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Governance and greenwashing in the BRICS: The moderating role of national ESG performance in sustainable finance outcomes

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ABSTRACT

The environmental sustainability of BRICS nations is connected with green finance and national environmental, social, and governance (ESG) performance. However, the fundamental mechanisms that regulate this integration have not been thoroughly examined at a macro level. In a period marked by the continuous war against climate change, it is vital to grasp this process to construct a sustainable economic model consistent with developmental aims and ecological responsibilities. By utilizing FMOLS and CCR estimating techniques, this research examines data from 1998 to 2022 to estimate the influence of green finance and national ESG performance on environmental sustainability. It also explores the link between green finance and national ESG performance among the BRICS nations. Additionally, by employing a moderating effect model, the research evaluates the influence of national ESG performance on the link between green finance and environmental sustainability. The results imply that green finance and national ESG performance significantly help to increase environmental sustainability. The research also demonstrates that green finance is crucial in boosting national ESG performance. In addition, the link between green finance and environmental sustainability is significantly moderated by national ESG performance, which also shows the possibility of greenwashing due to possible conflicts of interest between principal and agent. The results of the robustness testing through DOLS and DK standard error estimate techniques are similarly compatible with the baseline findings. Importantly, this research provides fresh insights into the dynamic linkages among green finance, national ESG performance, and environmental sustainability, offering strategic implications that enable governments, investors, lenders, enterprises, and regulators to make informed decisions.

Introduction

Despite the overwhelming global focus on the COVID-19 pandemic over the past five years, the deepening climate change crisis remains an urgent and unresolved challenge. The dual shock of the pandemic and the Russia-Ukraine war has strained global governance and, importantly, has jeopardized progress towards the United Nations Sustainable Development Goals (SDGs), particularly those related to environmental sustainability. Given climate change's potentially disastrous (and irreversible) effects – including but not limited to increased natural catastrophes, toxic emissions and rising sea levels – addressing climate change constitutes one of the most urgent and consequential objectives with the SDGs. According to Ibrahim and Vo (2021), increasing temperatures and pollution levels are the primary challenges that must be addressed. Environmental pollution is mainly caused by greenhouse gas (GHG) emissions (Usman, Ozturk, Ullah, & Hassan, 2021), among which carbon dioxide (CO_2) emissions are especially alarming due to its dominant share: in 2016, CO_2 accounted for 74.4% of all GHG emissions. Tollefson (2020) warns that in the upcoming decades, CO_2 emissions may cause a 5–6°C increase in global temperatures. As a result, CO_2 emissions are the main focus of this research to measure environmental sustainability (see also Bakry, Mallik, Nghiem, Sinha, &

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Vo, 2023). With a combined population of 50% of the world's population and 25% of global GDP (Wei, Yue, & Khan, 2024), as well as substantial foreign exchange reserves (Udeagha & Ngepah, 2023b), the BRICS countries – Brazil, Russia, India, China, and South Africa – have a significant role in influencing global economic and environmental outcomes; however, these nations also rank among the world's largest polluters (Shao, Wang, Zhou, & Balogh, 2019). Accordingly, this study investigates the interplay between green finance (GFN), national ESG performance (NESGP), and environmental sustainability (ENSUS) within the context of the BRICS economies.

GFN plays a pivotal role in enhancing environmental quality, mitigating climate change and promoting the efficient management of resources. It also provides the foundation for achieving carbon neutrality and promoting sustainable, low-carbon economic growth. The objectives of carbon neutrality and GFN are intertwined: realizing carbon neutrality requires the effective deployment of GFN to steer energy-intensive businesses towards a low-carbon and environmentally responsible trajectory (Z. Chen, Zhang, Wang, Ouyang, & Xie, 2022; G. Zhou, Zhu, & Luo, 2022). Thampanya, Wu, & Cowton (2021) provide evidence that, in advanced countries, GFN contributes to substantial declines in CO_2 emissions. Additionally, research by Al Mamun, Boubaker, & Nguyen (2022) and Yan, Yang, & Zhang (2023) underlines the relevance of GFN in continuously decreasing carbon intensity and emissions via better resource allocation, particularly in regions with high carbon intensity. Furthermore, according to Xie (2024), GFN is essential for encouraging energy transitions and lowering CO_2 emissions. Sun, Zhou, & Gan (2023) use a quasi-natural experiment from China to show that GFN policies can lead to an increase in corporate ESG scores in general, and the environmental component of ESG in particular. This finding is all the more important since investors, companies, and regulators consider that a firm's ESG scores is a reliable proxy for corporate sustainability (Li, Wang, Sueyoshi, & Wang, 2021). J. Li and Xu (2024) found that ESG ratings play a significant role in curbing corporate carbon emissions by easing corporate financing constraints and mitigating agency problems; W. Yang and Hei (2024) echo this finding: using empirical evidence from 208 Chinese cities, the authors show that strong corporate ESG performance plays a significant role in curbing CO_2 emissions.

NESGP can potentially moderate the GFN-ENSUS nexus in two opposing directions. On the one hand, organizations use ESG measures as a signaling mechanism to improve their image with stakeholders (J. Li & Xu, 2024). According to Christensen, Serafeim, and Sikochi (2022), ESG information sharing can strongly encourage businesses to take on more social responsibility. Furthermore, a positive ESG profile can lower funding costs (Wong & Zhang, 2022; J. Li and Xu, 2024), incentivizing green investments (such as energy-efficient projects) that enhance ENSUS. On the other hand, the benefits associated with ESG disclosure – namely, improved reputation and lower financing costs – might encourage activities known as "greenwashing", using ESG scores primarily to project a positive public image and secure external funding (Berrone, Fosfuri, & Gelabert, 2017; Delmas & Burbano, 2011; C. Li & Wang, 2022). By misleading external rating agencies, greenwashing can lead to information asymmetry and have detrimental effects (D. Zhang, 2023a). While greenwashing can attract external funding, it can also render GFN and other initiatives to lower CO_2 emissions less effectively.

Although the literature provides some empirical evidence regarding the GFN-CO_2 emissions nexus (Al Mamun et al., 2022; Wei et al., 2024; Yan et al., 2023), GFN-ESG nexus (Chen et al., 2022; Gao, Zhou, & Wan, 2024; Sun et al., 2023), and ESG-CO_2 emission nexus (J. Li & Xu, 2024; J. Lu & Li, 2024; W. Yang & Hei, 2024) at the micro level, a complete theoretical model incorporating NESGP, GFN, and ENSUS remains absent. Additionally, existing studies have largely focused on firms that belong to a single industry or to a single country, neglecting the interconnected and dynamic nature of NESGP and GFN across countries, regions and industries. Furthermore, the potential for greenwashing highlights the importance of examining how the link between GFN and ENSUS is moderated by NESGP. This gap limits our understanding of the contextual opportunities and challenges that influence the effectiveness of these strategies. Addressing it through interdisciplinary and multi-dimensional methodologies will help inform policies that simultaneously promote NESGP, GFN, and ENSUS.

This study therefore makes six key contributions to literature. Firstly, it presents an in-depth investigation of the impact of GFN and NESGP on ENSUS using an international dataset of BRICS economies. Secondly, whereas prior studies largely focused on firm-level data, this paper represents a novel effort to investigate the impact of GFN on NESGP at the macro level. Thirdly, in light of the potential for greenwashing, this study incorporates NESGP as a moderating variable to study its impact on the GFN-ENSUS relationship. Fourthly, in contrast to previous studies, this study pioneers a more robust ENSUS index by considering CO_2 emissions both on a per capita and a total (kiloton) basis. Fifthly, several robustness tests were conducted to address endogeneity concerns and strengthen the reliability of the results. Finally, the study's findings highlight the significance of GFN and NESGP in promoting ENSUS while initiating a discussion on the moderating role of NESGP in the GFN-ENSUS nexus.

The rest of the paper is organized as follows: Section 2 reviews the literature; section 3 presents the data and methodology; section 4 reports the estimation results and section 5 conclude, highlighting policy implications and suggesting directions for future research.

Literature review

Theoretical framework

The study draws on both stakeholder theory and agency theory to develop its theoretical framework. Firstly, stakeholder theory (Clarkson, 1995; Freeman & McVea, 2005) provides the theoretical basis for our analysis of the relationship between GFN, NESGP, and ENSUS. The proponents of stakeholder theory argue that companies (particularly those with high pollution levels) should prioritize the interests of all stakeholders rather than focusing solely on shareholders (Qian & Yu, 2024). Companies should therefore focus on activities that protect all its stakeholders from environmental harm. On the one hand, GFN can help to promote NESGP (Luo, Lu, Muhammad, & Yang, 2021; D. Zhang, 2021), and on the other, both GFN and NESGP can promote ENSUS (J. Lu & Li, 2024; Wu, Liu, & Cai, 2024). Therefore, GFN can align economic, social, and ecological objectives by creating a transformative mechanism that channels financial resources towards achieving long-term sustainability outcomes.

Secondly, agency theory suggests that because agents do not always act in the best interests of principals, conflicts of interest may arise between them (Jensen & Meckling, 2019). In the context of environmental sustainability, principals – such as investors, governments, and the public – expect agents, namely corporate managers, to use green financing responsibly to achieve environmental objectives. Nonetheless, agency theory sheds light on how these stakeholder-driven outcomes can be distorted by ESG greenwashing and information asymmetries. Friedman (2007) argued that corporate managers (as agents) should focus primarily on maximizing shareholder wealth by investing in financially profitable activities. This profit-oriented view can conflict with broader environmental goals, leading some firms to prioritize short-term financial gains over genuine sustainability efforts. When companies act irresponsibly toward sustainable performance, their reputation and stakeholder trust can suffer (Alon & Vidovic, 2015; Ching & Gerab, 2017). This can result in financial constraints for the company. This dual pressure can force corporations to get involved in greenwashing behavior. Companies engaging in greenwashing might benefit from lower costs by deceptively enhancing their reputation and social image (Ghisetti & Rennings, 2014; Yu, Van Luu, & Chen, 2020). Greenwashing, where ESG information is intentionally distorted, can mislead consumers and external lenders, affecting market returns and stakeholder decision-making (D. Zhang, 2023b). As a result, misleading ESG disclosures aimed at securing external financing (or lowering the cost of such financing) can undermine the effectiveness and potential of GFN in tackling environmental challenges. NESGP can suppress the positive environmental benefits of GFN. This negative moderating effect of NESGP reflects the potential conflict between stakeholder transparency and opportunism, where higher ESG standards can force businesses towards greenwashing practices.

Green finance and environmental sustainability

Recent empirical evidence indicates that green finance serves as an effective mechanism for reducing carbon emissions and promoting sustainable development, a finding supported by studies demonstrating the role of green finance and clean environmental taxes in curbing emissions (Wang et al., 2023) and the complementary impact of digital transformation in strengthening its sustainability effects (Safi et al., 2024). Similarly, Al Mamun et al. (2022) concluded that using green bonds – an important financial instrument under GFN – can contribute to reducing pollution and fostering renewable energy use. W. Zhang, Hong, Li, and Li (2021) analyzed provincial data from thirty Chinese cities and showed that green credit, another tool within GFN, can help lower the intensity of CO_2 emissions. Sustainable economic growth (defined as growth that does negatively affect the environment) is one of the major challenges for the BRICS nations. Nenavath and Mishra (2023) argue that GFN can promote economic growth while improving environmental quality and supporting a more sustainable financial system. However, one of the main obstacles to implementing sustainable projects is securing adequate funding. As Lazaro, Grangeia, Santos, & Giatti (2023) note, sustainable project financing objectives could play a key role in helping nations achieve their sustainability goals in the near future; empirical data supports this view: using data from Chinese cities, Wu et al. (2024) find that GFN contributes to a reduction in CO_2 emissions, a result which is corroborated by Udeagha & Ngepah (2023a) as well as Wei et al. (2024). We therefore formulate our first hypothesis:

H_1: GFN significantly promotes ENSUS.

National ESG performance and environmental sustainability

Recent literature highlights the importance of environmental, social, and governance performance in promoting environmental sustainability. Studies focusing on the environmental dimension show that environmental initiatives and CO_2 emissions are positively correlated (Hao, Li, Ren, Wu, & Hao, 2023; W.-C. Lu, 2017). Furthermore, Sarkodie & Strezov (2019) find that to enhance environmental performance, companies are encouraged to invest in energy-efficient and renewable energy projects. Regarding the social dimension, Wynes and Nicholas (2018) argue that achieving net-zero emissions can be facilitated by curbing overconsumption. In terms of governance, stronger institutional quality (Wenlong et al., 2023) and a more robust environmental legislative framework (Tam, Le, Tran, & Illankoon, 2021) can further support environmental protection.

However, most existing studies examine these ESG components in isolation. Only a limited number of recent studies have considered their combined impact at the firm (micro) level. For instance, using data from Chinese firms, S. Zhou, Rashid, Mohd. Zobair, Sobhani, & Siddik, (2023) find that ESG performance encourages innovation and sustainable outcomes in businesses. Similarly, J. Li and Xu (2024) report that ESG ratings help lower CO_2 emissions in Chinese A-share listed companies, while W. Yang and Hei (2024), using city-level data from 208 Chinese cities, find that cities with higher ESG ratings had lower CO_2 emissions.

Considering this evidence, we propose the following hypothesis:

H_2: NESGP significantly promotes ENSUS.

Green finance and national ESG performance

GFN is an emerging financial framework that integrates concepts such as resource conservation and environmental preservation into economic growth, thereby promoting holistic ESG development, across economic, resource, and ecological dimensions (Soundarrajan & Vivek, 2016). By aligning financial mechanisms with sustainability objectives, GFN accelerates the transition toward dynamic ESG-oriented development (Falcone, 2020). Additionally, the continued growth of GFN reinforces financial structures that improve the quality of ESG outcomes, particularly those related to environmental performance (Lagoarde-Segot, 2019).

In contrast GFN directs capital toward environmentally beneficial activities thereby improving environmental quality, reducing pollution, and fostering green economic growth. For instance, D. Zhang (2021) finds that green credit regulation policy can improve green total factor productivity. Ultimately, GFN should emphasize the dual benefits of improving human welfare as well as the environment, which demonstrates that natural resource conservation and economic development are not mutually exclusive; they can indeed coexist to advance sustainable development. Recent studies support this view, identifying GFN as an effective tool that helps mitigate the risk of environmental degradation (Chen et al., 2022; Gao et al., 2024; Sun et al., 2023).

We therefore propose the following hypothesis:

H_3: GFN significantly promotes NESGP.

Moderating role of national ESG performance

Prior studies have shown a significant and positive relationship between firms' environmental performance and the disclosure of ESG information (Brammer, Pavelin, & Porter, 2006). J. Chen, Dong, Tong, and Zhang (2018) find that publishing ESG information can incentivize companies to reduce emissions and to strengthen social commitments. This, in turn, can suppress the release of sulfur dioxide and wastewater, thereby lowering GHG emissions (Downar, Ernstberger, Reichelstein, Schwenen, & Zaklan, 2021). Likewise, disclosing ESG information can strongly encourage businesses to enhance their corporate social responsibility (Christensen et al., 2022). Like voluntary disclosure, mandatory ESG disclosure is also useful and relevant, as it can lower the likelihood of adverse ESG events, enhance the quality and credibility of ESG reports, and clarify possible business risks (Krueger, Sautner, Tang, & Zhong, 2021). Furthermore, corporate managers recognize that maintaining a solid ESG reputation can lead to lower financing costs, which in turn makes it easier for their companies to secure external investment, and support business continuity (Wong & Zhang, 2022). Additionally, a strong ESG reputation can encourage companies to invest in renewable and energy-efficient projects to support green transformation and mitigate environmental risk. These findings suggest that ESG disclosure can positively moderate the link between green finance initiatives and sustainability outcomes by encouraging genuine investment in renewable and energy-efficient projects that advance green transformation and mitigate environmental risk.

However, ESG disclosure can have unintended consequences: it may encourage greenwashing. In particular, companies may strategically use ESG reporting to project a positive public image to secure funding (Berrone et al., 2017; Delmas & Burbano, 2011; C. Li and Wang, 2022). In this regard, Raghunandan and Rajgopal (2022) show that companies' compliance records or real CO_2 emission levels had no bearing on ESG ratings; instead, the authors find that ESG scores are simply correlated with the quantity of voluntary ESG disclosures. This finding is corroborated by Basu, Naughton, & Wang (2022), who show that companies with high ESG ratings often achieve such ratings through a greater volume of disclosure, with no evidence of improvement to their environmental and financial performance. Furthermore, Thomas, Yao, Zhang, and Zhu (2022) find that while companies with high ESG ratings generally exhibit lower pollution levels, they may increase emissions to meet profit targets, relying on their solid reputation to mitigate the negative perceptions of their actions. These findings suggest that some companies do not meaningfully address the ESG issues that matter to stakeholders, engaging instead in symbolic actions whose sole purpose is to improve their ESG ratings, leading to what is known as greenwashing (D. Zhang, 2022b, 2023b); while such practices may help firms secure external financing at lower costs, they ultimately undermine the effectiveness of genuine carbon reduction initiatives, including those targeting CO_2.

In sum, ESG disclosure can act as a double-edged sword; on the one hand, it can strengthen the impact of green finance initiatives on sustainability when it reflects authentic commitment. On the other hand, it can weaken it when it facilitates superficial compliance or greenwashing.

In light of the foregoing information, we propose the following hypotheses:

H_4: NESGP can significantly moderate the relationship between GFN and ENSUS.

H_{4a}: NESGP can significantly and positively moderate the relationship between GFN and ENSUS.

H_{4b}: NESGP can significantly and negatively moderate the relationship between GFN and ENSUS.

Data and methodology

Population, sample selection, and data sources

This study uses a quantitative research design and a uses panel dataset to covering the BRICS countries over the 1998-2022 period. This time frame is chosen to encompass two significant global events – the Great Recession of 2008-2009 and ensuing global financial crisis, as well as the COVID-19 pandemic – thereby allowing for a comprehensive assessment of their potential influence on the studied relationships. The data used to construct the ENSUS, GFN, NESGP indices as well as the data used for the control variables have been obtained from the World Development Indicators (Jiang, Feng, & Yang, 2022; Udeagha & Ngepah, 2023a; Wei et al., 2024). Following Jiang et al. (2022), missing observations in the data used to construct the ENSUS and NESGP indices were supplemented using a mean-filling methodology. Furthermore, the ENSUS and GFN indices are constructed using a Principal Component Analysis (PCA) as in Wei et al. (2024), while the NESGP index is estimated using the entropy method following Jiang et al. (2022) and Niu (2024).

Variable selection

Dependent variable

The study's dependent variable, ENSUS, is constructed as an index based on two indicators of CO_2 emissions. Recent studies in the context of the BRICS countries have proxied environmental sustainability using either the CO_2 emission per capita (Wei et al., 2024) or the total CO_2 emission measured in kilotons (Udeagha & Ngepah, 2023a). This study extends the literature by constructing the ENSUS index from both indicators to provide a more robust and comprehensive measure of environmental sustainability.

Both indicators were first normalized and then combined using PCA, which is particularly appropriate for constructing the ENSUS index as it reduces dimensionality by objectively assigning weights to the strongly correlated measures of environmental performance. The first principal component is retained as the ENSUS index as it explains a substantial portion of the total variance across indicators.

Independent variable

This study's independent variable, GFN, is an index constructed from multiple variables: green credit and green securities (Wei et al., 2024), green investment (Hung, 2023) and carbon finance (H. Zhang, Geng, & Wei, 2022). As is the case for the dependent variable, all variables are first normalized then combined using PCA. This method is also suitable for the construction of the GFN index since it reduces the dimensionality problem without significant loss of information (Wei et al., 2024). As for ENSUS, we retain the first principal component as it accounts for most of the total variance across indicators.

Moderating variable

The study constructs the moderating variable, NESGP, following the approach of Jiang et al. (2022) . For each BRICS country, the ESG framework includes 23 environmental, 22 social, and 18 governance indicators (Jiang et al., 2022; Niu, 2024). Given the strong correlation among these indicators, a simple summation would not yield a reliable index of comprehensive ESG performance at the national scale (Jiang et al., 2022). Accordingly, the entropy weighting method is used for the construction of the NESGP index, as it can yield a more robust index when compared to PCA and other conventional methods in the case of a large number of indicators (Jiang et al., 2022; Niu, 2024). The NESGP index is thus constructed as follows;

$$NESGP = \sum weight_{tk}\, p_{itk} \quad (1)$$

$weight_{tk}$ represents the weight of the k^{th} indicator and p_{itk} represents the values of indicator k for country i in year t.

Control variables

This study uses several control variables to determine the true relationship between GFN, NESGP, and ENSUS: inflation (Cicchiello, Cotugno, & Foroni, 2023), GDP per capita, natural resource rent (Udeagha & Ngepah, 2023a) and government intervention (Ran, Liu, Razzaq, Meng, & Yang, 2023).

Definitions and preliminary statistics for the dependent, independent, moderation and control variables are presented in Table 1.

Model specification

This study uses a single dependent variable, independent variable, moderating variable, and four control variables, whose construction is detailed in section 3.2 above.

The econometric models below are estimated through Fully Modified Ordinary Least Squares (FMOLS) and Canonical Cointegrating Regression (CCR) – details on the estimation are presented in section 3.2 below.

Model 1 is used to study the interplay between GFN and ENSUS.

$$ENSUS_{i,t} = \omega_0 + \omega_1 GFN_{i,t} + \lambda m \sum_{m=1}^{n} X_{i,t} + \varepsilon_{i,t} \quad 2$$

Model 2 is used to study the interplay between NESGP and ENSUS.

$$ENSUS_{i,t} = \omega_0 + \omega_1 NESGP_{i,t} + \lambda m \sum_{m=1}^{n} X_{i,t} + \varepsilon_{i,t} \quad 3$$

Model 3 is used to study the interplay between GFN and NESGP.

$$NESGP_{i,t} = \omega_0 + \omega_1 GFN_{i,t} + \lambda m \sum_{m=1}^{n} X_{i,t} + \varepsilon_{i,t} \quad 4$$

Model 4 is used to study the moderating role of NESGP in the relationship between GFN and ENSUS.

$$ENSUS_{i,t} = \omega_0 + \omega_1 GFN_{i,t} + \omega_2 GFN * NESGP_{i,t} + \lambda m \sum_{m=1}^{n} X_{i,t} + \varepsilon_{i,t} \quad 5$$

Where *ENSUS* $_{i,\,t}$ represents the environmental sustainability of country 'i' at time't', *GFN* $_{i,\,t}$ *green finance index* of country *'i' at time't', NESGP* $_{i,\,t}$ *represents* the national ESG performance of country *'i' at time't' GFN*NESGP* $_{i,t}$ refer to interaction term (green finance and national ESG performance) of country $X_{i,t}$ represents country-specific control variables, and $\varepsilon_{i,\,t}$ represents the error term.

Table 1
Descriptive statistics and variable definition.

Variables	Definitions	Obs	Mean	Std. Dev.	Min	Max	Source
ENSUS	Environment sustainability index constructed with, CO_2 emission Metrix per capita and CO_2 emission kiloton	125	3.00e-08	0.998	-1.252	1.667	WDI
GFN	The green finance index is constructed with green credit, securities, investment, and carbon finance.	125	4.88e-08	1.000	-1.160	1.602	WDI
NESGP	National ESG performance index constructed with 23 environmental pillars, 22 social pillars, and 18 governance pillars.	125	5.334	1.044	0.003	6.905	WDI
INF	Inflation rate	125	7.673	7.908	-1.246	72.404	WDI
GDPPC	Gross domestic product per capita	125	5762	4098	412	15975	WDI
NNR	The ratio of natural resource rent to GDP	125	5.742	4.904	0.822	21.461	WDI
GI	Ratio of Final government expenditures to GDP	125	15.431	3.116	8.910	19.894	WDI

Source: Authors' Calculation

Estimation technique

Descriptive statistics and correlation matrix

First, descriptive statistics – namely the number of observations, mean, minimum, maximum, and standard deviation – are computed for each variable. Second, pairwise relationships among the variables are examined using Pearson's correlation analysis.

Diagnostic testing

We performed several diagnostic tests: cross-sectional dependence was evaluated using the Friedman test, while unit roots and stationarity were examined via the CIPS test. Additionally, we employ the Im, Pesaran, and Shin (2003) methodology to test for panel unit root test. Furthermore, we used the Pedroni (1999), Kao (1999) and Westerlund (2007) to test for cointegration in the panel dataset.

Estimation technique

This study uses the FMOLS estimation technique developed by Hansen and Phillips (1988) for the primary analysis, which helps account for the impact of cointegration on serial correlation and endogeneity in the explanatory variables. This technique can also account for stationary errors, integration processes, and polynomial regression of deterministic components. The FMOLS estimation technique is also capable of providing estimates of causal linkages between the studied variables (Pedroni, 2001a, 2001b). Additionally, it can also solve several other issues, such as autocorrelation and variance shift along and across dimensions. In this case, the constant term takes into consideration the potential link between the explanatory factors and the variations in the error terms (Gülmez & Yardımcıoğlu, 2012). As a secondary analysis, the study the CCR methodology developed by Park (1992) to validate the estimates of FMOLS. The CCR estimation technique is very similar to FMOLS, except that CCR reduces the long-term correlation between the cointegration equation and random shocks by employing stationary data modification (Gülmez & Yardımcıoğlu, 2012).

Results and discussion

Descriptive statistics, correlation analysis

This research uses the FMOLS and CCR estimation techniques to examine the relationship between GFN, NESGP, and ENSUS within the context of the BRICS economies. Prior to the estimation, Table 1 displays descriptive statistics (including the number of observations, mean, maximum, minimum, and standard deviation) and Table 2 reports the correlation matrix. The relatively low correlation coefficients among the variables validates the appropriateness of employing the FMOLS and CCR estimation techniques.

Table 2
Correlation analysis.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) ENSUS	(1) ENSUS						
(2) GFN	(2) GFN	(2) GFN					
(3) NESGP	(3) NESGP	(3) NESGP	(3) NESGP				
(4) INF	(4) INF	(4) INF	(4) INF	(4) INF			
(5) GDPPC	(5) GDPPC	(5) GDPPC	(5) GDPPC	(5) GDPPC	(5) GDPPC		
(6) NNR	(6) NNR	(6) NNR	(6) NNR	(6) NNR	(6) NNR	(6) NNR	
(7) GI	(7) GI	(7) GI	(7) GI	(7) GI	(7) GI	(7) GI	(7) GI

Diagnostic testing

Additionally, we conducted several diagnostic tests to confirm the suitability of the FMOLS and CCR estimation techniques for panel data analysis. First, cross-sectional dependence was assessed using the CD test, while the cross-sectional IPS (CIPS) test was employed to evaluate data stationarity. As noted by Hao et al., (2021), neglecting cross-sectional dependence in panel data studies may lead to unreliable and ambiguous results. Heterogeneity is diagnosed via the CIPS test (Phillips & Hansen, 1990). Table 3 presents the outcomes of the CD test. Statistically significant coefficients indicate the existence of cross-sectional dependence, whereas the statistically insignificant coefficients suggest that we cannot reject the null hypothesis of no cross-sectional dependence. The results reported in Table 3 confirm the existence of cross-sectional dependence, implying that changes in one BRICS country tend to influence the other countries. Table 3 also reports the results of the CIPS test, which is used to determine if the panel data is stationary. The statistically significant coefficients of the CIPS tests demonstrate that the series are stationary at the first difference, indicating the absence of a unit root. In addition, we have employed the Im et al. (2003) unit root test and the results, presented in Table 4, are

Table 3
Cross-Sectional Dependence and Stationarity Test.

Variables	CD Test	P-Value	CIPS Test	
			Level	First Difference
ENSUS	91.281	0.000***	-2.281*	-3.455***
GFN	25.167	0.000***	-3.377***	-4.750***
NESGP	10.590	0.032**	-0.415	-3.491***
INF	43.961	0.000***	-3.232***	-5.475***
GDPPC	13.994	0.007***	-0.487	-3.254***
GI	52.903	0.000***	-2.588***	-4.825***
NNR	84.257	0.000***	-2.750***	-5.714***

Note: * and *** is for the significance level of 10% and 1%

Table 4
Unit Root Test of the Panel.

Variables	Im Pesaran and Shin Unit Root			
	I (0)		I (0)	
	C	C & T	C	C & T
ENSUS	0.470	-1.823**	-5.740***	-5.792***
GFN	-1.029	-2.495***	-6.786***	-6.849***
NESGP	5.680	-1.393	-2.651***	-2.356***
INF	-3.399***	-4.139***	-7.129***	-7.120***
GDPPC	3.440	-0.815	-5.261***	-4.925***
GI	-1.163	-2.144**	-5.331***	-5.276***
NNR	-3.176***	-3.732***	-6.999***	-7.017***

Note: ** & *** is for the significance level of 5% and 1%

consistent with those obtained using the CIPS test.

Subequently, the cointegration and long-term relationship between the variables were examined using the Pedroni (1999), Kao (1999), and Westerlund (2007) tests. The Pedroni (1999) test's null hypothesis posits no cointegration among the variables. The results, presented in Table 5, reject this hypothesis, indicating the presence of cointegration. The Kao (1999) test results, also reported in Table 5, corroborate the results of the Pedroni (1999) test, confirming the cointegration of the variables at the 1% statistical significance level. Similarly, the Westerlund (2007) test results, presented in Table 6, reject the null of no cointegration, further supporting the results of the Pedroni (1999) and Kao (1999) tests.

Having performed the preliminary diagnostics tests, the FMOLS and CCR estimation techniques were employed. The empirical findings reveal both positive and negative relationships among the variables, consistent with the theoretical expectations.

Main findings

Table 7 reports the results of the estimations of models 1, 2, 3, and 4 using the FMOLS and CCR techniques. Model 1 examines the impact of the GFN index on the ENSUS index (CO_2 emissions). The FMOLS estimate shows a statistically significant negative relationship between the GFN index on CO_2 emissions at a 1% level. Specifically, a 1% increase in the GFN index is associated with a 0.719% reduction in CO_2 emissions in the long run. The negative relationship highlights the importance of GFN in promoting environmental sustainability by reducing CO_2 emissions in BRICS economies. Control variables were included in the model to assess the robustness of the GFN-ENSUS nexus. GDPPC, government intervention, and natural resources rent were found to be statistically significant at the 1% level, while inflation was statistically insignificant. To validate the FMOLS results, the CCR estimation was used, yielding consistent findings: a 1% increase in the GFN index can is linked to a 0.718% reduction in CO_2 emissions in the long run and this relationship is statistically significant at the 1% level. These results are in line with prior research (Udeagha & Ngepah, 2023a; Wei et al., 2024; Wu et al., 2024). We therefore cannot reject hypothesis 1, confirming that GFN significantly promotes ENSUS by reducing CO_2 emissions.

Model 2 investigates the influence of NESGP on the ENSUS index (CO_2 emissions). The FMOLS results indicate a statistically significant relationship between NESGP and CO_2 emissions at the 10% level. Specifically, a 1% increase in NESGP leads to a 0.188% reduction in CO_2 emissions in the long run. This negative relationship underscores the role of NESGP in promoting environmental sustainability and reducing CO_2 emissions within the BRICS economies. To ensure robustness, control variables were included. GDPPC and government intervention were statistically significant at 1%, natural resource rent was statistically significant at the 10% level, whereas inflation was statistically insignificant. The CCR estimation, used to validate the FMOLS results, also revealed a significant negative influence of NESGP on CO_2 emissions with a 10% statistical significance level, with a 1% increase in the NESGP leading to a 0.193% reduction in CO_2 emissions in the long term. These empirical findings are consistent with prior studies (J. Li & Xu, 2024; W. Yang & Hei, 2024; S. Zhou et al., 2023). Accordingly, hypothesis 2 is accepted, confirming that NESGP significantly enhances ENSUS by lowering CO_2 emissions.

Table 5
Panel Cointegration Test.

	Pedroni Test for Cointegration			Kao Test for Cointegration	Decision
	MPP t	PP t	ADF t	ADF t	Cointegration Exist
Statistics	1.846	-1.691	-1.493	-3.436	
p-value	0.032**	0.045**	0.068*	0.000***	

Note: ** & *** is for the significance level of 5% and 1%

Table 6
Westerlund (2007) Panel Cointegration Test.

Statistics	Gt	Ga	Pt	Pa	Decision
Value	-3.205	-11.293	-8.817	-11.732	Cointegration Exist
Z-value	-3.551	-1.688	-5.449	-3.595	
p-value	0.000***	0.046**	0.000***	0.000***	

Note: ** & *** is for the significance level of 5% and 1%

Model 3 examines the impact of the GFN index on NESGP. The FMOLS estimate reveals a statistically significant positive relationship at the 1% statistical significance level, indicating that an increase of 1% in the GFN index is linked with a 0.342% increase in NESGP in the long run. This positive relationship shows the crucial role that GFN plays in advancing NESGP within the BRICS economies. To ascertain the true impact of the GFN index on national ESG performance, we have included control variables. The control variables GDPPC, government intervention, and natural resource rent were all found to be statistically significant at the 1% level, while inflation remained insignificant. The CCR estimation further validates these results, showing a significant positive association at the 1% level, with a 1% increase in GFN corresponding to a 0.345% increase in NESGP. These results align with previous studies (Gao et al., 2024; Sun et al., 2023). Therefore, Hypothesis 3 is accepted, indicating that GFN significantly enhances NESGP.

Moderating the role of national ESG performance in the relationship between green finance and environmental sustainability

Model 4 studies the moderating effect of NESGP on the relationship between GFN and ENSUS. The FMOLS results reveal that NESGP significantly and negatively moderates this relationship at the 1% level of statistical significance. The coefficients of the GFN index ($\beta = -0.342$, $p < 0.01$) and the interaction term ($\beta = -0.071$, $p < 0.01$) suggest that the impact of GFN on ENSUS is strengthened by higher levels of NESGP. The control variables GDPPC, natural resource rent, government intervention, and inflation were found to be statistically significant at the 1% level. The CCR estimation was employed to validate the FMOLS estimates, and it produced consistent findings: NESGP exerts a significant negative moderating effect on the GFN-ENSUS nexus at the 1% statistical significance level, with a coefficient of $\beta = -0.337$ ($p < 0.01$) for GFN and $\beta = -0.072$ ($p < 0.01$) for the interaction term. The negative moderation effect indicates that NESGP enhances the CO_2-reducing impact of GEN, suggesting that in countries already exhibiting high levels of ESG performance, additional investments in sustainability initiatives such as GFN may yield progressively smaller environmental benefits.

ESG and greenwashing

An alternative interpretation for the negative moderation might be drawn from agency theory, which suggests a potential conflict of interest between principal and agent. Overstated ESG scores may create the appearance of a solid ESG performance, but weak implementation can undermine the effectiveness of green financing in reducing CO_2 emissions within the BRICS economies. This claim is consistent with agency

Table 7
Baseline Regression FMOLS and CCR.

	Base-Line Regression Fully Modified Ordinary Least Square				**Base-Line Regression Canonical Cointegration Regression**			
Variables	**Model-1 Coefficient St. Error CO_2 Emission**	**Model-2 Coefficient St. Error CO_2 Emission**	**Model-3 Coefficient St. Error ESG**	**Model-4 Coefficient St. Error CO_2 Emission**	**Model-1 Coefficient St. Error CO_2 Emission**	**Model-2 Coefficient St. Error CO_2 Emission**	**Model-3 Coefficient St. Error ESG**	**Model-4 Coefficient St. Error CO_2 Emission**
GFN	-0.719***		0.342***	-0.342***	-0.718***		0.345***	-0.337***
	(0.014)		(0.093)	(0.066)	(0.015)		(0.099)	(0.082)
NESGP		-0.188*				-0.193*		
		(0.107)				(0.116)		
GFN*NESGP				-0.071***				-0.072***
				(0.012)				(0.015)
INF	0.003	-0.014	0.010	0.005***	0.002	-0.014	0.010	0.005*
	(0.002)	(0.014)	(0.011)	(0.001)	(0.003)	(0.018)	(0.020)	(0.003)
GDPPC	0.001***	0.000***	0.001***	0.000***	0.000***	0.000***	0.000***	0.000***
	(3.62e)	(0.001)	(0.000)	(3.22e)	(3.87e)	(0.000)	(0.000)	(3.46e)
GI	0.032***	0.060***	0.095***	0.050***	0.032***	0.064*	0.093***	0.050***
	(0.005)	(0.037)	(0.031)	(0.006)	(0.004)	(0.036)	(0.031)	(0.006)
NNR	0.044***	0.146*	0.072***	0.035***	0.044***	0.146***	0.073**	0.035***
	(0.003)	(0.023)	(0.022)	(0.003)	(0.005)	(0.026)	(0.029)	(0.004)
_Cons	-1.036***	-1.139**	2.684***	-1.237***	-1.037***	-1.166**	2.670***	-1.241***
	(0.062)	(0.566)	(0.416)	(0.076)	(0.061)	(0.512)	(0.415)	(0.085)
R^2	0.846	0.089	0.108	0.869	0.829	0.045	0.176	0.858
Adj. R^2	0.839	0.049	0.069	0.862	0.821	0.029	0.139	0.850

Note: *, ** & *** is for the significance level of 10%, 5% and 1%
The Environmental Sustainability Index is measured through CO_2 Emissions

theory's premise that information asymmetry creates the incentive (and opportunity) for businesses to overstate their ESG scores to signal strong sustainability commitments to both internal and external stakeholders. From the perspective of stakeholder theory, business managers may engage in greenwashing practices to balance high profitability with sustainability requirements, thereby maintaining legitimacy among diverse stakeholder groups. These findings are consistent with existing literature on GFN, ESG, and ENSUS. For instance, D. Zhang (2022a) argues that intentional distortions may facilitate greenwashing through selective disclosure, a practice that allows firms to deceive external rating agencies, exploit information asymmetry, and superficially enhance ESG disclosure. Additionally, Ghisetti & Rennings (2014) and Yu et al. (2020) argue that organizations engage in greenwashing practices to attract additional long-term creditors at lower rates by enhancing their perceived ESG reputation. As such, information asymmetry stemming from greenwashing could potentially weaken the role of GFN, but our results show the opposite in the BRICS context, where stronger NESGP enhances environmental outcomes. We therefore accept hypothesis 4b, which states that a NESGP significantly moderates the relationship between GFN and ENSUS.

Finally, we applied the Dumitrescu and Hurlin (2012) panel causality test to determine the nature of causality between the studied variables (Wei et al., 2024). The results of this test, presented in Table 8, confirm the presence of both unidirectional and bidirectional causality among the variables. This finding indicates that the dependent variables and the predictors can influence each other in either direction. The causal linkages from the predictors to the dependent variables are consistent with the relationships identified in the FMOLS and CCR estimations. Overall, these results highlight the importance of GFN and NESGP in maintaining ecological standards through the promotion of a more sustainable environment.

Robustness check

We use a Dynamic Ordinary Least Square (DOLS) estimation to assess the robustness of the findings. Similar to FMOLS, DOLS provides reliable estimates even in the presence of endogeneity and heterogeneity (Latif et al., 2018), and it accommodates for heteroskedastic standard errors. This enables us to fit a model with heteroskedastic residuals while ensuring that the outcomes are free from endogeneity and heteroskedasticity issues (L. Yang, Ma, & Zhao, 2017). Table 9 reports the results of the DOLS estimation, which are consistent with the primary estimates obtained from FMOLS and CCR. The coefficients indicate that GFN and NESGP significantly enhance ENSUS by lowering CO_2 emissions. Furthermore, the results confirm that GFN can significantly enhance NESGP, and that NESGP significantly and negatively moderates the GFN-ENSUS nexus.

Table 8
Dumitrescu Hurlin Panel Causality Test.

Null Hypothesis	**W-stats**	**Z-Stats**	**P-value**
GFN Index-CO_2 Emissions	0.726	-0.433	0.665
CO_2 Emission- GFN Index	7.412	4.028	0.000***
NEGSG-CO_2 Emissions	3.979	4.710	0.000***
C02 Emissions-NESGP	10.138	2.672	0.007***
NESGP-GFN Index	2.406	2.233	1.716**
GFN Index-NESGP	16.345	8.022	0.000***
CO_2 Emission-INF	1.005	0.008	0.994
INF-CO_2 Emission	3.346	3.709	0.000***
CO_2 Emission -GDPPC	6.974	2.351	0.019**
GDPPC-CO_2 Emission	7.099	3.743	0.000***
CO_2 Emission -GI	2.159	0.176	0.859
GI-CO_2 Emission	4.644	5.761	0.000***
CO_2 Emission -NRR	4.532	1.398	0.162
NRR-CO_2 Emission	9.162	2.041	0.041**
NESGP-INF	0.409	-0.935	0.350
INF- NESGP	10.571	2.951	0.003***
NESGP -GDPPC	6.140	2.867	0.004***
GDPPC- NESGP	5.530	-0.303	0.761
NESGP -GI	2.155	1.1826	0.069*
GI- NESGP	7.584	1.827	0.068*
NESGP-NRR	4.037	-1.267	0.205
NRR- NESGP	3.965	2.197	0.028**

Note: *, ** & *** is for the significance level of 10%, 5% and 1%
Environmental Sustainability Index is measured through CO_2 Emissions

Further robustness check

We used Driscoll and Kraay (1998) standards error (DKse) for additional robustness verification. DKse are heteroskedasticity- and

Table 9
Robustness Check (DOLS and DKse).

	Robustness Check Dynamic Ordinary Least Square					Further Robustness Check Driscoll-Kraay standard errors method			
Variables	Model-1 Coefficient St. Error CO_2 Emission	Model-2 Coefficient St. Error CO_2 Emission	Model-3 Coefficient St. Error ESG	Model-4 Coefficient St. Error CO_2 Emission		Model-1 Coefficient St. Error CO_2 Emission	Model-2 Coefficient St. Error CO_2 Emission	Model-3 Coefficient St. Error ESG	Model-4 Coefficient St. Error CO_2 Emission
GFN	-0.720***		0.487*	-0.495*		-0.737***		0.265**	-0.394***
	(0.037)		(0.292)	(0.263)		(0.020)		(0.087)	(0.066)
NESGP		-0.332*					-0.144*		
		(0.191)					(0.062)		
GFN*NESGP				-0.085**					-0.040*
				(0.042)					(0.016)
INF	0.008	-0.054	-0.041	0.006		0.006**	-0.002	0.013	0.003*
	(0.010)	(0.049)	(0.079)	(0.008)		(0.002)	(0.017)	(0.007)	(0.001)
GDPPC	0.000***	0.000**	0.000	0.000***		0.000***	0.000*	0.000**	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)		(6.85e)	(0.000)	(0.000)	(7.67e)
GI	0.019	0.022	0.302***	0.009		0.030***	0.059**	0.109	0.013
	(0.013)	(0.067)	(0.040)	(0.019		(0.005)	(0.020)	(0.052)	(0.013)
NNR	0.047***	0.198***	0.135	-0.007		0.041***	0.134**	0.054**	0.007
	(0.012)	(0.057)	(0.098)	(0.010)		(0.005)	(0.016)	(0.019)	(0.003)
_Cons	-0.956***	-	-	7.44e		-0.962***	-1.317**	2.650**	-0.481*
	(0.155)			(9.81e)		(0.076)	(0.319)	(0.651)	(0.201)
R^2	0.978	0.734	0.373	0.985	Prob>F	0.000	0.000	0.000	0.000
Adj. R^2	0.973	0.682	0.250	0.980	Adj. R^2	0.972	0.647	0.497	0.781

Note: *, ** & *** is for the significance level of 10%, 5% and 1%
The Environmental Sustainability Index is measured through CO_2 Emissions

autocorrelation-consistent and robust to various forms of cross-sectional and temporal dependence (Hoechle, 2007). We estimated fixed-effects models to account for persistent cross-country differences between countries and mitigate heterogeneity bias (Driscoll & Kraay, 1998; Hoechle, 2007). Table 9 reports the results, which show DKSE estimates are consistent with those obtained using the FMOLS and CCR estimation techniques. The estimated coefficients indicate that GFN and NESGP can significantly enhance ENSUS by lowering CO_2 emissions, that GFN can significantly promote the NESGP of BRICS economies, and that NESGP significantly and negatively moderates the GFN-ENSUS nexus.

Conclusion, policy recommendation, and future research

Conclusion

The objective of this study was to empirically examine the interplay between GFN, NESGP and ENSUS (proxied by CO_2 emissions), specifically focusing on the moderating role of NESGP. Addressing a significant gap at the macro-level literature within the context of the BRICS economies, this research is the first to analyze how NESGP impacts the GFN-ENSUS nexus.

The analysis used the FMOLS and CCR estimation techniques to address the issues of cross-sectional dependence and slope heterogeneity, with the DOLS and the estimation of DKse providing a robustness assessment.

The long-run results demonstrate that GFN and NESGP are significantly and negatively correlated with CO_2 emissions, highlighting their important role in fostering ENSUS. Furthermore, we find that GFN significantly and positively impacts NESGP, suggesting that green finance is crucial in enhancing ESG performance within the BRICS economies. Crucially, the findings confirm that NESGP significantly and negatively moderates the relationship between GFN and CO_2 emission. This negative moderation suggests two mechanisms: firstly, it indicates a diminishing marginal impact from additional green financing in countries that have already made substantial ESG investments via NESGP. Secondly, it may reflect the undermining effect of greenwashing (stemming from a conflict of interest between the principal and agent, as agency theory posits) on GFN effectiveness, where firms prioritize the perceived ESG image over genuine ecological impact through a reduction of CO2 emissions.

Policy recommendations

Based on our findings, BRICS economies must implement tailored and collective policies. Nationally, recommendations are as follows:

- Firstly, Brazil should prioritize public-private green credit programs to promote renewable energy expansion which would in term help curb CO_2 emissions.
- Secondly, since green finance markets in Russia are still nascent, the government should develop a robust green taxonomy framework, incentivize energy-efficient initiatives, and implement environmental accounting standards.
- Thirdly, India, with its growing financial market, should strengthen its ESG assessment and corporate reporting frameworks under the supervision of the Reserve Bank of India.
- Fourthly, China should encourage green financial pilot zones by promoting third-party verification systems to enhance transparency in ESG disclosures.
- Fifthly, South Africa should utilize green credits to mitigate persistent energy security issues.

Collectively, governments should encourage businesses to pursue aggressive carbon reduction strategies through targeted tax incentives and other financial support mechanisms. Critically, governments must engage with relevant regulatory agencies to develop a unified set of ESG performance standards and a framework to improve the ESG disclosure to maximize investment confidence as well as ecological impact.

Limitations and future research

The study's primary limitation is the focus solely on the BRICS countries, which restricts the generalizability of the results and may not fully capture country-specific effects due to heterogeneous institutional structures. Future studies are encouraged to employ country-specific methodologies for a more in-depth, informed, and granular policy formulation. Secondly, we have performed a symmetric assessment of the variables; future work should investigate the asymmetric effects of these variables. Thirdly, we used the FMOLS and CCR estimation techniques; we suggest that future research can conduct cross-country analyses using QARDL and NARDL. Finally, incorporating variables such as human capital, the use of renewable energy, government effectiveness and economic freedom (Işık et al., 2023; Işık, Sirakaya-Turk, & Ongan, 2020) will further enrich our understanding of ENSUS determinants and its interplay with GFN and NESGP.

CRediT authorship contribution statement

Zheng Liya: Resources, Project administration, Formal analysis. **Chi-Wei Su:** Project administration, Funding acquisition, Conceptualization. **Salim Baz:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Ziru Xue:** Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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