Name of Publisher: BRIGHT EDUCATION RESEARCH SOLUTIONS

Area of Publication: Business, Management and Accounting (miscellaneous)

Journal of Management & Social Science

ISSN Online: 3006-4848
ISSN Print: 3006-483X

https://rjmss.com/index.php/7/about

Let's Start!

RECOGNIZED IN "Y" CATEGORY BY

[Decoding BRICS Green Growth in the 2010s: An Empirical Analysis of Policy, Technology, and Investment]

Dr. Farah Nasreen
Department of Commerce, University of Gujrat. Email: Farah.nasreen@uog.edu.pk
Dr. Anam Tasawar
Department of Commerce, University of Gujrat, Pakistan. Email : anam.tasawar@uog.edu.pk
Aansah Rani
Scholar, Department of Commerce, University of Gujrat, Pakistan
Muhammad Talha
Assistant professor, Department of Architecture, University of Gujrat. Email: muhammad.talha@uog.edu.pk

Review Type: Double Blind Peer Review

ABSTRACT

Green Growth is now a highly significant goal for developing countries as climate challenges are worsening. This study examines the temporal evolution of the relationship among the environmental policy stringency index, renewable energy investment, and imports of eco-friendly technologies. The analysis is based on panel data consisting of BRICS countries from 2011 to 2020. Different analysis modules: Ordinary Least Squares (OLS) regression, correlation matrices, and Principal Component Analysis (PCA) highlight all the factors that affect sustainability transitions. The analysis highlights that consistently and significantly putting money into renewable energy leads to three benefits: less carbon emissions, a higher GDP, and increased electricity generation from renewable sources. The environmental policy stringency index demonstrates that stronger laws might assist in lowering emissions and boosting the economy, but it also shows that these policies could have unintended impacts on the usage of renewable energy, especially if infrastructure and institutions aren't ready. Imports of Eco-friendly technologies help the economy move forward; however, technologies do not truly help the environment. This technical solution alone is not adequate; the need for better domestic capabilities and governance frameworks is required. These results suggest that it is very vital to have a policy that is both robust and current, as well as direct, long-term investment in clean energy infrastructure. BRICS countries can work together, and they need to establish a balance between economic expansion and taking care of the environment. It also supplies vital knowledge to other developing economies that want to grow in a way that doesn't hurt the environment.

Keywords Green Growth, Renewable Energy Investment, Environmental Policy Stringency, Carbon Emissions Reduction, Sustainable Development

Introduction

Ten years ago, the primary purpose of green growth was to make policies. Now, it is about staying alive. As disasters related to climate change become more regular, the need for large economies to separate wealth from environmental damage has never been greater. For instance, South Asia has experienced devastating floods, and Siberia and South America have witnessed wildfires that have never occurred before *(Peduzzi, 2019).* As a result, people have come together to work toward slowing global warming, cutting greenhouse gas (GHG) emissions, and promoting inclusive, low-carbon economic growth through global environment agreements *(Iacobuță et al., 2022).* In this light, green growth has emerged as a long-term development strategy that underscores the need for economic progress and environmental responsibility to work in tandem *(Adanma & Ogunbiyi, 2024).*

Green growth is based on three fundamental principles: strict environmental policies, investment in renewable energy, and the use of environmentally friendly technologies (ESTs). Strong environmental regulations that foster new ideas and keep pollution in check are what make up green governance *(Awewomom et al., 2024).* Investing in green energy sources is one approach to securing the funds needed to transition to carbon-neutral infrastructure. Meanwhile, the proliferation of ESTs through foreign direct investment or global trade accelerates the switch to sustainable production and energy. When these pieces function together, they can help the economy become more modern, more climate-resilient, and reduce carbon emissions *(Tariq et al., 2022).*

Brazil, Russia, India, China, and South Africa are all part of the BRICS group, which plays a very peculiar role in the global arena. They comprise more than 40% of the world's population and approximately 25% of the world's GDP. However, they also release a significant amount of CO_2 into the air *(Rahman et al., 2021).* The union is at the center of global climate policy, as both are detrimental to the environment and are necessary to address it. These countries must cope with two concerns simultaneously: ensuring their economies continue to develop rapidly and transitioning toward sustainability *(Nach & Ncwadi, 2024).*

The 2010s greatly influenced the BRICS' green policies and initiatives. In this decade, all five nations strengthened their environmental regulations or established new ones. They also invested significantly more in renewable energy and collaborated to acquire new green technologies *(Miranda et al., 2021).* However, they employed very different approaches to achieve green growth.

Some were able to reduce emissions and generate more renewable electricity, while others saw their economies grow without harming the environment's returns *(Fu et al., 2021).* This disparity suggests that we need to conduct detailed research in the real world to understand how policies, investments, and technologies work together to achieve sustainable results *(Udeagha & Muchapondwa, 2023).*

This study focuses on three primary things: the Environmental Policy Stringency Index (EPSI), investments in renewable energy, and imports of technologies that are good for the environment. Three primary goals for sustainability are the amount of CO_2 emissions per person, the amount of GDP per person, and the quantity of power made from renewable sources. *Li & Shao (2023)* suggest that stronger environmental regulations can encourage businesses to adopt cleaner practices and generate innovative ideas. Investing in renewable energy sources immediately shifts energy portfolios away from fossil fuels *(Holechek et al., 2022).* Bringing in technology, especially to countries with weaker. Home innovation systems enable people to learn how to use clean technology and fill in the gaps in their abilities *(Pandey et al., 2022).*

In principle, these factors should work well together; however, few studies have examined their actual interaction, especially in BRICS countries. What people are saying now is that they prefer to focus on just one part or just high-income or OECD countries. Additionally, evaluations based on long-term data that encompass the complete 2010s, a decade of significant growth, are quite rare in global energy markets and policy changes. This makes it hard for us to understand all the things that help developing countries flourish in a green way.

Research Objectives

- To empirically analyze BRICS policy, technology and investment and their impact on carbon emission, economic growth and green power output.
- To compare how the impact differs across BRICS over the period of 10 years.

Research Questions

1. *How do green investments, laws, and imports work together to change carbon emissions, the economy, and the amount of renewable electricity that BRICS countries make?*
2. *Do these links change a lot from one country to another and over time in the 2010s?*
3. *Which of the three drivers has the most consistent positive influence on green growth?*

Hypotheses

H1: There is notable relation between the green growth and environmental regulations.
H2: Investment in renewable energy resources is significantly linked to lowering pollution and enhancing economy.
H3: The deployment of efficient eco-friendly technologies is associated to bring change in sustainable growth trajectories.

This study looks at the green growth trajectories of BRICS from different points of view. It helps us comprehend changes toward sustainability in the Global South better by illustrating both the progress that has been made and the difficulties that still exist in the structure.

Literature Review

Green Growth and the Need for Sustainability in Emerging Economies

Green growth is a crucial topic in the global discourse on sustainability. It helps the economy thrive while also safeguarding the environment that makes growth possible *(Adamowicz, 2022).* The Sustainable Development Goals (SDGs) and the Paris Agreement are two examples of plans that integrate green growth principles. These goals aim to address pressing issues, including climate change, biodiversity loss, and resource depletion (Hariram et al., 2023). Green growth is a way of thinking about development that helps the economy expand while also conserving the environment. It focuses on utilizing resources more efficiently, developing new technologies, and constructing additional infrastructure that supports a low-carbon economy *(Mahmood et al., 2024).*

The green growth model is particularly suitable for emerging economies, notably the BRICS countries. These countries are coping with the combined challenges of keeping pace with rapid industrialization and addressing growing social needs, all while also dealing with environmental externalities *(Mahalik et al., 2024).* As cities grow and populations rise, there are more developmental conflicts. This makes it even more necessary to find environmentally friendly ways to grow (*Chen et al., 2022; Henderson & Loreau, 2023).* However, much of the research on green growth remains focused on developed countries. People don't pay enough attention to the BRICS, even though it is an important part of the global climate equation *(Petrone, 2019).*

Environmental Policy Stringency Index: Institutional Leverage for Green Transitions. The Environmental Policy Stringency Index (EPSI) measures the stringency of environmental protection regulations. There are both market-based instruments, such as carbon taxes and emissions trading systems, and command-and-control tools, including emission thresholds and technical mandates *(Kruse et al., 2022).* This model is based on the Porter Hypothesis. It states that strong yet well-thought-out environmental policies can help foster competition instead of damaging it *(Zhao et al., 2022).* Prior studies on OECD countries have shown that higher EPSI scores are associated with lower emissions intensity, improved energy efficiency, and a greater number of patents for clean technologies *(Albulescu et al., 2022).* However, the BRICS countries don't always enforce their policies in the same manner. China and India have strengthened their environmental laws, but enforcement remains challenging due to weak institutional frameworks, informal economies, and state-owned enterprises that often fail to comply with regulations. Due to this, we still don't know how stringent policies affect these circumstances, and we require more research, particularly in long-term, multi-country studies *(Anwar et al., 2021; Rajesh et al., 2022).*

Investing in Renewable Energy: Financial Drivers for Decarbonization

Investing in renewable energy infrastructure is a key way to achieve green growth. It immediately reduces greenhouse gas emissions, enhances energy safety, and creates jobs in the green economy (Ma & Wang, 2025). Investing in renewable energy worldwide increased significantly in the 2010s, reaching over $300 billion annually. The BRICS countries became key players (Shah, 2024).

China has been a leader in global investment in renewable energy, particularly in solar and wind energy, due to a solid industrial strategy and government-backed financing *(Ladislaw et al., 2021).* India has also taken similar steps: it has set high national targets, secured funding from other countries, and engaged businesses *(Majid, 2020).* Brazil is still maximizing its hydropower potential (de Faria & Jaramillo, 2017), whereas South Africa and Russia have made less progress due to insufficient funding and infrastructure *(Ramluckun et al., 2024).* However, the less developed parts of these countries still face challenges, including inconsistent policies, insufficient funding, and inadequate grid capacity *(Zhu et al., 2024).* A study has shown that investing in renewable energy helps reduce emissions, but there is a lack of research that examines how investment trends impact the environment and the economy in BRICS.

The Role of Imports in Sustainability Transitions and Technology Transfer

Environmentally Sound Technologies (ESTs) are innovative approaches that conserve energy, reduce pollution, harness renewable energy, and manage waste effectively. Technology transfer is particularly vital for disseminating ESTs, and trade, foreign direct investment, and development co-operation all play a role in this process. for countries that lack substantial research and development (R&D) resources at home *(Pigato et al., 2020)*. Numerous studies indicate that incorporating environmental, social, and governance (ESG) factors is associated with greater environmental performance and more productive industries *(Zhang et al., 2021)*. Within the BRICS framework, China and India have actively introduced clean technologies, often with support from global alliances and initiatives addressing climate change—systems that make money *(Khosla et al., 2020).*

On the other hand, Russia and South Africa face challenges in adopting new technology due to stringent trade regulations, inadequate institutional frameworks, and a shortage of technical skills ***(De, 2019).*** These distinctions suggest that technology has both its advantages and disadvantages. Imports aren't always the same; they depend on the conditions that make them possible in the place of origin.

Moving Toward a Common Understanding: How Policy, Investment, and Technology Work Together

A considerable amount of research has been conducted on EPSI, renewable energy investment, and EST imports as standalone strategies to promote green growth. However, there are still few empirical frameworks that operate in tandem. But all of these things are linked. For example, effective environmental regulations can encourage consumers to purchase green items. Technologies: Acquiring new technology might make it cheaper to follow the rules and encourage people to do so. The policy climate and the readiness of the technology are affecting the amount of money and investment that flows *(Tiwari et al., 2024).* Many of these studies focus on developed countries and examine them for limited periods, resulting in a lack of research on emerging economies.

Research Gap

The study concurs that environmental legislation, technology, and investments in renewable energy are essential for environmentally friendly development. Few studies examine these factors together, especially for the BRICS countries, and even fewer do so in a clear empirical model. We still need to swiftly determine how these drivers interact over time and impact the economy and the environment in different countries. This study fills this gap by examining the impact of EPSI, green investment, and the consequences of EST imports on the carbon emissions, GDP per capita, and renewable energy production of BRICS countries in the 2010s. This helps policymakers make more informed decisions that consider individual situations and develop integrated green growth models in developing countries.

Research Question: How do stricter environmental laws, investments in renewable energy, and the import of technology that is good for the environment affect carbon emissions, the economy, and making and using electricity from renewable sources in BRICS countries?

Methodology

Research Design

This study employs a quantitative, explanatory research design to examine the impact of stringent environmental policies, green investments, and the importation of environmentally friendly technology on three key sustainability indicators: carbon emissions per capita, GDP per capita, and renewable electricity generation. The primary focus is on the BRICS countries (Brazil, Russia, India, China, and South Africa) from 2011 to 2020.

Data Collection Methods

Secondary data were collected from internationally recognized and credible sources from 2011 to 2020 to ensure complete and consistent data availability across all variables for comprehensive data analysis:

- *Environmental Policy Stringency Index (EPSI)**:*** Sourced from the Organization for Economic Co-operation and Development (OECD), measuring the relative strictness of a country's environmental regulations.
- *Renewable Energy Investment (REI)**:*** Compiled by the International Renewable Energy Agency (IRENA), representing annual financial flows (investments, loans, grants) into renewable energy technologies.

- *Environmentally Sound Technology Imports (ESTI)***:** Extracted from Our World in Data, capturing the economic value of imports related to renewable energy and environmental protection technologies.
- *Carbon Emissions per Capita (CE)***:** Retrieved from the World Bank, measured in metric tons per person.
- *GDP per Capita***:** World Bank data, in constant USD.
- *Renewable Electricity Generation (REG)***:** This information, sourced from Our World In Data, illustrates the amount of electricity generated from solar, wind, and hydroelectric sources.

Sampling Technique

A purposive sample technique was employed to focus on the five BRICS countries, as they are becoming increasingly significant in global environmental governance, economic growth, and the transition to greener energy. These countries form a strategically important group of emerging economies that are simultaneously transforming their economies and environments *(Yadav et al., 2024).*

Data Analysis Methods

Panel Data Analysis

Line graphs showed how each variable changed from 2011 until 2020. This phase of inquiry made it easy to see trends, shifts, and outliers that happened over the decade.

Multiple Linear Regression Analysis

This study employed the Ordinary Least Squares (OLS) estimation technique to examine the effect of independent variables such as the Environmental Policy Stringency Index (EPSI), Renewable Energy Investment (REI), and Environmental Sustainability Technology Index (ESTI) on the dependent variables, namely Carbon Emissions (CE), Gross Domestic Product (GDP), and Regulatory Quality (REG) (Seabold & Perktold, 2010). We came up with three different regression equations:

$$E_t = \alpha + \beta 1 \cdot EPI_{(it)} + \beta 2 \cdot REI_{(it)} + \beta 3 \cdot EI_{(it)} + \epsilon_{(it)}$$
$$DP_t = \alpha + \beta 1 \cdot EPI_{(it)} + \beta 2 \cdot EI_{(it)} + \beta 3 \cdot EI_{(it)} + {}_t$$
$$EP_t = \alpha + \beta 1 \cdot EPI_{(it)} + \beta 2 \cdot REI_{(it)} + \beta 3 \cdot EI_{(it)} + \epsilon_{(it)}$$

Where:

CEit : Carbon Emissions
REPit : Renewable Energy Production
GDPit : Gross Domestic Product
EPSIit : Environmental Policy Stringency Index
REIit : Renewable Energy Investment
ESTIit : Environmentally Sound Technology Imports
α: Constant term
εit : Error term capturing unobserved influences

Correlation Analysis

A Pearson correlation matrix was constructed to evaluate the strength and direction of relationships between variables (Virtanen et al., 2020). The matrix was visualized using a heatmap to detect potential multicollinearity and to inform the robustness of the regression analysis.

Principal Component Analysis (PCA)

Principal component analysis was used to identify the main components that explain the most variance in the dataset and to reduce the number of dimensions, thereby revealing hidden structure (Pedregosa et al., 2011). A PCA biplot was created to illustrate how variables and countries align and cluster together along the main component axes.

Statistical Significance Testing

All regression models were tested for statistical significance using p-values and 95% confidence intervals. The analyses were conducted in Visual Studio Code using Python 3.11.9 and statistical libraries such as Pandas, NumPy, and Matplotlib.

Ethical Considerations

The research only used secondary data from reputable, publicly available sources. Due to this, no ethical approval was required, and there were no direct human participants or personal data involved.

Reliability and Validity

To ensure reliability, this study utilized only standardized, peer-reviewed, or institutionally verified datasets (e.g., OECD, World Bank, IRENA). Construct validity was maintained by selecting well-established indicators that aligned with the study's theoretical framework. The findings were even more reliable and valid because they were triangulated using multiple methods (regression, PCA, and correlation analysis).

Results

Time-Series Trends of Study Indicators across BRICS Nations

Figure 1 (I-VI) shows how the importance of environmental and economic indicators for BRICS countries changed from 2011 to 2020. These indicators are: (I) Environmental Policy Stringency Index (EPSI), (II) Renewable Energy Investment (REI), (III) Environmentally Sound Technology Imports (EST), (IV) Carbon Emissions per Capita (CO_2E), (V) GDP per Capita, and (VI) Renewable Electricity Production (REP).

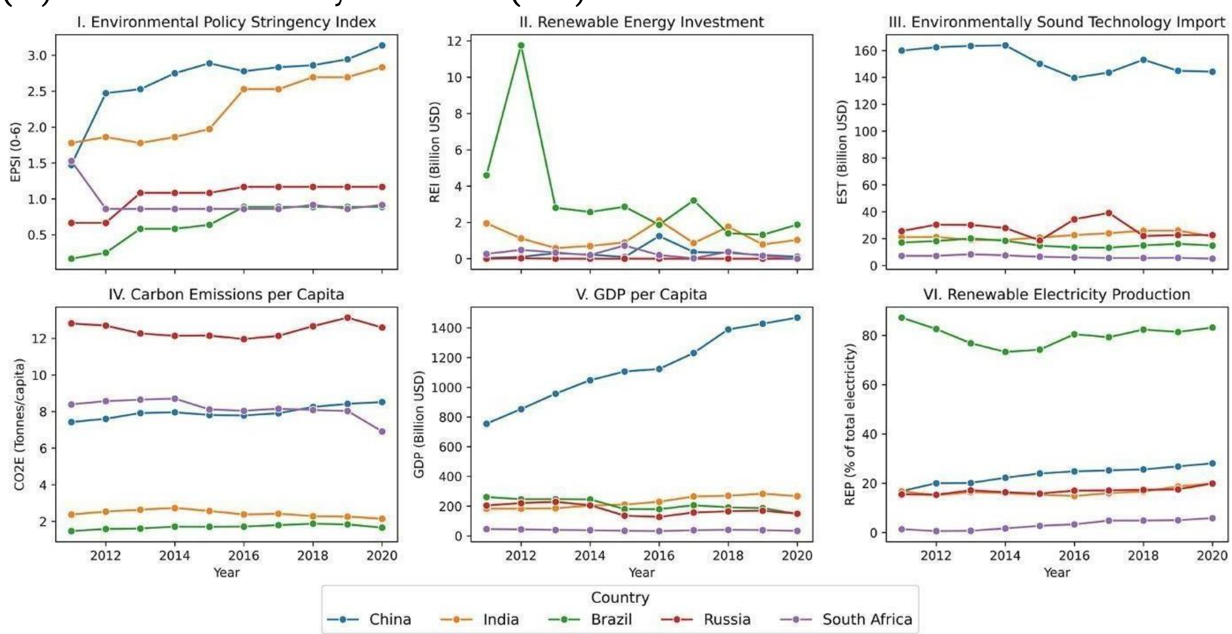

Figure 1. Time series trends of study variables over duration (2011-2020)

China and India's EPSI values have been steadily increasing, indicating that environmental regulations are becoming stronger. China's EPSI value has increased significantly, from approximately 2.0 in 2011 to over 3.0 in 2020. India's EPSI value has also increased, but not by as much. On the other hand, Russia and South Africa's EPSI values have remained relatively low and stable, indicating that policies in this area haven't changed significantly *(Figure 1.I)*.

Investing in renewable energy sources is unstable in all countries. Brazil saw a big jump in 2011, reaching almost USD 12 billion, but then it dropped sharply. India and China have experienced small increases, with noticeable fluctuations, over the past decade. Russia and South Africa have maintained low investment levels throughout the period, suggesting that they are not highly committed to transitioning to renewable energy *(Figure 1.II)*.

China leads in EST imports, with values consistently above USD 140 billion, peaking around 2013–2014. Other BRICS countries, such as India, Brazil, and Russia, show moderate but relatively stable imports, while South Africa consistently registers the lowest EST values. The declining trend in China's EST imports post-2015 may suggest increased domestic capacity or policy shifts.
(Figure 1.III).

Russia records the highest CO_2 emissions per capita, consistently exceeding 12 tons per person.

China's per capita emissions show a gradual increase, surpassing 8 tons by 2020. South Africa follows a similar trajectory. Brazil and India maintained significantly lower emissions values, with India remaining below 2 tons, indicating relatively low per capita emissions *(Figure 1.IV)*.

China's GDP per capita has been rising steadily and firmly, going from about 750 billion USD in 2011 to over 1,400 billion USD in 2020. This indicates that the economy is experiencing rapid growth. Other BRICS countries have more moderate and fluctuating trends. Brazil and Russia saw small drops in the mid-2010s, followed by small recoveries, while India saw steady growth. South Africa's GDP per capita stayed relatively stable at a low level throughout the decade *(Figure 1.V)*.

Brazil consistently outperformed other BRICS countries in renewable electricity production, maintaining values above 75% of the territory's total electricity generation. China and India show gradual improvement, with China increasing from ~18% to ~28% and India from ~14% to ~22% over the study period. Russia and South Africa exhibit minimal changes, remaining below 20%, indicating limited diversification of their electricity generation mix *(Figure 1.VI)*.

Combined Interpretation of Regression Results

The three OLS regression models *(Table 1-3)* give a full picture of how environmental policy stringency, renewable energy investment, and environmentally sound technology imports affect carbon emissions, economic output (GDP), and renewable electricity production in the BRICS countries. While each model has different strengths and weaknesses, some clear patterns emerge that can help policymakers find a balance between economic growth and environmental sustainability.

The Environmental Policy Stringency Index (epsi) has different effects across the models

(Table.
1). As expected, it significantly reduces carbon emissions (β = -2.608, p = 0.001), showing that it works to protect the environment. However, it also has a positive and significant effect on GDP (β = 91.107, p = 0.003), suggesting that stricter environmental regulations may encourage green innovation, industrial upgrading, or improved efficiency, which would help the economy grow.

On the other hand, the index has a big negative effect on making renewable electricity (β = -10.105, p = 0.041), which could mean that stricter rules make it harder for the renewable sector to grow.

This shows how important it is to have policies that are consistent and frameworks that help make it easier for renewables to be used.

OLS Regression Results Dep.
Variable: c2e R-squared: 0.478 Model: OLS Adj. R-squared: 0.444

Method:	Least Squares	F-statistic:	14.05
Date:	Sun, 13 Apr 2025	Prob (F-statistic):	1.24E-06
Time:	18:22:57	Log-Likelihood:	-124.17
No. Observations:	50	AIC:	256.3
Df Residuals:	46	BIC:	264
Df Model:	3		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	10.432	1.024	10.192	0.000	8.372	12.492
epsi	-2.6079	0.707	-3.689	0.001	-4.031	-1.185
rei	-1.3858	0.243	-5.694	0.000	-1.876	-0.896
est	0.0332	0.011	3.072	0.004	0.011	0.055

Omnibus:	0.760	Durbin-Watson:	2.319
Prob (Omnibus):	0.684	Jarque-Bera (JB):	0.860
Skew:	0.219	Prob (JB):	0.650
Kurtosis:	2.530	Cond. No.	196.

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

Table 1: OLS Regression Results Summary for Carbon Emissions (c2e) against independent variables

Renewable Energy Investment (REI) consistently yields positive and substantial effects (*Table 2*). It lowers carbon emissions (β = -1.386, p < 0.001), raises GDP (β = 23.811, p = 0.022), and is the strongest driver of renewable electricity production (β = 8.801, p < 0.001). These results collectively support the idea that investing in clean energy is a multifaceted strategy for combating climate change, stimulating the economy, and transforming the way we generate energy. They also provide strong evidence for scaling up investments in renewable energy infrastructure and the associated technology.

OLS Regression Results Dep.

Variable: gdp R-squared: 0.915 Model: OLS Adj. R-squared: 0.909
Method: Least Squares F-statistic: 164.5
Prob (F- 1.35E-
Date: Sun, 13 Apr 2025 statistic): 24
Time: 18:22:57 Log-Likelihood: -310.09
No. Observations: 50 AIC: 628.2
Df
Residuals: 46 BIC: 635.8
Df Model: 3
Covariance Type: nonrobust coef std err t P>|t| [0.025 0.975]
-
const -86.696 42.173 -2.056 0.046 171.59 -1.805 epsi 91.1066 29.125 3.128 0.003 32.481
149.732 rei 23.8113 10.028 2.375 0.022 3.626 43.996 est 6.2676 0.446 14.06 0.000 5.37 7.165
Durbin-
Omnibus: 8.221 Watson: 1.998 Prob Jarque-Bera
(Omnibus): 0.016 (JB): 12.516 Skew: 0.392 Prob (JB): 0.00191 Kurtosis: 5.322 Cond. No.
196.
Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

Table 2: OLS Regression Results Summary for GDP per capita (gdp) against independent variables

Importing environmentally friendly technology (est) has several effects *(Table 3)*. For example, they significantly increase GDP ($\beta = 6.268$, $p < 0.001$), demonstrating that they can enhance productivity and contribute to sustainable economic growth. However, their effect on carbon emissions is surprisingly positive ($\beta = 0.033$, $p = 0.004$), which may be because high-emission countries are also increasing their imports of green technology. The effect on the production of renewable electricity is positive, albeit slight ($\beta = 0.129$, $p = 0.087$). This suggests that imports of green technology align with clean energy goals, but they may operate more effectively if the country has adequate infrastructure, absorptive capacity, and institutional support.

OLS Regression Results Dep.			
Variable:	re	R-squared:	0.466
Model:	OLS	Adj. R-squared:	0.431
Method:	Least Squares	F-statistic:	13.36
Date:	Sun, 13 Apr 2025	Prob (F-statistic):	2.11E-06
Time:	18:22:57	Log-Likelihood:	-220.04
No. Observations:	50	AIC:	448.1
Df Residuals:	46	BIC:	455.7
Df Model:	3		
Covariance Type:	nonrobust		

coef std err t P>|t| [0.025 0.975] const 28.3641 6.964 4.073 0.000 14.345 42.383 epsi -10.105 4.81 -2.101 0.041 -19.787 -0.424 rei 8.8013 1.656 5.315 0.000 5.468 12.135 est 0.1289 0.074 1.751 0.087 -0.019 0.277

Omnibus:	6.83	Durbin-Watson:	1.887
Prob (Omnibus):	0.033	Jarque-Bera (JB):	5.742

Skew: 0.733 Prob (JB): 0.0566 Kurtosis: 3.778 Cond. No. 196.

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

Table 3: OLS Regression Results Summary for Renewable electricity production (re) against independent variables

The GDP model has the highest R-squared value (0.915), which suggests it fits very well. The carbon emissions model comes next (0.478), followed by the renewable electricity generation model (0.466). All three models pass essential diagnostic tests. The Durbin-Watson statistic indicates that there is no autocorrelation, and the residual distributions appear to be satisfactory. However, the GDP and renewable electricity models are not quite normal.

Correlation Analysis

How strongly the primary explanatory variables and outcome indicators are related? The Pearson correlation matrix is shown in *Figure 2* as a heatmap. The matrix shows us how variables are related to each other for the first time.

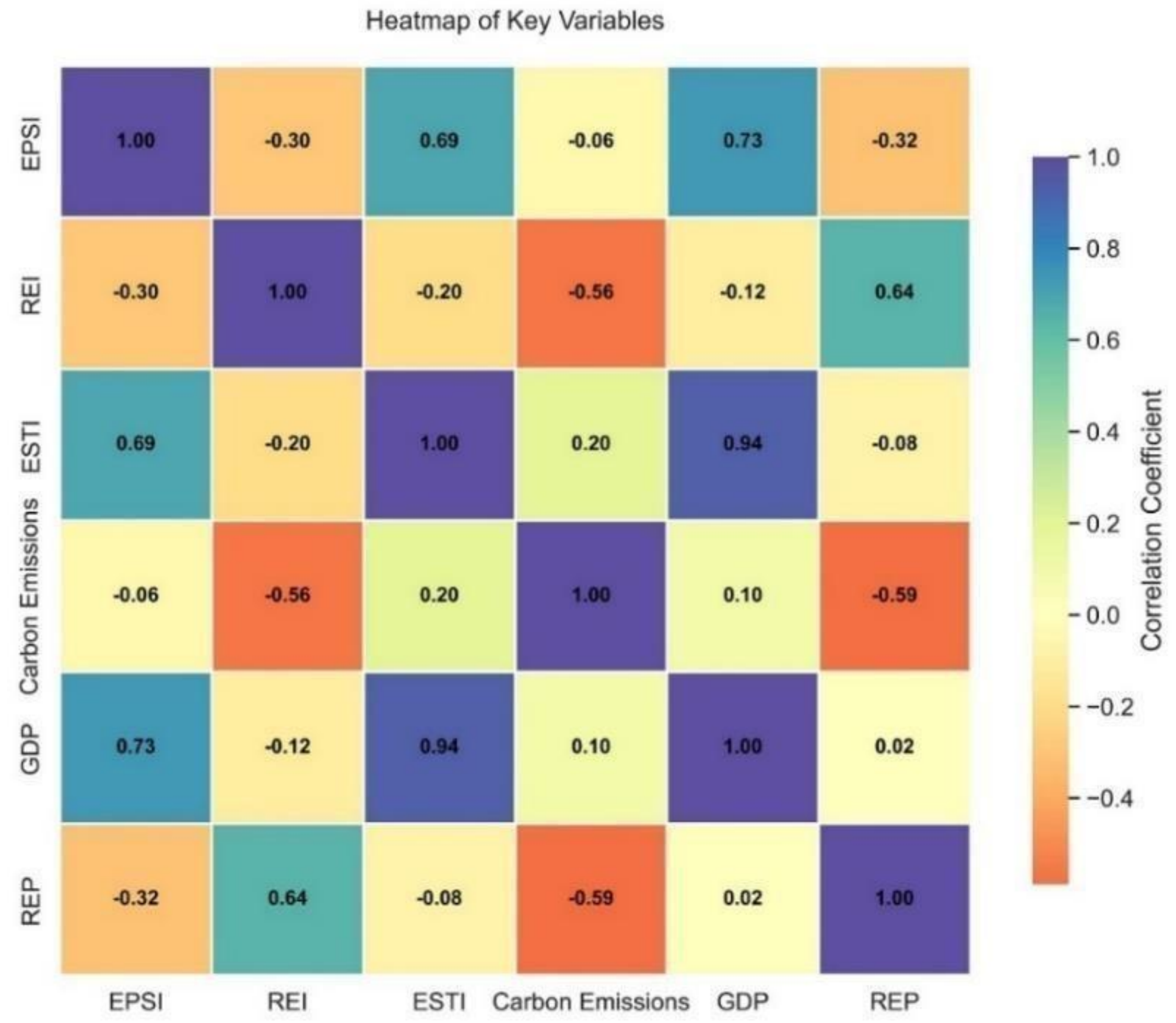

Figure 2. Heatmap correlation matrix

EPSI shows a moderate to strong negative correlation (r = -0.69) with carbon emissions per person

(Figure 3. i) in BRICS countries. This result suggests that tougher EPSI has a strong positive relationship (r = 0.71) with GDP per capita *(Figure 3. ii).* The stricter environmental policies may go hand in hand with economic growth, possibly because of efficiency gains from innovation. On the other hand, EPSI has a moderate negative correlation (r = -0.48) with renewable electricity production (Figure 3.*iii).* It is somewhat surprising, possibly due to delays in transitioning the energy system to new technologies or phasing out fossil-based systems.

Renewable Energy Investment (REI) and variables that depend on it. There are strong and statistically significant links between REI and all three dependent variables. For instance, there is a strong negative correlation (r = -0.74) between REI and CO_2 emissions per capita (Figure 3. iv). The study highlights the importance of funding initiatives that utilize renewable energy to reduce emissions. At the same time, it is moderately positively linked (r = 0.53) to GDP per capita *(Figure 3. v)* and strongly positively linked (r = 0.82) to renewable electricity production (Figure 3. vi). These results demonstrate that investing in renewables is beneficial for both the environment and the economy, highlighting the importance of this approach for energy transition efforts. Environmentally Sound Technology Imports (ESTI) is contrasted with factors that depend on them. There is a weak positive link between ESTI and carbon emissions per person *(Figure 3. vii).* There is a weak positive relationship between emissions and imports (r = 0.29), indicating that countries with high emissions tend to have high imports. Results could be due to reactive policy behaviour. On the other hand, there is a powerful positive relationship between ESTI and GDP per capita (r = 0.85) *(Figure 3. viii).* The results show how technological imports can help the economy, possibly by modernizing industries. Furthermore, it has a moderate and positive relationship with the amount of renewable electricity produced *(Figure 3. ix),* but it doesn't explain things as well as other predictors. In general, REI appears to be the best and most significant predictor for all three outcomes. EPSI provides significant benefits for the environment and the economy, but it can mean making some short-term trade-offs for certain aspects, especially when it comes to generating more renewable electricity and reducing emissions. ESTI has a significant impact on the economy. Still, its effect on the environment may depend on other factors that enable it, such as how well it can absorb pollutants and how effectively the regulations are implemented.

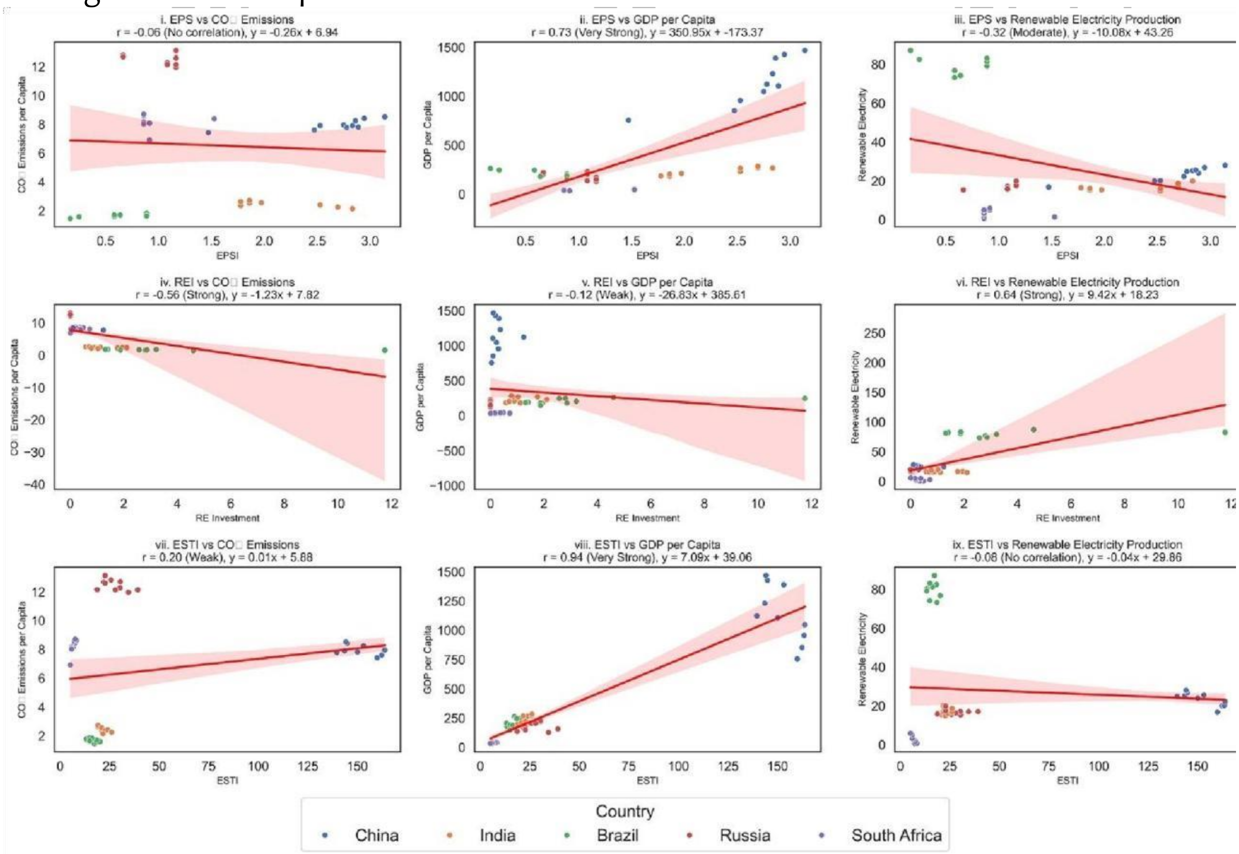

Figure 3. Independent Correlation analysis between independent and dependent variables with correlation coefficients, equations, and regression lines

EPSI: Environmental Policy Stringency Index (0-6), REI: Renewable Energy Investment, EST: Environmentally Sound Technology Imports, REP: Renewable Electricity Production

(% of total electricity).

Principal Component Analysis

We used Principal Component Analysis (PCA) to examine the relationships between the Environmental Policy Stringency Index (EPSI), Renewable Energy Investment (REI), and other variables in multiple dimensions. Environmentally Sound Technology Imports (ESTI), CO_2 emissions per person, GDP per person, and Renewable Electricity Production (REP) in the BRICS countries. The first two primary components account for 82.2% of the total variance, with PC1 explaining 49.3% and PC2 explaining 32.9%. The results suggests that the data has a strong structure that can be understood in two different ways *(Figure 4).*

The strong positive loadings from EPSI, GDP, and ESTI contribute to the formation of PC1. These loadings suggest a development regulation-technological modernization axis. This suggests that countries that score higher in this segment tend to have stricter rules regarding the environment, greater economic activity, and more environmentally friendly technology usage. On the other hand, PC2 captures a transition to renewable energy, with strong positive loadings from REI and REP, and CO_2 emissions demonstrate the relationship between clean energy and emissions—–mitigation nexus. The arrangement of the variables in the PCA biplot indicates that increased spending on renewable energy is significantly associated with higher production of renewable electricity and lower emissions per person.

The PCA confirms what earlier regression and correlation studies found: REI has the largest and most consistent effect on both environmental and energy outcomes. EPSI and ESTI have a significant impact on the economy, but they have a lesser effect on emissions and renewable energy. The production appears to be indirect, which could be due to challenges with infrastructure or the transition process. Overall, the PCA results suggest that a dual-focus strategy—one that combines regulatory strength and economic growth—can Enable Emerging countries to achieve long-term growth and lower emissions by investing directly in clean energy and modernization.

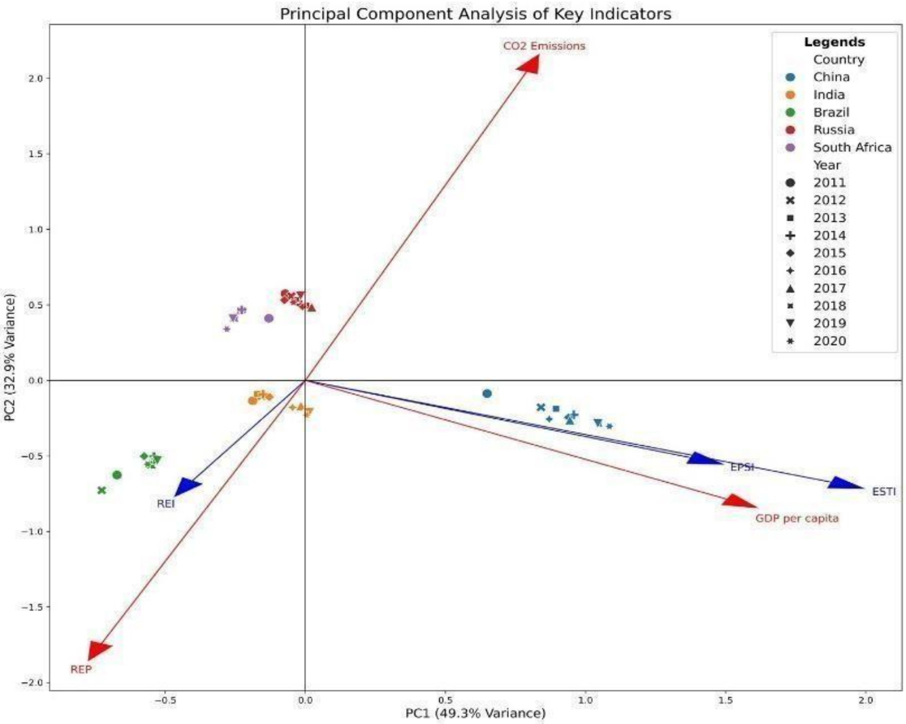

Figure 4. Principal Component Analysis Biplot

The results support the premise that stricter rules will help address the first study question. The regression model shows a negative and statistically significant coefficient, which supports this association. The results for the second question of the study indicate that investment in renewable energy has a substantial impact on the development of renewable energy. The third research question suggested that importing environmentally friendly technology had a significant and favourable impact on GDP per capita. However, it wasn't immediately apparent how these technologies impacted carbon emissions and the production of renewable electricity. It wasn't as clear. These numbers demonstrate that the third hypothesis is only partially true, especially in terms of the economy growing.

Discussion

This study investigates the dynamic interrelationships among environmental policy stringency (EPSI), renewable energy investment (REI), and environmentally sound technology imports (ESTI) concerning key sustainability indicators, CO_2 emissions per capita, GDP per capita, and renewable electricity production (REP), across BRICS nations from 2011 to 2020. The results suggest that while environmental policy and renewable energy investments play a crucial role in driving sustainable outcomes, their effectiveness is shaped by institutional readiness and sector-specific dynamics. These findings provide new insights into how emerging economies can optimize environmental governance and clean technology investment to advance decarbonization without compromising economic growth.

The Environmental Policy Stringency Index showed a steady increase in China and India, indicating a growing commitment to environmental sustainability. Meanwhile, Russia and South Africa showed relatively flat trends, reflecting slower regulatory adaptation. The regression and correlation results confirm a statistically significant negative association between EPSI and carbon emissions per capita, reinforcing the argument that well-designed environmental regulations can reduce pollution while promoting economic resilience. These findings support previous findings *(Albulescu et al., 2022; Sezgin et al., 2021)*, which argue that stricter policies incentivize cleaner production processes and stimulate innovation. However, an unexpected result emerged: EPSI was negatively associated with renewable electricity production. This paradox suggests that while broad policy measures may reduce emissions through general efficiency improvements or shifts away from coal, they do not necessarily promote the deployment of renewable energy. This finding deviates from studies such as *those by Godawska and Wyrobek (2021), which found a positive link between stringent policies* and renewables. The discrepancy may reflect differences in infrastructure maturity and administrative efficiency, highlighting that stringent regulation, if not paired with targeted energy sector reforms and investment incentives, can unintentionally hinder the integration of renewable energy.

A Triple-Win Strategy Renewable energy investment emerged as the most consistent and impactful predictor across all three dependent variables. The data reveal a strong negative correlation between REI and carbon emissions, as well as robust positive associations with both GDP and renewable electricity production. These results support prior research *(Lyeonov et al., 2019; Kou et al., 2022)*, affirming that investments in renewable infrastructure yield not only environmental but also economic dividends. Countries like Brazil and China, which have channelled significant capital into clean energy, have exhibited higher shares of renewable electricity and stronger economic performance, pointing to REI's strategic role in achieving climate and development targets simultaneously. This three-benefit profile highlights the importance of investing more in renewable energy, particularly in countries like Russia and South Africa, which are lagging in this area and where investment levels and clean energy output remain low. These results also support the idea that one of the most effective ways for emerging economies to decouple emissions from growth is to make a financial commitment to the energy transition.

The effects of importing environmentally friendly technology were more complicated and less clear-cut. The regression analysis revealed a strong positive correlation between ESTI and GDP per capita, likely due to the increasing modernization of production systems and subsequent increase in productivity. However, the link between ESTI and carbon emissions was not what you would expect. In some cases, higher technology imports were associated with increased emissions. The phenomenon could mean that BRICS countries tend to import green technologies reactively, in response to already high emission levels, rather than as part of a proactive decarbonization strategy. This pattern may also show transitional phases where old, high-emission industrial infrastructure remains dominant despite technological upgrades *(Khan et al., 2020)*. The small effect of ESTI on renewable electricity production also indicates that introducing new technologies alone is insufficient to alter the energy mix. Other researchers *(Luken & Saieed, 2023)* have found similar results: the benefits of technology transfer depend significantly on the domestic context, particularly how well the country can absorb new technologies, the level of support from regulations, and the industry's readiness. If these things aren't in place, imported technologies may not be utilized as effectively or may not align with national development goals.

Principal Component Analysis reveals the connections between the various sections of the system. The "development-regulation-modernization" axis was the first axis. It grouped high values of EPSI, ESTI, and GDP. The results indicate that economic growth is closely tied to regulatory progress and the adoption of new technologies. The second axis, the "renewable transition" axis, was defined by REI, REP, and lower CO_2 emissions. Focused on how renewable energy investments are good for both the environment and energy. This dual-axis interpretation makes an important point: making things more contemporary and making rules better don't always lead to clean energy outcomes. The PCA biplot indicates a closer REI and decarbonization metrics are more spatially aligned than EPSI or ESTI and those same metrics. These findings highlight that while regulation and innovation can help the economy grow, their environmental benefits are greatest when they are combined with direct and long-term investment in renewable infrastructure *(Batra, 2023)*.

The findings of this study should be taken into consideration by policymakers in the BRICS and other nations. First and foremost, regulatory frameworks must employ sector-specific instruments, such as incentives for innovation, modernization projects, and subsidies for renewable energy. Strengthening environmental regulations is a good concept, but it can make the problem worse. Unless there are strategic support measures in place, cease using renewable energy (Onabowale, 2024). Second, the statistics clearly show that investing in renewable energy should be a top priority. According to Bi et al. (2024), this is a technology that can help you produce clean energy, boost the economy, and reduce emissions simultaneously.

Third, we need policies that focus on education, training, and institutional reform to build absorptive capacity *(Paliokaitė, 2019)*. Without a supportive ecosystem, imported technologies may not work as well as they should. Finally, the PCA results suggest a dual-focus strategy: macro-level regulation and modernization efforts should be combined with micro-level renewable investments. This combination offers the clearest path toward decarbonization while sustaining inclusive economic growth that involves all people.

These are helpful insights, but the study has some flaws. For one, the sample only includes BRICS countries and only spans a decade, which may make it impossible to generalize the results in other places or for longer-term patterns. There can be significant differences between countries, especially in vast and diverse ones like India and Brazil. This study should include more emerging economies and use longer periods or subnational data to get more thorough conclusions. It should also examine how the quality of institutions affects these outcomes. We could also learn more about the relationships we observe by examining energy subsidies or the dynamics of public-private partnerships. Using mixed-method approaches, such as case studies or qualitative policy analysis, could help us better understand the quantitative findings and develop more effective environmental governance frameworks.

Conclusion

This study enhances our understanding of the multifaceted relationships among environmental policy stringency index, renewable energy investment, and environmentally sound technology imports and how these factors influence key sustainability indicators, such as carbon emissions per capita, GDP per capita, and renewable electricity production, across BRICS nations. Through the integration of time-series trends, OLS regression, correlation matrices, and Principal Component Analysis, this research provides a nuanced and comprehensive portrait of how emerging economies manage the balance between environmental integrity and economic growth.

The core takeaway is that renewable energy investment is the most consistently effective driver of sustainability. It not only contributes significantly to emissions reduction but also supports economic expansion and accelerates the deployment of renewable electricity. These results strongly advocate for expanding financial mechanisms, developing infrastructure, and implementing policy incentives that foster green energy transitions in developing contexts.

Environmental policy stringency is also shown to play a vital role, particularly in reducing carbon emissions and stimulating GDP growth, likely through mechanisms such as improved efficiency and technological innovation. However, its unintended negative association with renewable electricity production highlights a critical need for policies that not only regulate but also enable clean energy progress—through grid modernization, market reform, and targeted subsidies. While environmentally sound technology imports contribute to GDP growth, their complex and sometimes contradictory relationship with carbon emissions signals the importance of institutional capacity, strategic planning, and local readiness to reap their environmental benefits.

In summary, the study highlights that for BRICS and other emerging economies, a dual strategy combining effective regulation and modernization with targeted, large-scale investments in renewables is essential for achieving an inclusive, low-carbon development trajectory in the years ahead.

References

Adamowicz, M. (2022). Green deal, green growth and green economy as a means of support for attaining the sustainable development goals. *Sustainability*, *14*(10), 5901.

Adanma, U. M., & Ogunbiyi, E. O. (2024). A comparative review of global environmental policies for promoting sustainable development and economic growth. *International Journal of Applied Research in Social Sciences*, 6(5), 954-977.

Albulescu, C. T., Boatca-Barabas, M.-E., & Diaconescu, A. (2022). The asymmetric effect of environmental policy stringency on CO2 emissions in OECD countries. *Environmental Science and Pollution Research*, *29*(18), 27311-27327.

Anwar, M. N., Shabbir, M., Tahir, E., Iftikhar, M., Saif, H., Tahir, A., Murtaza, M. A., Khokhar, M. F., Rehan, M., & Aghbashlo, M. (2021). Emerging challenges of air pollution and particulate matter in China, India, and Pakistan and mitigating solutions. *Journal of Hazardous Materials*, *416*, 125851.

Awewomom, J., Dzeble, F., Takyi, Y. D., Ashie, W. B., Ettey, E. N. Y. O., Afua, P. E., Sackey, L. N., Opoku, F., & Akoto, O. (2024). Addressing global environmental pollution using environmental control techniques: a focus on environmental policy and preventive environmental management. *Discover Environment*, 2(1), 8.

Batra, G. (2023). Renewable energy economics: achieving harmony between environmental protection and economic goals. *Social science chronicle*, *2*(2), 1-32.

Bi, Z., Guo, R., & Khan, R. (2024). Renewable adoption, energy reliance, and CO2 emissions: a comparison of developed and developing economies. *Energies*, *17*(13), 3111.

Chen, M., Chen, L., Cheng, J., & Yu, J. (2022). Identifying interlinkages between urbanization and Sustainable Development Goals. *Geography and Sustainability*, *3*(4), 339-346.

de Faria, F. A., & Jaramillo, P. (2017). The future of power generation in Brazil: An analysis of alternatives to Amazonian hydropower development. *Energy for Sustainable Development*, *41*, 24-35.

De, G. Z. (2019). Motivations, preferences, barriers to going abroad: Russian high-tech start-ups and small innovative enterprises. *Контуры глобальных трансформаций: политика, экономика, право*, *12*(6), 94-129.

Fu, Q., Álvarez-Otero, S., Sial, M. S., Comite, U., Zheng, P., Samad, S., & Oláh, J. (2021). Impact of renewable energy on economic Growth and CO2 emissions—evidence from BRICS countries. *Processes*, *9*(8), 1281.

Godawska, J., & Wyrobek, J. (2021). The impact of environmental policy stringency on renewable energy production in the visegrad group countries. *Energies*, *14*(19), 6225.

Hariram, N., Mekha, K., Suganthan, V., & Sudhakar, K. (2023). Sustainalism: An integrated socioeconomic-environmental model to address sustainable development and sustainability. *Sustainability*, *15*(13), 10682.

Henderson, K., & Loreau, M. (2023). A model of Sustainable Development Goals: Challenges and opportunities in promoting human well-being and environmental sustainability. *Ecological modelling*, *475*, 110164.

Holechek, J. L., Geli, H. M., Sawalhah, M. N., & Valdez, R. (2022). A global assessment: can renewable energy replace fossil fuels by 2050? *Sustainability*, *14*(8), 4792.

Iacobuță, G. I., Brandi, C., Dzebo, A., & Duron, S. D. E. (2022). Aligning climate and sustainable development finance through an SDG lens. The role of development assistance in implementing the Paris Agreement. *Global Environmental Change*, *74*, 102509.

Khan, Z., Ali, M., Kirikkaleli, D., Wahab, S., & Jiao, Z. (2020). The impact of technological innovation and public-private partnership investment on sustainable environment in China: Consumption-based carbon emissions analysis. *Sustainable Development*, *28*(5), 13171330.

Khosla, R., Kamat, A. S., & Narayanamurti, V. (2020). Successful clean energy technology transitions in emerging economies: learning from India, China, and Brazil. *Progress in Energy*, 2(4), 043002.

Kou, G., Yüksel, S., & Dinçer, H. (2022). Inventive problem-solving map of innovative carbon emission strategies for solar energy-based transportation investment projects. *Applied Energy*, *311*, 118680.

Kruse, T., Dechezleprêtre, A., Saffar, R., & Robert, L. (2022). Measuring environmental policy stringency in OECD countries: An update of the OECD composite EPS indicator. *OECD Economic Department Working Papers*(1703), 0_1-56.

Ladislaw, S., Zindler, E., Nakano, J., Tsafos, N., Carey, L., Goldie-Scot, L., Lezcano, P., & Chase, J. (2021). Industrial policy, trade, and clean energy supply chains. *Center for Strategic and International Studies*, *24*.

Li, S., & Shao, Q. (2023). How do financial development and environmental policy stringency affect renewable energy innovation? The Porter Hypothesis and beyond. *Journal of Innovation & Knowledge*, *8*(3), 100369.

Luken, R. A., & Saieed, A. (2023). Exploring measures beyond energy efficiency with the transfer of environmentally sound technology methodology. *Cleaner Environmental Systems*, *10*, 100133.

Lyeonov, S., Pimonenko, T., Bilan, Y., Štreimikienė, D., & Mentel, G. (2019). Assessment of green investments' impact on sustainable development: Linking gross domestic product per capita, greenhouse gas emissions and renewable energy. *Energies*, *12*(20), 3891.

Ma, B., & Wang, A. (2025). Exploring the role of renewable energy in green job creation and sustainable economic development: An empirical approach. *Energy Strategy Reviews*, *58*, 101642.

Mahalik, M. K., Pal, S., Le, T.-H., & Mishra, S. (2024). Does environmental policy stringency improve nature's health in BRICS economies? Implications for sustainable development. *Environmental Science and Pollution Research*, *31*(1), 509-528.

Mahmood, S., Sun, H., Iqbal, A., Alhussan, A. A., & El-kenawy, E.-S. M. (2024). Green finance, sustainable infrastructure, and green technology innovation: pathways to achieving sustainable development goals in the belt and road initiative. *Environmental Research Communications*, 6(10), 105036.

Majid, M. (2020). Renewable energy for sustainable development in India: current status, future prospects, challenges, employment, and investment opportunities. *Energy, Sustainability and Society*, *10*(1), 1-36.

Miranda, I. T. P., Moletta, J., Pedroso, B., Pilatti, L. A., & Picinin, C. T. (2021). A review on green technology practices at BRICS countries: Brazil, Russia, India, China, and South Africa. *Sage Open*, *11*(2), 21582440211013780.

Nach, M., & Ncwadi, R. (2024). BRICS economic integration: Prospects and challenges. *South African Journal of International Affairs*, *31*(2), 151-166.

Onabowale, O. (2024). Energy policy and sustainable finance: Navigating the future of renewable energy and energy markets. *World Journal of Advanced Research and Reviews*, *25*, 22352252.

Paliokaitė, A. (2019). An innovation policy framework for upgrading firm absorptive capacities in the context of catching-up economies. *Journal of Entrepreneurship, Management and Innovation*, *15*(3), 103-130.

Pandey, N., de Coninck, H., & Sagar, A. D. (2022). Beyond technology transfer: Innovation co-operation to advance sustainable development in developing countries. *Wiley Interdisciplinary Reviews: Energy and Environment*, *11*(2), e422.

Pedregosa, F., Varoquaux, G., Gramfort, A., Michel, V., Thirion, B., Grisel, O., ... & Duchesnay, É. (2011). Scikit-learn: Machine learning in Python. the *Journal of machine Learning research*, 12, 2825-2830.

Peduzzi, P. (2019). The Disaster Risk, Global Change, and Sustainability Nexus. *Sustainability*, *11*(4), 957. https://www.mdpi.com/2071-1050/11/4/957

Petrone, F. (2019). BRICS, soft power and climate change: new challenges in global governance? *Ethics & Global Politics*, *12*(2), 19-30.

Pigato, M., Black, S., Dussaux, D., Mao, Z., Rafaty, R., & Touboul, S. (2020). *Technology transfer and innovation for low-carbon development*. World Bank Publications.

Rahman, H. U., Zaman, U., & Górecki, J. (2021). The role of energy consumption, economic growth and globalization in environmental degradation: empirical evidence from the BRICS region. *Sustainability*, *13*(4), 1924.

Rajesh, R., Kanakadhurga, D., & Prabaharan, N. (2022). Electronic waste: A critical assessment on the unimaginable growing pollutant, legislations and environmental impacts. *Environmental Challenges*, *7*, 100507.

Ramluckun, R., Malumbazo, N., & Ngubevana, L. (2024). A review of the energy policies of the BRICS countries: the possibility of adopting a just energy transition for South Africa.

Seabold, S., & Perktold, J. (2010). Statsmodels: econometric and statistical modeling with python. SciPy, 7(1), 92-96.

Sezgin, F. H., Bayar, Y., Herta, L., & Gavriletea, M. D. (2021). Do environmental stringency policies and human development reduce CO2 emissions? Evidence from G7 and BRICS economies. *International Journal of Environmental Research and Public Health*, *18*(13), 6727.

Shah, S. S. (2024). Recent Trends in Renewable Energy Adoption and Their Economic Implications. *Journal of Environmental Science*, *1*, 100004.

Sustainability, *16*(2), 703.

Tariq, G., Sun, H., Ali, I., Pasha, A. A., Khan, M. S., Rahman, M. M., Mohamed, A., & Shah, Q. (2022). Influence of green technology, green energy consumption, energy efficiency, trade, economic development and FDI on climate change in South Asia. *Scientific reports*, *12*(1), 16376.

Tiwari, S., Mohammed, K. S., Mentel, G., Majewski, S., & Shahzadi, I. (2024). Role of circular economy, energy transition, environmental policy stringency, and supply chain pressure on CO2 emissions in emerging economies. *Geoscience Frontiers*, *15*(3), 101682.

Udeagha, M. C., & Muchapondwa, E. (2023). Green finance, fintech, and environmental sustainability: fresh policy insights from the BRICS nations. *International Journal of Sustainable Development & World Ecology*, *30*(6), 633-649.

Virtanen, P., Gommers, R., Oliphant, T. E., Haberland, M., Reddy, T., Cournapeau, D., ... & Van Mulbregt, P. (2020). SciPy 1.0: fundamental algorithms for scientific computing in Python. *Nature methods*, 17(3), 261-272.

Yadav, A., Gyamfi, B. A., Asongu, S. A., & Behera, D. K. (2024). The role of green finance and governance effectiveness in the impact of renewable energy investment on CO2 emissions in BRICS economies. *Journal of environmental management*, *358*, 120906.

Zhang, S., Collins, A. R., Etienne, X. L., & Ding, R. (2021). The environmental effects of international trade in China: measuring the mediating effects of technology spillovers of import trade on industrial air pollution. *Sustainability*, *13*(12), 6895.

Zhao, A., Wang, J., Sun, Z., & Guan, H. (2022). Environmental taxes, technology innovation quality and firm performance in China—A test of effects based on the Porter hypothesis. *Economic Analysis and Policy*, *74*, 309-325.

Zhu, R., Xu, Q., Xiqiang, X., Sibt-e-Ali, M., Waqas, M., Ullah, I., & Anwar, A. (2024). Role of resources rent, research and development, and information and communication technologies on CO2 emissions in BRICS economies. *Resources Policy*, *93*, 105072.