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DECARBONIZING THE ECONOMY: UNPACKING THE ROLES OF GREEN TRANSITION, NATURAL RESOURCES, FINANCIAL GLOBALIZATION, AND CARBON PRICING IN CARBON INTENSITY

Yasmin Akhtar[1], Yasir Abbas[2], Rehana Bibi[3], Javeria Sherani[4], Syed Ali Asghar Rizvi[5] & Ruqia BiBi[6]

[1]Department of Plant Protection, Ghazi University, Dera Ghazi Khan, Pakistan. Email: yakhter@gudgk.edu.pk
[2]Department of Plant Protection, Ghazi University, Dera Ghazi Khan, Pakistan. Email: yabbas753@gmail.com
[3]Department of Plant Protection, Ghazi University, Dera Ghazi Khan, Pakistan. Email: rbibi@gudgk.edu.pk
[4]Department of Horticulture, Ghazi University, Dera Ghazi Khan, Pakistan. Email: jsherani@gudgk.edu.pk
[5]Department of Plant Protection, Ghazi University, Dera Ghazi Khan, Pakistan. Email: aasgharrizvi@gmail.com
[6]Department of Zoology, Ghazi University, Dera Ghazi Khan, Pakistan. Email: ruqiasaeed34@gmail.com

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ABSTRACT

BRICS economies account for a large share of global emissions; however, the forces that reduce their carbon intensity remain contested. This study examines how the green transition, natural resources, financial globalization, and carbon pricing relate to carbon intensity. We use annual data for Brazil, Russia, India, China, and South Africa from 1990 to 2023. Diagnostics show cross-sectional dependence, a mix of I(0) and I(1) variables, and provide qualified evidence of cointegration. Therefore, we estimate long-run relationships with fully modified OLS and check them using Driscoll-Kraay standard errors. Carbon pricing and green transition are associated with lower carbon intensity under both estimators, with baseline coefficients of -0.567 and -0.139, respectively. Financial globalization is associated with higher carbon intensity (0.519) and a Pollution Haven pattern in which international capital has not, on average, favored cleaner activity. Trade openness is linked to lower carbon intensity, and the natural resource proxy has a small negative association. Population growth also carried a negative sign, which reflected the per-capita measure and should not be read as a mitigation lever. The findings indicate that decarbonizing BRICS economies depends on fiscal pricing and energy transition, and steering foreign capital toward low-carbon assets.

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Corresponding Author Yasmin Akhtar
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Introduction

A few fast-growing economies will play a major role in determining climate targets. In 2023, global fossil CO2 emissions were approximately 36.8 GtCO2, of which China and India contributed approximately 11.9 and 3.2 GtCO2, respectively, to the total of 37.4 GtCO2 (Friedlingstein et al., 2025). Brazil, Russia, India, China, and South Africa (BRICS) are therefore relevant not only within their own countries, but they do not have one emissions profile. The five are very different in terms of coal use, regional structure, and emissions, and a single national story does not apply to the group (Wen et al., 2024). Population is another dimension, as in most income groups, the growth in emissions has been primarily due to population growth (Tamburino et al., 2023). It is a global question, as well as a regional question, what bends the emissions curve in this group.

The energy transition is the most direct lever. Recent BRICS evidence indicates that green energy, green innovation, energy efficiency, and green finance are linked to lower emissions, whereas economic growth and resource rents are linked to higher emissions (Amin et al., 2025). The asymmetric estimates also reveal that renewable energy shares in the energy mix are negatively associated with emissions and that financial development is positively associated with emissions, as it funds it (Mehta & Shah, 2024; Waqas et al., 2026). Green finance and green technology also help lower consumption-based emissions in the long run (Liu et al., 2023). However, the effect is not always the same, as the starting energy mix is very different, ranging from hydropower-rich Brazil to coal-rich India, China, and South Africa.

Natural resources are not as constant as human resources. Over 1989–2021, resource rents, imports, and GDP were positively associated with emissions in BRICS (Huang et al., 2023), and abundance and public-private partnerships were linked to environmental degradation (Çağlar et al., 2022). The effect of resource rents is not uniform but varies depending on geopolitical risk and economic complexity, as seen in 38 countries (Wang et al., 2024). One BRICS study even showed a decrease in emissions, natural resources, and fintech (Kai et al., 2024). The sign is dependent on the extraction, the method of extraction, and the institutions under which the extraction is performed.

The same conflicts occur in the case of external openness. Financial globalization is associated with increased green growth in the BRICS countries using the technique effect (Chen et al., 2023) and increased renewable energy consumption (Majeed et al., 2022). However, when environmental policy was combined with trade and foreign investment, it did not necessarily lead to a decrease in CO2, which the authors interpreted as Pollution Haven behavior. The haven hypothesis is also corroborated by a larger sample of developing countries (Ke et al. 2022). The results are similar for trade openness, with some studies indicating that trade openness increases emissions in the long run in the BRICS countries (Selmey et al., 2024) and others suggesting that trade and economic complexity enhance environmental quality (Çağlar et al., 2022).

This group has the least evidence of carbon pricing worldwide. Although the prices are low in most cases, a meta-analysis of 80 ex-post evaluations of 21 schemes showed that there are significant emission reductions of approximately 5% to 21% (or 4% to 15% after publication bias correction) (Döbbeling-Hildebrandt et al., 2024). Environmental policy stringency is associated with reduced emissions in the long run in BRICS (Udeagha & Ngepah, 2023), and environmental taxes have varying impacts on energy transition and financial development across European economies along the distribution (Fatima et al., 2024). What is lacking is evidence on fiscal pricing itself, in the form of environment-related taxes, and other forces that impact BRICS emissions.

These strands leave space between them. The above studies have focused on green energy, resources, financial integration, or policy stringency individually, for shorter time horizons, or with trade and finance as moderators. We are not aware of any study that integrates green transition, natural resources, financial globalization, and environment-related taxation and controls trade openness and population growth for the five BRICS economies for the entire period of 1990–2023. This is important because the blocks interact. Carbon prices must have cleaner alternatives to alter behavior, and foreign capital can be invested in either coal or solar energy.

Thus, this study poses four questions. Are there any links between lower per-capita carbon emissions and a larger green transition? Do they require additional resources? Is financial globalization a pollution haven or pollution halo? However, do environmental taxes lead to lower emissions when considering trade and demographic pressure? We reply to them with annual data for Brazil, Russia, India, China, and South Africa from 1990 to 2023. Due to the small size of this panel and the high level of interconnectedness, cross-sectional dependence and slope heterogeneity are likely to occur. Therefore, we use second-generation diagnostics and long-run estimators that are robust to these issues, namely, the CIPS and PSADF unit root tests, Westerlund cointegration, FM-OLS, and Driscoll-Kraay standard errors, as a robustness check.

The results were consistent with this finding. Environment-related taxes and green transition are negatively related to emissions, financial globalization is positively related to emissions, and trade openness is negatively related to emissions. Both signs are valid for both estimators; the policy-relevant result is the one on financial globalization: financial openness has not, on average, had the halo effect that is often assumed for emerging markets.

This study makes three contributions. First, it is a combination of four mechanisms in one model and sample. Second, it covers 34 years, which is beyond the scope of many BRICS studies that do not go beyond 2020. Third, it signals to the policy reader where evidence is qualified, such as mixed cointegration tests and conflicting slope heterogeneity results, and thus how much weight is given to each finding. The remainder of this paper is organized as follows. Section 2 reviews the literature, Section 3 presents the theoretical framework, Section 4 reports the results and discussion, and Section 5 presents the conclusion and policy implications.

Review of literature

Green transition and carbon intensity

The argument for a green transition begins with simple accounting: emissions per unit of energy are lower when fossil fuels are substituted with low-carbon energy sources. The evidence for the BRICS countries mostly agrees. Renewable energy use reduced long-run CO2 emissions in Brazil, Russia, India, and China between 1990 and 2020, whereas policy uncertainty increased emissions, and corruption control contributed to emissions (Sadiq et al., 2024). A 1% rise in renewable energy consumption is associated with a 0.75% drop in emissions, and a 1% rise in green innovation is associated with a 0.041% drop in emissions for consumption-based emissions in the period 1990-2019 (Shekhawat et al., 2025). Asymmetric estimates are in the same direction and suggest that financial development has a positive impact by providing financing for cleaner energy (Mehta and Shah, 2024; Waqas et al., 2026). Evidence on green energy, innovation, efficiency, and green finance helps paint the picture (Amin et al., 2025), and green finance and technology help reduce trade-adjusted emissions (Liu et al., 2023).

However, the impact is not consistent. Alam et al. (2024) found that the renewable transition has no significant impact on the growth rate of CO2 emissions in BRICS during the period 1996-2021. This is important in combination with improved institutions. In the G7, the green energy transition is only beneficial for environmental sustainability in Japan, while policy stringency does not have a consistent impact on any member (Degirmenci et al., 2025). A 1% increase in renewable energy is associated with a 1.25% decrease in per-capita emissions in 43 resource-dependent economies, with greater reductions in those with a stronger rule of law and voice and accountability (Szetela et al., 2022). Two lessons follow. The sign is typically negative, but the magnitude varies with the institutions and initial energy mix. Some of these studies also consider consumption-based emissions or composite sustainability indices, and the impact of a green transition on per-capita emissions in BRICS is not as evident.

Natural resources and carbon intensity

The resource literature has two viewpoints: a curse viewpoint and a blessing viewpoint, and the BRICS evidence supports both viewpoints to some extent. Liu et al. (2022) disaggregated rents for 1995-2018 and show that total resource rents are correlated with a decrease in CO2 emissions, whereas mineral, forest, and oil rents are correlated with an increase in CO2 emissions. Other BRICS research shows that resource rents are positively associated with imports, GDP, and emissions (Huang et al., 2023) and that resource rents have an impact on emissions beyond economic growth (Amin et al., 2025). However, according to Kai et al. (2024), emissions are lower in the natural resources and fintech countries of the BRICS in the period 2000-2020.

Part of the disagreement is due to the larger sample size. Resource rents are associated with increased emissions in the long run in 38 countries, depending on the level of geopolitical risk and

economic complexity, with rents decreasing emissions under high complexity (Wang et al., 2024). Thus, the sign relies on the nature of what is taken, how, and under which institutions. The bulk of this work is based on the measurement of resources in terms of rents. The proxy used here, dependence on primary activity (agriculture, forestry, and fishing), is a measure of structural change and has not been studied much in the BRICS panel.

Financial globalization and carbon intensity

This connection is framed in two opposing views. Pollution halo view: Foreign capital imports cleaner technology and management methods. FDI reduces the ecological footprint and consumption- and production-based emissions in 46 emerging economies for 2010–2020 (Padhan & Bhat, 2026). Financial globalization increases green growth via the technique effect (Chen et al., 2023) and increases renewable energy consumption in the long run (Majeed et al., 2022) in the BRICS countries. The BRICS study on simultaneous equations shows that emissions are lowered with FDI and renewable adoption in the time frame of 2000–2022 (Kayani et al., 2024).

The Pollution Haven view is the exact opposite. Globalization leads to more CO2 emissions, and the Haven hypothesis is valid in 77 developing economies (Ke et al., 2022). Financial globalization is associated with a 0.12% rise in consumption-based emissions in BRICS (Shekhawat et al., 2025), and net FDI receipts are associated with an increase in the growth rate of emissions in BRICS (Alam et al., 2024). The interaction between environmental policy stringency, trade, and FDI has a positive impact on emissions (Mahalik et al., 2024). The financial system is no exception. Financial development increases GHG emissions in four out of five BRICS economies during 1991–2020 (Dhingra, 2023), but in BRICS-T, it decreases GHG emissions directly in the long run, while growth, trade openness, and population growth increase GHG emissions (Yıldırım et al., 2025). Financial globalization has a mixed impact on environmental sustainability in Türkiye (Yardımcı & Oskay, 2025). The direction of the effect seems to be dependent on the indicator, sample, and outcome, and not a single mechanism.

Financial globalization and Carbon Intensity

At the global level, the evidence for the effectiveness of pricing carbon to reduce emissions is the strongest. A meta-analysis of 80 ex-post evaluations of 21 schemes shows that the reductions are substantial, ranging from 5% to 21% (or 4% to 15% after publication bias correction) (Döbbeling-Hildebrandt et al., 2024). Research on environment-related taxes is generally consistent but varies specifically. Environmental taxes lower carbon intensity in more than half of the quantiles in China and foster environmental innovation (Zhang et al., 2023). Environmental taxes reduce emissions in 26 EU countries, energy taxes reduce emissions, and transport taxes increase emissions (Khan et al., 2023; Özmen & Mutascu, 2025). The coefficient of environmental tax is highly negative in 23 African economies, with governance having little effect (Kamil et al., 2025). BRICS: Environmental policy stringency, green innovation, and renewable R&D reduce long-run emissions (Udeagha &

Ngepah, 2023). However, stringency is not always correlated with emissions reduction when combined with trade and FDI (Mahalik et al., 2024), and in European economies, the link between environmental taxes and energy transition is only visible in higher quantiles (Fatima et al., 2024).

These findings indicate that financial and trade openness affect the price of carbon. Capital can go to jurisdictions with less stringent policies and offset the policy signal, or it can invest in cleaner assets and reinforce the policy signal. The results of the ten emerging economies (including four BRICS countries) indicate that green financing enhances the emission reduction impact of trade openness; the greater the green financing, the stronger the emission reduction impact. No single BRICS model analyzes fiscal pricing and financial globalization.

Research gap

The review identified four gaps. First, the BRICS studies analyzed one or two blocks at a time: financial globalization and green innovation (Chen et al., 2023), resource rents and green finance (Amin et al., 2025), or policy stringency and trade and FDI (Mahalik et al., 2024). We could not find a BRICS panel that includes green transition, natural resources, financial globalization, and environment-related taxation. Second, this group is not well measured in terms of carbon pricing. The evidence for the tax is mainly from China, the EU, and Africa, and for the BRICS, mainly from policy stringency indices, not environment-related taxes.

Third, there are variations in outcomes and proxies among studies. Many rely on total, consumption-based, or load capacity measures, and resources are primarily captured via rents. The use of per-capita emissions and structural proxies for resource dependence is less common. Fourth, there is uncertainty regarding the demographic impact. Population growth is the primary factor behind the global increase in emissions for most income groups (Tamburino et al., 2023) and has a positive impact on the BRICS-T panel (Yıldırom et al., 2025); however, its direct impact on a per-capita measure for the five core economies is not frequently tested.

Theoretical framework

This study analyzes the per-capita carbon emissions in Brazil, Russia, India, China, and South Africa (1990-2023) because of the combined effect of energy structure, dependence on resources, external openness, carbon policy, and demographic pressure. The argument is presented in four bodies of theory: the STIRPAT identity as the organising frame, the pollution haven and halo debate for the external channels, resource curse reasoning for natural resources, and Pigouvian and Porter logic for carbon pricing.

Dietz and Rosa (1997) developed a model of environmental impact that is a function of population, affluence, and technology (STIRPAT). It is estimated in logs, which makes the coefficients elasticities and comparable across five very different economies, making it well-suited for this study. In this instance, the demographic factor is population growth (PG). The technology and

institutional terms are green transition (GT) and carbon pricing (CP), respectively. Natural resources (NR), financial globalization (FG), and trade openness (TO) are the structural and external factors that affect the increase or decrease in emissions due to technology and scale.

The energy transition theory states that the transition from fossil fuels to low-carbon energy decreases emissions per unit of energy. This is supported by recent BRICS evidence. Amin et al. (2025) find that green energy, green technological innovation, energy efficiency, and green finance are conducive to environmental sustainability in the BRICS economies in 1995-2022, while economic growth and natural resource rents are associated with emissions. The mix of the group is quite diverse, ranging from hydropower in Brazil to gas in Russia and coal in China, India, and South Africa. Thus, on average, the impact of GT should be negative, but with a varied impact across countries, and the impact should be slow to materialize where the share of renewables is low.

Çağlar et al. (2022) found a relationship between natural resource abundance, public-private partnerships, and environmental degradation in the BRICS countries during the period 1990-2018. Two competing mechanisms are involved. The pollution haven view is that open capital markets attract carbon-intensive capital to less stringent regulations. Pollution halo view: Foreign capital will bring cleaner technology and management. Both have evidence from BRICS-T for the period 2000-2020: de facto financial globalization increases emissions, and de jure measures decrease emissions. Another BRICS study revealed that financial globalization has a positive impact on green growth through the technique effect. The complex theoretical framework is presented in Figure-1, the net effect depends on the direction of capital and governance quality.

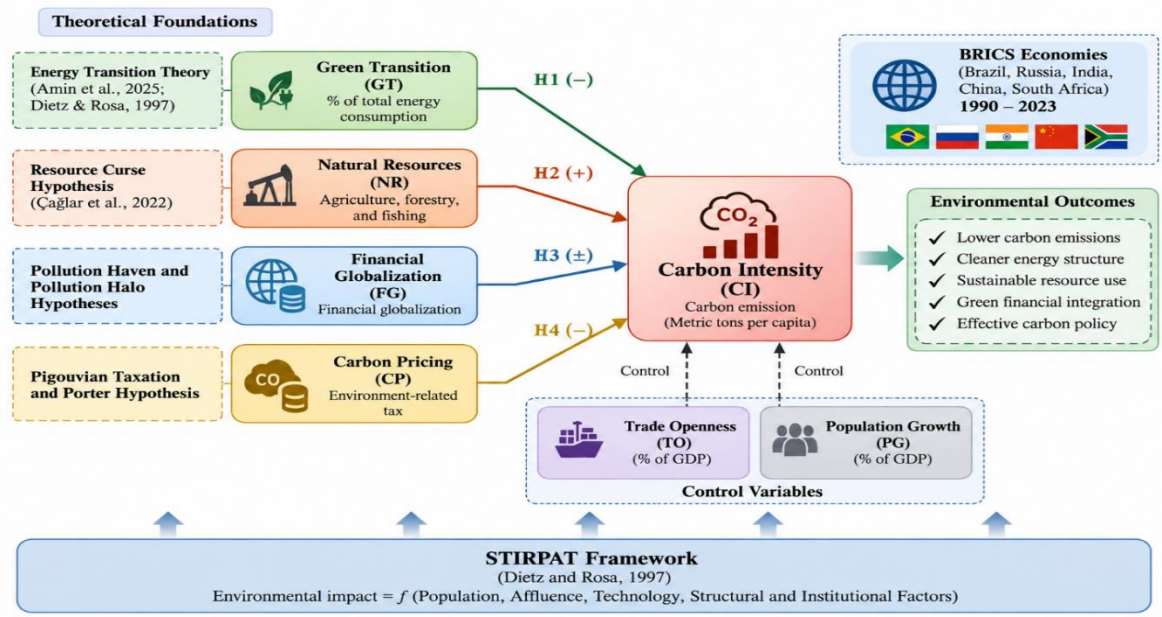


Figure 1: Theoretical Framework

Data

We employ an annual panel for the five original BRICS countries (Brazil, Russia, India, China, and South Africa) from 1990 to 2023. Carbon intensity (CI) is the dependent variable and is defined as CO2 emissions in metric tons per capita. The explanatory variables follow the theoretical framework outlined in Section 3. The green transition (GT) is the proportion of renewable energy in the total final energy consumption. Natural resources (NR) are the value added of agriculture, forestry, and fishing as a share of GDP, which captures structural dependence on primary activity and non-resource rents. Financial globalization (FG) is the KOF financial globalization index, which is a composite of de facto and de jure measures of capital account openness (Gygli et al., 2019). Environmental tax revenue from OECD data is referred to as carbon pricing (CP). Trade openness (TO) is defined as total trade divided by GDP, and population growth (PG) is the percentage change in the population per year. Table 1 provides the definitions and sources.

Table 1: Variables Description

Symbol	Description	Measurement unit	Source
CI	Carbon Intensity	Carbon emission (Metric tons per capita)	WDI
GT	Green Transition	% of total energy Consumption	WDI
NR	Natural Resources	Agriculture, forestry, and fishing	WDI
FG	Financial Globalization	financial globalization	KOF Index
CP	Carbon Pricing	Environment related tax	OECD
TO	Trade Openness	(% of GDP)	WDI
PG	Population Growth	(% of GDP)	WDI

The specification is based on STIRPAT logic, which posits that environmental impact is a function of population, affluence, and technology (Dietz & Rosa, 1997; York et al., 2003). Demographic terms are population growth, technology, and institutional terms are green transition and carbon pricing, and structural and external conditions are natural resources, financial globalization, and trade openness. The base model is:

$$\ln CI_{it} = \alpha_i + \delta_t + \beta_1 \ln GT_{it} + \beta_2 \ln NR_{it} + \beta_3 \ln FG_{it} + \beta_4 \ln CP_{it} + \beta_5 \ln TO_{it} + \beta_6 \ln PG_{it} + \varepsilon_{it} \quad (1)$$

Where i index the five countries and t is the year. α_i is a country-specific intercept, δt is a linear trend that absorbs common drift, and εit is the error term. The framework suggests that $\beta 1$ and $\beta 4$ are negative. The signs of $\beta 2$, $\beta 3$, and $\beta 5$ are left open as they are dependent on whether the pollution haven or halo effect is more important for finance and whether scale or technique effects are more important for trade. In a total-emissions model, the sign of $\beta 6$ should be positive, but in the case of CI, it is measured per capita and may vary.

Fully modified OLS

Phillips and Hansen (1990) suggested using FM-OLS for single cointegrating equations, and Pedroni (2000, 2001) generalized it to heterogeneous panels. It solves two issues that are problematic in ordinary least squares regressions of cointegrated variables: endogeneity of the regressors and serial correlation of errors. The panel regression is discussed in this section.

$y_{it} = \alpha_i + x_{it}'\beta + u_{it}$ (2)

$x_{it} = x_{i,t-1} + \varepsilon it$ (3)

The vector of explanatory variables is xit, and the regressors are integrated into order one, with y_{it} being lnCI. The long-run covariance matrix of the error vector (u_{it}, εit) is Ωi, and the one-sided long-run covariance is Δ_i. The dependent variable is transformed to correct for endogeneity.

$y_{it} = y_{it} - \hat{\omega}_u\varepsilon,i\ \hat{\Omega}_\varepsilon\varepsilon,i\text{^}(-1)\ \Delta x_{it}$ (4)

A bias term is subtracted from the numerator of the estimator to correct for serial correlation:

$\hat{\beta}_FM = [\Sigma i\ \Sigma t\ (x_{it} - \bar{x_i})(x_{it} - \bar{x_i})']\text{^}(-1)\ [\Sigma_i\ (\Sigma_t\ (x_{it} - \bar{x_i})\ y+it - T\ \hat{\Delta}+u\varepsilon,i)]$ (5)

where $\hat{\Delta}+_u\varepsilon,i$ is the corrected, one-sided, long-run covariance. The long-run covariances are estimated nonparametrically with [Bartlett kernel and Newey-West bandwidth: confirm]. The estimator is super-consistent, and the test statistics are asymptotically normal; hence, standard z-tests can be used for each coefficient. Specify whether the estimator is the pooled or group-mean version and the software command.

There are four reasons for using FM-OLS. It corrects for endogeneity and serial correlation without lag selection, which is useful in a panel with few countries. This enables country-specific intercepts and a deterministic trend. It is a common long-run estimator in recent panel studies on emissions, such as environmental taxes and energy transition (Fatima et al., 2024), and green finance and financial globalization (Yardımcı & Oskay, 2025). It also provides coefficients that can be read as long-run elasticities. For comparison, the same specification is re-estimated using Driscoll-Kraay standard errors (Driscoll & Kraay, 1998), which are robust to heteroskedasticity, serial correlation, and cross-sectional dependence. This method has also been applied as a robustness check in recent studies on BRICS and emerging economies (Mahalik et al., 2024; Xia et al., 2024).

Results and Discussion

Table 2 presents the descriptive statistics of the BRICS economies. The mean of carbon intensity (CI) is 1.313, and the mean of green transition (GT) is 2.849, which shows that there is variation in the distribution of the study variables. The average of natural resources (NR) is 1.422, financial globalization (FG) is 3.824, and carbon pricing (CP) is −1.409. The average for trade openness (TO) is 3.625, and the average for population growth (PG) is −0.140. The skewness values show that CI,

GT, FG, CP, TO, and PG are negatively skewed, while NR is positively skewed. The kurtosis values indicate significant differences in the distributional shape, especially for FG (5.121) and PG (6.284) which indicate relatively heavy tails and possible extreme observations. Overall, these descriptive patterns indicate that there is much variation across the variables; therefore, further econometric testing is warranted before attempting to estimate relationships with carbon intensity.

Table 2: Features of variables

Factors	Mean	Min	Max	SD	Skewness	Kurtosis
CI	1.313	-0.438	2.682	0.913	-0.211	1.633
GT	2.849	1.157	3.969	0.972	-0.529	1.851
NR	1.422	-0.146	3.068	0.728	0.331	2.579
FG	3.824	2.398	4.500	0.378	-1.176	5.121
CP	-1.409	-6.166	2.477	1.813	-0.313	2.084
TO	3.625	2.718	4.706	0.391	-0.438	2.536
PG	-0.140	-3.503	1.124	0.826	-1.747	6.284

Table 3 shows the correlations between the study variables for the BRICS economies. Carbon intensity (CI) has a negative correlation with the GT(-0.924) and CP(-0.774) and a positive correlation with NR (0.609), financial globalization (FG, 0.556) and trade openness TO (0.671). Population growth (PG) was negatively correlated with CI (-0.554), indicating that population growth is linked to a decrease in per-capita carbon emissions in the sample. The highest correlation between the explanatory variables was between CI and GT, followed by the negative correlation between GT and NR (-0.730), and between GT and TO (-0.704). These correlations provide preliminary evidence of the direction and magnitude of bivariate relationships but do not necessarily indicate causal relationships. The correlation between CI and GT is very high (-0.924), and this should be considered along with the VIF results to check the multicollinearity between the regressors.

Table 3: correlation

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) CI	1.000						
(2) Gt	-0.924*	1.000					
	(0.000)						
(3) NR	0.609*	-0.730*	1.000				
	(0.000)	(0.000)					
(4) FG	0.556*	-0.416*	0.201*	1.000			
	(0.000)	(0.000)	(0.011)				
(5) CP	-0.774*	0.624*	-0.365*	-0.263*	1.000		
	(0.000)	(0.000)	(0.000)	(0.003)			
(6) TO	0.671*	-0.704*	0.575*	0.470*	-0.325*	1.000	

	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
(7) PG	-0.554*	0.630*	-0.530*	-0.238*	0.187*	-0.414*	1.000
	(0.000)	(0.000)	(0.000)	(0.005)	(0.038)	(0.000)	

*** p<0.01, ** p<0.05, * p<0.1

Multicollinearity diagnostics are shown in the iceberg plot in Figure-2 with variance inflation factors (VIF) above the waterline and reciprocal VIF values (or tolerance) below the waterline. Carbon pricing (CP) has the highest VIF value of 3.811, followed by trade openness (TO, 3.308), and the lowest VIF value is for population growth (PG, 1.176). All the VIF values of the six explanatory variables were less than the usual cut-off value of 5, indicating that there was no serious multicollinearity. The corresponding tolerance values were between 0.262 for CP and 0.850 for PG, which were well above the critical value of 0.10. In general, the diagnostics suggest that multicollinearity is not a significant problem in estimating the proposed model. However, these findings do not preclude other econometric issues, such as cross-sectional dependence, endogeneity, or slope heterogeneity, which must be tested separately.

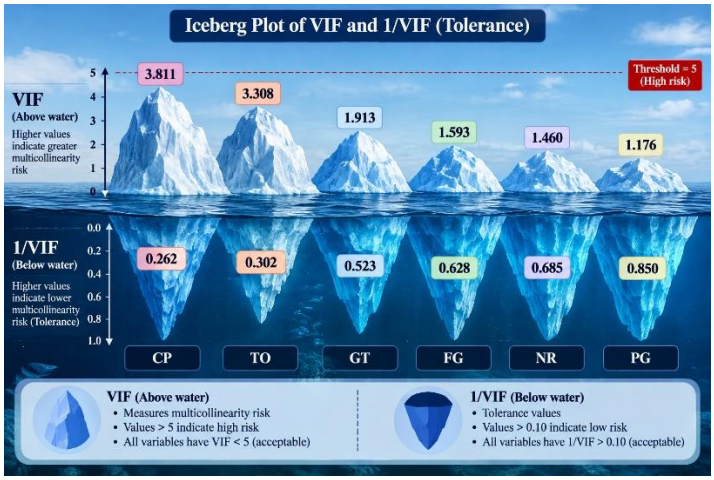


Figure 2: Test for multicollinearity

Table 4 presents the preliminary diagnostic tests for slope heterogeneity and heteroskedasticity. Both the delta (10.112, $p < 0.01$) and adjusted delta (11.676, $p < 0.01$) statistics are significant, and the Pesaran and Yamagata (2008) test rejects the null hypothesis of slope homogeneity, suggesting significant cross-country heterogeneity in the estimated relationships. However, the Blomquist and Westerlund (2013) test does not reject slope homogeneity, and the delta (0.103, $p = 0.918$) and adjusted delta (0.118, $p = 0.906$) statistics are insignificant. This contradictory evidence indicates that the heterogeneity of slopes should be evaluated with caution and not be considered a fact. In addition, the Breusch–Pagan/Cook–Weisberg test is used to test the null hypothesis of constant variance, which is rejected ($\chi^2 = 12.28$, $p = 0.0005$), indicating the presence of heteroskedasticity.

The results indicate that estimators and inference procedures which accommodate heteroskedasticity and, subject to further diagnostics, cross-country BRICS panel heterogeneity are suitable.

Table 4: pre-diagnostics

Testing for slope heterogeneity Pesaran, Yamagata. 2008. H0: The slope coefficients are homogenous.		Testing for slope heterogeneity Blomquist, Westerlund. 2013. H0: The slope coefficients are homogenous.	
	Delta	p-value	Delta	p-value
	10.112	0.000	0.103	0.918
adj.	11.676	0.000	0.118	0.906
Breusch–Pagan/Cook–Weisberg test for heteroskedasticity chi2(1) = 12.28; Prob > chi2 = 0.0005				

The results of the cross-sectionally augmented IPS (CIPS) and panel stationarity (PSADF) unit root tests at levels and first differences are reported in Table 5. From the CIPS results, it is found that the variables CI, GT, FG, TO, and PG are stationary at levels, while NR and CP are stationary after the first differencing, which means that there is a mix of (I(0)) and (I(1)) variables. The PSADF results also indicate that CI, GT, FG, CP, and TO are stationary at levels, while NR and PG are non-stationary at levels but stationary after the first differencing. The overall results suggest that the variables are integrated of order zero or one. This integration pattern allows for the possible use of ARDL-type estimation techniques if the other model assumptions are met. However, the NR CIPS level statistic is not significant in the table reported, and the CP and CIPS first difference statistics are also not significant; therefore, the integration classifications should be compared to the appropriate critical values before finalizing the results.

Table 5: Unit root test

	CIPS		PSADF	
Variables	Level	1st Diff	Level	1st Diff
CI	-2.339**	-3.355***	-2.536**	-2.424*
GT	-2.353**	-3.840***	-2.553**	-2.706**
NR	-3.840	-5.107***	-1.849	-4.586***
FG	-2.705***	-5.675***	-2.460**	-4.329***
CP	0.242	-1.990	-3.219***	-2.592**
TO	-2.795***	-4.333***	-3.123***	-4.109***
PG	-2.825***	-4.003***	-2.209	-4.473***

Table 6 shows the results of the cross-sectional dependence (CSD) test for the variables in the BRICS panel. The null hypothesis of cross-sectional independence was rejected for CI (CD = 7.389, p = 0.022), GT (CD = 9.957, p = 0.015), NR (CD = 10.032, p = 0.025), FG (CD = 15.235, p < 0.01), TO (CD = 5.411, p < 0.01), and PG (CD = 2.629, p = 0.009). However, carbon pricing (CP; CD = 1.327, p = 0.184) does not reject the null hypothesis, which means that there is not enough evidence of cross-sectional dependence for this variable. The positive mean correlation coefficients also suggest that the cross-country associations are mostly positive, with the highest mean absolute correlation coefficient of 0.85 for FG and the lowest of 0.30 for PG. The results indicate that all variables are cross-sectionally dependent, which may be due to common economic shocks, regional interactions, and common environmental and/or financial developments. Thus, second-generation panel unit root tests and estimators that allow for cross-sectional dependence are suitable for the empirical analysis that follows.

Table 6: CSD

Variable	CD-test	p-value	average joint T	mean ρ	mean abs(ρ)
CI	7.389	0.022	32.00	0.41	0.56
GT	9.957	0.015	32.00	0.56	0.56
NR	10.032	0.025	32.00	0.56	0.56
FG	15.235	0.000	32.00	0.85	0.85
CP	1.327	0.184	32.00	0.07	0.53
TO	5.411	0.000	32.00	0.30	0.45
PG	2.629	0.009	32.00	0.15	0.30

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

Table 7 shows the panel cointegration results based on the Kao, Pedroni, and Westerlund tests to check the presence of a long-run equilibrium relationship between the study variables. The Kao test provides relatively strong evidence of cointegration, as the modified Dickey–Fuller, Dickey–Fuller, augmented Dickey–Fuller, and unadjusted modified Dickey–Fuller statistics reject the null hypothesis of no cointegration at the 5% level. However, the unadjusted Dickey–Fuller test is only significant at the 10% level (p = 0.0595). The Pedroni results are mixed: the Phillips–Perron (p = 0.0623) and augmented Dickey–Fuller (p = 0.0241) statistics are significant at the 10% and 5% levels, respectively, but the modified Phillips-Perron test is insignificant (p = 0.1053). The Westerlund variance ratio statistic (2.5680, p = 0.0051) also rejects the null hypothesis of no cointegration at the 1% level, suggesting the existence of a long-run relationship. The overall results provide qualified evidence of cointegration between carbon intensity, green transition, natural resources, financial globalization, carbon pricing, trade openness, and population growth in the BRICS economies.

Table 7: Cointegration

Kao	Statistics	P-value
Modified Dickey-Fuller t	-3.6680	0.0001
Dickey-Fuller t	-1.9685	0.0245
Augmented Dickey-Fuller t	-1.6972	0.0448
Unadjusted modified Dickey-Fuller t	-2.0438	0.0205
Unadjusted Dickey-Fuller t	-1.5586	0.0595
Pedroni		
Modified Phillips-Perron t	1.2520	0.1053
Phillips-Perron t	-1.5358	0.0623
Augmented Dickey-Fuller t	-1.5358	0.0241
Westerlund		
Variance ratio	2.5680	0.0051

Table 8 shows the fully modified ordinary least squares (FM-OLS) estimates of the long-run relationships between carbon intensity (CI) and its explanatory variables in the BRICS economies. The results indicate a statistically significant negative relationship between Carbon pricing (CP) and CI (β=-0.567, $p < 0.01$), suggesting that an increase in environmental fiscal measures may help decrease emissions. The coefficient of trade openness (TO) is also negative and significant (β =-0.247), $p = 0.022$), indicating that technology transfer and efficiency gains may outweigh the emissions-increasing effect. The coefficient of green transition (GT) is significant and negative (β =-0.139, $p < 0.01$), in line with the environmental benefits of shifting to cleaner energy systems. Financial globalization (FG), on the other hand, is positively related to CI (β =0.519, $p < 0.01$), which is consistent with the idea that international financial integration facilitates carbon-intensive investment. The relationship between population growth (PG) and CI is significant and negative (β =-0.278, $p < 0.01$) and needs to be interpreted considering per-capita emissions and demographic changes. The linear trend (β =0.004) was positive and statistically significant ($p = 0.048$), suggesting a small temporal increase in CI after controlling for the regressors included. The FM-OLS results indicate the various environmental connections of green transition, environmental taxation, and trade openness vis-à-vis financial globalization.

Table 8: FM-OLS results

CI	Coefficient	Std. err.	z	P>z
CP	-0.567	0.108	-5.24	0.000
TR	-0.037	0.013	-2.77	0.006
FG	0.519	0.075	6.90	0.000
GT	-0.139	0.012	-11.4	0.000
TO	-0.247	0.108	-2.29	0.022

PG	-0.278	0.042	-6.56	0.000
linear	0.004	0.002	1.98	0.048
_cons	1.504	0.665	2.26	0.024

Table 9 presents the Driscoll–Kraay standard error estimates as a robustness check for the baseline FM-OLS estimates presented in Table 8. The baseline finding is confirmed by the CP's statistically significant negative association with CI, which is −0.854 ($p < 0.01$). Likewise, GT is negatively related to CI ($\beta = -0.109$, $p < 0.01$), and TO has a significant negative coefficient of −0.284 ($p = 0.004$). In contrast, FG is positively and significantly associated with CI ($\beta = 0.505$, $p < 0.01$), as the FM-OLS estimates. PG was also negatively associated with CI ($\beta = -0.167$, $p = 0.001$). The coefficient signs and statistical significance are the same for all five explanatory variables in both specifications, although the magnitudes of the coefficients differ from those in Table 8. Overall, these results provide greater confidence in the qualitative validity of the baseline results to an alternative inference procedure that is valid under appropriate asymptotic conditions for heteroskedasticity, serial correlation, and cross-sectional dependence. However, Driscoll–Kraay standard errors primarily correct for statistical inference and do not address endogeneity or causal relationships alone.

Table 9: Robust test (Drisc Kraay)

CI	Coefficient	std. err.	t	P>t
CP	-0.854	0.068	-12.65	0.000
TR	-0.012	0.006	-2.21	0.036
FG	0.505	0.048	10.42	0.000
GT	-0.109	0.015	-7.13	0.000
TO	-0.284	0.091	-3.14	0.004
PG	-0.167	0.043	-3.86	0.001
_cons	2.788	0.484	5.76	0.000

Discussion

The findings reveal that the five BRICS economies have varying trends in the relationship between environmental policy, energy transition, and international economic integration. The results indicate that there are negative relationships between environment-related taxation, green transition, and per-capita carbon emissions, and a positive relationship between financial globalizations. The signs of these relationships are unchanged under the FM-OLS and Driscoll–Kraay estimations, providing qualitative robustness.

The coefficient of green transition is negative and significant at −0.139 (FM-OLS) and −0.109 (Driscoll–Kraay) methods. This finding aligns with the evidence that renewable energy helps reduce long-run emissions in BRICS (Sadiq et al., 2024; Shekhawat et al., 2025) and that green energy, technological innovation, energy efficiency, and green finance support environmental sustainability (Amin et al., 2025; Mehta & Shah, 2024; Waqas et al., 2026). However, the relatively modest coefficient might be due to variations in national energy structures, transition speeds, and institutional capacity. This contrasts with the continued use of coal in China, India, and South Africa (Wen et al., 2024). The results align with Alam et al. (2024) and indicate that the transition to cleaner energy sources may require additional institutional support to achieve significant emissions reductions. However, the high negative correlation between the green transition and carbon intensity (r = -0.924) should be taken with a pinch of salt, as common trends might affect the estimated relationship. Thus, the coefficient should be viewed as a conditional long-run association and not as causal effect.

The absolute value of the coefficient for environment-related taxation is the largest negative coefficient, -0.567 under FM-OLS and -0.854 under the Driscoll-Kraay estimation. This finding aligns with the evidence that carbon pricing helps reduce emissions (Döbbeling-Hildebrandt et al., 2024), environmental taxes help improve carbon performance in China and Europe (Khan et al., 2023; Zhang et al., 2023), and environmental policy measures help reduce emissions in African and BRICS economies (Kamil et al., 2025; Udeagha & Ngepah, 2023). However, these results contradict those of Mahalik et al. (2024), who found that the stringency of policies is not always associated with a decrease in emissions when considering trade and foreign investment. This difference may be partly due to differences in the measurements. Environmental taxes and composite policy indices reflect various aspects of environmental governance, and the impacts of individual tax categories can be contradictory (Özmen & Mutascu, 2025). The results suggest that the overall relevance of environmental taxation is supported, but the effect of a specific carbon-pricing instrument cannot be identified because of the differences in the magnitudes of the coefficients.

Financial globalization is positively related to carbon intensity, with coefficients of 0.519 and 0.505 in the two specifications. This result confirms the Pollution Haven hypothesis and is consistent with the results of other studies that have found a positive relationship between globalization, financial integration, foreign investment, and emissions (Alam et al., 2024; Ke et al., 2022; Mahalik et al., 2024; Shekhawat et al., 2025). However, in contrast to the pollution halo evidence, financial globalization can foster green growth and renewable energy use (Chen et al., 2023; Majeed et al., 2022), and foreign direct investment can enhance environmental outcomes in emerging economies (Padhan & Bhat, 2026). This difference could be due to the environmental impact being assessed: renewable energy uptake and green growth can be enhanced even if the total emissions per capita are rising because of growth in industrial activity. Financial globalization also exhibits the highest cross-country co-movement, with a mean correlation of 0.85, suggesting a large common variation

across the BRICS countries. The results indicate that international capital should be directed towards renewable energy and cleaner production and that financial openness is not necessarily good for the environment. This interpretation is supported by evidence that green financing enhances the emissions-reducing relationship of trade openness (Xia et al., 2024).

Carbon intensity is negatively associated with natural resources, although the association is small (FM-OLS: -0.037; Driscoll-Kraay: -0.012). This result is consistent with studies that have revealed that resource rents and resource abundance are linked to reduced emissions in the BRICS countries (Kai et al., 2024; Liu et al., 2022) but contradicts studies that have shown that resource rents and resource abundance are associated with environmental degradation (Amin et al., 2025; Çağlar et al., 2022; Huang et al., 2023). It is important to note that the indicator in this study is for agriculture, forestry, and fishing, and not fossil fuel extraction or natural resource rents. Thus, it is not a test of the resource curse hypothesis but rather a measure of the association between primary sector activity and per-capita emissions. This finding highlights the need to differentiate between primary sector structure and extractive dependence, as the environmental impact of resource rents depends on economic complexity and geopolitical risk (Wang et al., 2024).

In summary, the results suggest that energy transition, environmental fiscal policy, and international integration are all necessary for decarbonization in BRICS. The negative coefficients of cleaner energy and environmental taxation are related to emission reductions, and the positive coefficient of financial globalization underscores the significance of investment allocation. The negative trade openness coefficient suggests that the efficiency and technology effects may outweigh the emissions-increasing scale effects. These relationships are subject to the econometric limitations of the study, variable measurements, and country heterogeneity.

Conclusion and Policy Implications

This study investigates the long-run relationship between carbon intensity and green transition, natural resources, financial globalization, and environment-related taxation for the five BRICS economies over the period 1990-2023. The results reveal that the green transition, environment-related taxation, and trade openness are negatively related to per-capita carbon emissions, whereas financial globalization is positively related to emissions. These relationships were stable under the Driscoll–Kraay estimation. The natural resources proxy also has a small negative coefficient, but this is limited by the fact that it is measured as agriculture, forestry, and fishing. Overall, the results suggest that cleaner energy, well-designed environmental fiscal policies, and environmentally oriented foreign investment are relevant factors to consider when pursuing decarbonization. However, the coefficients should be interpreted as long-run associations, not as definitive causal effects, because of mixed diagnostic evidence and measurement limitations.

Policy priorities should be placed on strengthening environmental fiscal instruments, accelerating the transition to renewable energy, and making financial globalization environmentally friendly.

Environmental taxes should be based on emissions-intensive activities and consider enforcement and distributional impacts. National energy systems and infrastructure should be considered as green transition strategies. Financial regulators must improve environmental reporting and climate risk analysis to encourage investment in renewable energy and less polluting industrial manufacturing. Trade policies should promote access to efficient technology and enhance environmental standards. Finally, resource and demographic policies should be directed towards sustainable primary production, efficient infrastructure, clean transport, and low-carbon public services.

There are several limitations to this study: the five countries, the various national structures, and the measurement of the key variables. In particular, the natural resource indicator fails to directly reflect resource rents, and environment-related taxes are not the same as explicit carbon pricing. Some evidence of cross-sectional dependence, slope heterogeneity conflicts, and mixed cointegration evidence also exists. Future studies should consider estimators that allow for cross-sectional dependence and heterogeneous slopes, disaggregated measures of resources and environmental taxes, and interactions between financial globalization, green transition, and environmental governance. Nonlinear and country-specific analyses may reveal variations in emission distributions and structural regimes. Lastly, per capita, aggregate, and consumption-based emissions would help understand the impact of trade and international investment on the overall decarbonization process.

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