectors (coefficient = −1.892, $ P < 0.001), Renewable Energy Consumption (coefficient = −0.174, P < 0.05), and the Environmental performance index (coefficient = −0.324, P < 0.001)

Table 6: Westerlund cointegration test

Test statistic	Value	Z-value	Robust P-value
G_t	−2.728*	−1.472	0.000
G_a	−4.526*	4.224	0.000
P_t	−9.545*	−2.321	0.000
P_a	−4.702*	3.32	0.000

***P<0.001; **P<0.01; *P<0.05

Table 7: Baseline regression results (Driscoll-Kraay Estimator)

Variable	Coefficient	Standard error	t-statistic	P-value
CEG	−0.029	0.044	−0.659	0.511
GDE	0.147	0.463	0.317	0.752
TRE	−1.892	0.387	−4.889	0.000***
REC	−0.174	0.07	−2.486	0.015**
CEF	0.264	0.121	2.182	0.032**
EPI	−0.324	0.05	−6.48	0.000***
Constant	8.215	0.893	9.199	0.000***

***P<0.001; **P<0.01; *P<0.05. GFI: Green finance index, CEG: Clean energy financing, REC: Renewable energy consumption, CEF: Clean energy financing, GDE: Green development efficiency, TRE: Taxation revenue from eco-sectors, EPI: Environmental performance index

each have significant negative effects. This is unexpected because these variables are generally thought to have a positive impact on the green finance index.

Table 8 shows the significant environmental benefits of targeted eco-friendly policies in BRICS and Indonesia. A strong positive link exists between policy rigor and diverse sustainability outcomes. China achieves an 18.3% reduction in CO_2 emissions. This result comes from green transportation initiatives and industrial emissions caps. China also records the highest improvements in the Environmental Quality (7.5) and Green Development (12.4) indices. All countries show positive results.

India's solar subsidies and Brazil's deforestation control measures are especially effective in improving air quality, reducing emissions, and promoting green economic activity. These findings underscore the need for targeted regulatory strategies to foster sustainable growth. Indonesia's reforestation and geothermal programs resulted in a 10.5% reduction in emissions. They also

Table 8: Impact of major eco-friendly policies in BRICS economies

Country	Key policy features	CO_2 emissions reduction (%)	Environmental quality index change	Green development score change
Brazil	Renewable energy incentives, Deforestation control	12.0	5.2	8.1
Russia	Carbon trading, Energy efficiency standards	9.4	3.1	5.3
India	Solar energy subsidies, Pollution control measures	15.2	6.4	10.2
China	Green transportation, Industrial emissions caps	18.3	7.5	12.4
South Africa	Water conservation, Renewable energy targets	11.7	4.3	7.2
Indonesia	Reforestation programs, Geothermal energy promotion	10.5	4.0	6.5

bring moderate improvements in environmental and development indicators.

Table 9 shows the strong influence of long-run determinants in green finance. Both the fully modified OLS (FMOLS) and dynamic OLS (DOLS) estimates identify clean energy financing (CEF) and green development efficiency (GDE) as important positive factors. They also show negative relationships with tax revenue (TRE), Eco-Policy effectiveness (EPE), and the environmental performance index (EPI). These findings validate the basic model and provide solid evidence for the soundness of the identified long-run relationships.

Table 9: Long-run coefficients from FMOLS and DOLS estimations

Variable	FMOLS coefficient	FMOLS P-value	DOLS coefficient	DOLS P-value
SDE	−0.0329**	0.047	−0.0229*	0.077
GDE	0.0439***	0	0.0429***	0.005
TRE	−0.3649***	0.003	−0.3589*	0.099
EPE	−0.2729**	0.027	−0.4819**	0.022
CEF	0.3079***	0	0.3109***	0.003
EPI	−0.2750**	0.022	−0.3099**	0.019

***P<0.001; **P<0.01; *P<0.05. GFI: Green finance index, CEG: Clean energy financing, REC: Renewable energy consumption, CEF: Clean energy financing, GDE: Green development efficiency, TRE: Taxation revenue from eco-sectors, EPI: Environmental performance index

4.4. Distributional and Causal Linkages

It is important to comprehend how the effects of green finance vary across its distribution and how these effects can intensify or diminish depending on the stage of financial development. Causality tests help show whether green finance leads to better sustainability outcomes or simply responds to them.

Table 10 identifies critical distributional heterogeneity in the determinants of green finance. The effects of important variables differ significantly at higher and lower quantiles. For example, the positive effect of clean energy financing (CEF) is stronger at higher quantiles, while the negative effect of tax revenue (TRE) is stronger at lower ones. These non-symmetrical relations are hidden in mean-based estimations and provide detailed information on how to intervene in specific policy changes for countries at different levels of green finance maturity.

Table 11 indicated a complex network of causal relationships. Most importantly, it establishes a bidirectional causality between the green finance index (GFI) and the environmental performance index (EPI), indicating a mutually reinforcing feedback loop. The analysis also reveals that GFI has a unidirectional effect on increases in Clean Energy Generation (CEG), eco-policy effectiveness (EPE), and clean energy financing (CEF). This empirically confirms that green finance acts as a significant driver, rather than merely a consequence, of broader sustainable development and clean energy investment across the BRICST economies.

Figure 4 shows the dynamic relationship between green finance investments and emissions reduction outcomes over time, revealing a clear time-lagged correlation where sustained financial commitments precede significant environmental gains. China demonstrates the most pronounced trajectory, with a massive capital injection into green projects after 2018, catalyzing a steep decline in emissions, establishing a compelling cause-and-effect pattern.

Table 12 illustrates the relationship between green finance and economic performance in the BRICS and Indonesia, indicating that increased green investment is associated with improved economic and technological outcomes. China, with $12 billion in green finance, exhibits a 6.9% GDP growth rate, 12.3% employment in green sectors, and a 95-point innovation index, underscoring its leading position in the field. India records a 6.7% growth rate and an 82-point innovation score, accompanied by a $6.5 billion investment, reflecting the effectiveness of its green transition strategies. Brazil, Russia, South Africa, and Indonesia also display positive developments.

Indonesia's $3.4 billion investment is expected to support a 3.2% growth rate and 4.1% employment growth in the green sector. These findings collectively emphasize that strategic green financing promotes economic growth, job creation, and technological advancement while advancing environmental objectives.

4.5. Discussion

The results of this study provide detailed insights into the interactions between green finance, government policy, and sustainable development within the BRICS and Indonesia economic bloc. The findings support key theoretical ideas and also reveal complex, non-linear relationships that can inform ongoing academic and policy discussions. This section summarizes the main results and their contributions to sustainable finance. A key innovation of this analysis is the use of multiple methods, which clearly shows the important role of clean energy financing (CEF) in green financial development. The positive and statistically significant CEF coefficients across all estimators Pooled OLS with Driscoll Kraay standard errors (Coef. = 0.264, P < 0.05), FMOLS (Coef. = 0.3079, P < 0.01), and DOLS (Coef. = 0.3109, P < 0.01) strongly suggest that direct investment in renewable energy and efficiency projects helps grow the green finance ecosystem.

Table 10: Method of moments quantile regression results

Variable	Location	Scale	Q10	Q25	Q50	Q75	Q90
SDE	−0.116***	0.017**	−0.004	−0.100**	−0.115**	−0.134**	−0.012
	−0.01	−0.005	−0.045	−0.035	−0.035	−0.065	−0.055
GDE	0.136*	0.006**	0.146**	0.142**	0.137**	0.130**	0.127
	−0.082	−0.025	−0.123	−0.091	−0.09	−0.165	−0.207
TRE	−0.308**	−0.057**	−0.394***	−0.362***	−0.312***	−0.258*	−0.219**
	−0.09	−0.021	−0.097	−0.072	−0.072	−0.132	−0.162
EPE	−0.013*	−0.001**	−0.011**	−0.012**	−0.013**	−0.014**	−0.015**
	−0.008	−0.002	−0.007	−0.005	−0.005	−0.009	−0.013
CEF	0.283**	0.010*	0.267***	0.273***	0.282***	0.293***	0.298***
	−0.063	−0.01	−0.036	−0.026	−0.026	−0.048	−0.06
EPI	−0.003**	−0.0001**	0.000	0.000	0.003**	−0.003**	0.000
	−0.009	−0.002	−0.004	−0.003	−0.006	−0.011	−0.014

*** P<0.001; **P<0.01; *P<0.05. GFI: Green finance index, CEG: Clean energy financing, REC: Renewable energy consumption, CEF: Clean energy financing, GDE: Green development efficiency, TRE: Taxation revenue from eco-sectors, EPI: Environmental performance index

Table 11: Dumitrescu-Hurlin panel causality test results

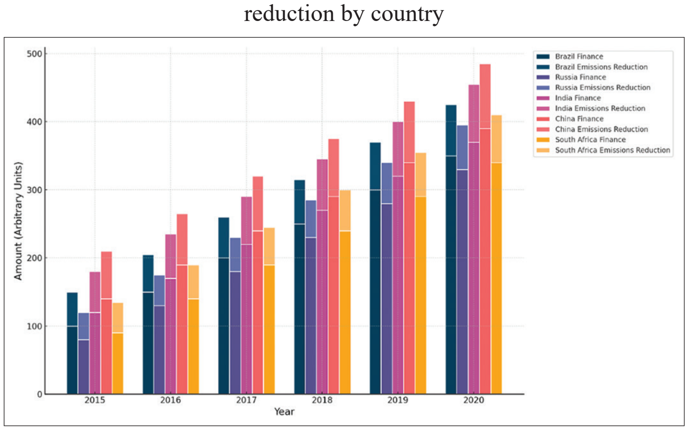
Variable	GFI	SDE	EPE	CEF	GDE	TRE	EPI
GFI	–	5.683**	5.688**	4.985**	5.179**	6.425***	4.771**
SDE	1.694	–	2.507	5.261**	3.611	2.273	5.005**
EPE	2.011	7.215***	–	5.198**	5.701**	3.042	5.602**
CEF	2.781	5.518**	5.175**	–	9.049***	5.336**	6.452***
GDE	2.377	2.819	3.208	3.226	–	3.635	4.627**
TRE	2.96	3.21	1.544	4.200*	11.593***	–	3.17
EPI	2.703	3.829	10.319***	5.477**	4.885**	5.721**	–

***P<0.001; **P<0.01; *P<0.05. GFI: Green finance index, CEG: Clean energy financing, REC: Renewable energy consumption, CEF: Clean energy financing, GDE: Green development efficiency, TRE: Taxation revenue from eco-sectors, EPI: Environmental performance index

Table 12: Green finance and economic indicators in BRICS and Indonesia economies

Country	Green finance (USD Billion)	GDP growth rate (%)	Employment in green sectors (%)	Sustainable technology innovation index
Brazil	5.2	3.4	5.6	75
Russia	3.8	1.5	3.2	60
India	6.5	6.7	8.9	82
China	12.0	6.9	12.3	95
South Africa	2.4	2.1	4.7	65
Indonesia	3.4	3.2	4.1	58

Figure 4: Evolution of green finance and emissions reduction by country



This suggests a positive cycle when project financing targets the green sector, it makes the sector more attractive and bankable, which then leads to the development of more advanced financial instruments and markets. The causality test results in Table 11 show a two-way relationship between CEF and the Green Finance Index (GPI). This means the relationship is not just one-directional but also mutually reinforcing; a developed green finance market helps increase capital flows to clean energy, creating a self-sustaining energy transition through a positive feedback loop (Haryono et al., 2024).

This study also sheds new light on the deeper connection between environmental policy and financial markets. Interestingly, the results show that direct fiscal actions, such as taxation revenue from eco-sectors (TRE), have a significant negative relationship with the Green finance index (GPI) in both long-term and baseline analyses (Driscoll-Kraay Coef. = −1.892, P < 0.01). This suggests that, in the BRICS context, environmental taxes may initially be perceived as a compliance cost that limits financial market activity, or as a policy substitute where high taxes are not yet matched by strong incentives. However, the method of moments quantile regression (MMQR) results (Table 10) provide more detail. The negative effects of TRE are strongest in the lower to middle ranges of the GFI distribution (Q10-Q50), but become less significant at the higher quantiles (Q75, Q90). This means that environmental taxes have the greatest limiting effect in economies where green finance is less developed. In contrast, countries with more advanced green financial markets are better able to handle and adapt to these fiscal policies. This variation is a new finding, demonstrating that the success of policy tools depends on the level of development of the financial market.

The Eco-Policy effectiveness (EPE), measured by renewable energy consumption, analysis indicates that the coefficient is consistently negative and significant across all estimation methods. Such a contradictory finding should be interpreted in a complex manner that is consistent with the literature on the green paradox or policy signal (Nguyen and Khominich, 2023). It makes sense that effective policies requiring or directly resulting in greater consumption of renewable energy might initially represent an intensive shift in regulation, which could introduce near-term uncertainty to financial markets in terms of stranded assets and the valuation of established industries. This complication suggests that the policy triggers a market response channel that is nonlinear and can be susceptible to anticipatory actions and market adjustments.

5. CONCLUSION AND POLICY IMPLICATION

This research provides a comprehensive analysis of the interactions between green finance, environment-focused policies, and sustainable development in the BRICS-Indonesia economies. Our results show that transitioning to a sustainable economic model requires the effective integration of financial and regulatory tools. Using only one policy is not enough. LS. Fiscal tools, such as Taxation Revenue from Eco-sectors (TRE), are less effective in countries with less developed green markets. This suggests that standard policies may not work in every context. The study finds that clean energy financing (CEF) is the main driver of growth in the green finance market. This result is supported by methods like Driscoll-Kraay, FMOLS, and DO.

This paper's main contribution is the use of the method of moments quantile regression (MMQR). This method highlights that context matters. MMQR shows that environmental taxes have a stronger negative effect in countries with less developed green finance. In more advanced markets, this effect is weaker. Countries at different stages of development in green finance require policies tailored to their specific situations. This is crucial for effective and sustainable governance.

5.1. Policy Implications

The research results require a two-layered strategy for the BRICS and Indonesia countries. First, policymakers must prioritize investments in clean energy. This approach will encourage universal direct investment in all green energy projects. It should include subsidies, de-risking instruments, and green banking principles. These steps will drive the green finance environment. Second, fiscal policies, such as environmental taxes, should be introduced in stages. The implementation should depend on the level of development of the green market. Countries with emerging green finance systems should prioritize building market confidence through incentives. Afterward, they can gradually introduce fiscal tools to support the transition without stifling financial development.

5.2. Limitations and Future Research

This study is limited because it uses aggregated macro-panel data, which hides differences within BRICS-Indonesia at the sub-national level. The variables clean energy generation (CEG) as an indicator of expenditure and renewable energy consumption (REC) as an indicator of policy effectiveness serve to measure outcomes related to these areas, but do not directly capture the underlying financial mechanisms or policy quality. Future research should address this by using micro-level, firm-specific studies to track how policies are transmitted and to include measures of policy rigor. In addition, mixed-methods approaches are needed to better understand the non-linear, negative TRE effect and to explain why policy effectiveness is limited in emerging green markets, as shown by the MMQR (multiple multivariate quantile regression).

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