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Original Article

Does Renewable Energy Consumption Lead to Low Carbon Emissions? Evidence from BRICS Countries

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Abstract: *Through the use of the ARDL model, this empirical analysis seeks to determine how the use of renewable energy affects carbon emissions in the BRICS nations between 1990 and 2020. With the exception of Brazil, all BRICS countries exhibit a long-term correlation between their use of renewable energy and their carbon emissions, according to the exact outcome of the bound test. On the other hand, the outcome of the short-run analysis exhibits that renewable energy consumption leads to a fall in carbon emissions in Russia, India, China, and South Africa. The final finding of the long-term analysis reveals that renewable energy use has a negative influence on carbon emissions in India but not in the other BRICS countries. From a policy perspective, the current investigation suggests that policymakers need to rethink their perception of renewable energy to mitigate carbon emissions.*

Keywords: *Carbon Emissions, Energy Consumptions, BRICS Countries.*

1. INTRODUCTION

Climate change is one of the critical global challenges the world community is facing. The negative spillover impact of climate change is not limited to any specific economy or sector. When the climate is a common property, the entire world community is responsible for its care. However, with the passage of time, the natural environment is degrading, which ultimately affects the natural ecosystem. Environmental degradation is mostly due to raceless excessive use of natural resources, creating an imbalance in the resource taxonomy. Human activities in terms of production to meet the excess demand due to the increase in population has created excessive demand for energy and resource use. Therefore, the major challenges in the recent modern days are low rainfall with high temperatures leading to low productivity, food insecurity, sea level rise, erosion of coastal zones, rise in the intensity of natural disasters, species extinction, and most significantly, an unpredictable rise in the number of vector-borne diseases (NAPCC;2021). The key factor that causes an increase in carbon emissions is what causes climate change and global warming. which is due to the higher demand for energy in the process of urbanization and development. Massive exploitation of natural resources is unbalancing the natural composition. Massive deforestation and burning of fossil fuels are mainly responsible for natural imbalance **(Huisingh et al. 2015).**

The negative spillover impact of natural resource depletion has alarmed the global community to use alternative sources of energy and to adopt necessary steps to check pollution levels. Recently, the international community agreed to restrict the rise in global average temperature to 1.5 degrees Celsius above pre-industrial levels (UNFCCC) in the Paris Climate Agreement (PCA) and to ensure that the rise in worldwide average temperature stays below 2 degrees Celsius above pre-industrial levels. They have set benchmarks to curb the negative impact of climate change. It is basically a legally binding international treaty on climate change that has been adopted by the 196 parties at COP21 in Paris. The focus is more on the utilization of renewable energy regimes for a multiplicity of purposes, thereby earmarking a shift from conventional means. In the framework of sustainable development, renewable energy is the source of energy that is expected to be the alternative source that will create less pollution and can supplement the energy demand. This resource mainly refers to those sources of energy which are derived from natural sources. It is believed that renewable energy consumption emits far fewer emissions than fossil fuel consumption. So, renewable energy can serve as a major source of energy, which can not only meet the energy demand but can also play a key role in addressing the climate crisis (United Nations Climate Action, 2023).

Energy from organically renewing but flow-limited sources is another definition of renewable energy. The lifespan of renewable resources is nearly endless, but their energy content is constrained to a certain amount per unit of time (U.S. Energy Information Administration, 2023). Consequently, renewal energy consumption also has two important issues, such as its rate of consumption and whether it creates pollution in terms of carbon emission or not. In this perspective, the BRICS countries, i.e., **Brazil, Russia, India, China, and South Africa,** exhibit a significant impact on the global map in the matter of global economic and environmental issues. These nations are characterized by carbon-intensive economic systems and, most importantly, a fast-moving growth trajectory in terms of industrialization and urbanization. The high demand for energy is causing rapid deforestation due to heavy dependency on fossil fuel consumption. contributing to environmental degradation and climate change. **Brazil** plays a significant role in the global climate change scenario. According to studies, land use patterns and deforestation are the major contributors to the emission of greenhouse gases in Brazil. The emission level has increased in Brazil since the 1990s (Viola et al. 2016). The increase in per capita emission is mostly due to deforestation (Vieira et al. 2022). Similarly, **Russia** is a carbon-intensive economy. It exports huge amounts of fossil fuels. However, the pollution level in Russia decreased by 18% from 1990 to 2012. The share in global emissions has reduced. Energy production and its use are the major contributors to carbon emissions in Russia. **China,** being the most popular country, plays a significant role in the case of pollution emissions. The pollution level has increased by 230% over time, with a global share of 22% (WRI 2019). Similarly, India is another populous country, emerging with rapid urbanization and industrialization. It registers a faster rate of growth but along with a faster rate of emission level. Studies show a more than 140% increase in pollution levels. Other than industrial pollution, the agriculture sector also plays a significant role in emitting pollution (Myllyvirta et al., 2020). South Africa registers within 15 of the most contributors to emissions of greenhouse gas, and the emission level has increased by around 45%. Thus, when, on the one hand, the BRICS nations are able to be emerging economies, on the other hand, the major challenge they are facing is reducing pollution and mitigating and adapting to climate change. These countries alone consume 40% of the world's energy and are major contributors to CO_2 emissions (Baloch and Danish, 2022) (Danish and Ulucak, 2020). Therefore, these nations have also joined hands with the global community to achieve sustainable development goals and are committed to achieving net zero emissions by 2050 **(Chapungu et al., 2022).**

The above issue encourages the investigation of the case of carbon emission and renewable energy consumption for BRICS nations. The importance of this study lies in the characteristics of these countries and the search for alternative sources of energy. The present study will be helpful in understanding the dynamics of carbon emission and renewable energy consumption for policy formulation for sustainable development.

II. LITERATURE REVIEW

The prominent literatures reviewed during the work includes the research of **(Isoaho et al.; 2016),** which mainly aims to investigate the need to transform the electric power system, especially in the context of India and China, in an effort to separate resource usage that is not sustainable from economic growth. The study concludes that factors such as growing environmental pollution-related social tensions and a confluence of political and geographic factors enable the respective state governments to facilitate the promotion of Renewable Energy Technologies.

(Sonnenschein; 2016) aims to study the role of additional research development as well as a demonstration of low-carbon energy technologies to facilitate Rapid Decarbonization alongside the achievement of various SDGs through an exploratory case study of public Research, Development, and Demonstration financing of Low Carbon Energy Technologies in the Nordic Countries. It concludes that the Nordic countries provide a compelling example to examine the selection of indicators in areas pertaining to policy assessment, acceptability, robustness, and ease of monitoring.

(Oliveira et al; 2016) his paper aims to examine the factors influencing the adoption of Clean Energy Initiatives in two states of Brazil and its influence on Clean Development Mechanisms through a case study methodology combined with a qualitative examination of the political economics of the two states' clean energy projects. The study concludes that factors such as local political economy, local technical capacity to carry out technological changes and international market mechanisms account influence the development of large-scale clean energy initiatives.

(Kruger et al., 2016) in his study focuses on the strategies as well as ways adopted by South Africa as well as Indonesia to address energy poverty. The work highlights the role of energy subsidies and the socio-political history of the nations in influencing residential energy policy. The work concludes that energy subsidies in both nations serve as a medium for generating extensive political currency**.**

(Sovacool; 2016) his study aims to draw a comparison between the two conflicting opinions on the necessary time domain to adapt to the energy transition. In the study, the author highlights the factors that support the viewpoints of energy transitions, such as historical records, the validity of looking at the bigger picture, the literature on 'lock-in' and 'path dependency,' historical records, and the trends witnessed. The authors conclude that energy transitions are complex, and hence, multiple factors influence Energy transitions**.**

(Chaudhary et al; 2014) in their study aims to determine the factors shaping climate action in India. The work undertakes an actor-centric perspective, taking into account the government, private players, and civil society by adopting a case study approach with the inclusion of data regarding the Wind energy and Solar Power Sector in the country. The work concludes that shifting priorities, changes in the perception of the states, and the emergence of indirect hindrances to renewables and other related factors influence climate action as well as the adoption of alternative sources of energy.

(Dai; 2015) in a study that aims to determine the factors influencing Climate Relevant Policy Implementation in China. The study mainly seeks to answer the research question regarding the players responsible for Renewable Energy Development and their interests and how the interaction between these factors influences the policy implementation regarding the same in China. The study concludes that every single entity inclined towards certain aspects of the policy impacts its implementation.

(Dubash et al., 2015) Their study aims to determine the targets that India should put up as the mitigation component of its climate contribution. The study undertakes a comparative review of the seven major studies focusing on CO_2 emissions in India's energy and industrial sectors. The work opines the need for India to enhance the process for energy and climate scenario analysis, with the government taking the lead. The study comes to the conclusion that constructive model use for policy may formalize relationships and interactions between modeling groups and policymakers, allowing for the design of more robust scenarios and aiding the consistency of input premises.

(Fouquet; 2010) their study highlights the history of the Energy transition across the major sectors of the United Kingdom, including Power, Transport as well as Households, and undertakes an analysis regarding energy substitutions and transitions. The work concludes that on the basis of past experiences, the Carbon Dioxide emissions are supposed to grow further for many years, thereby raising the GHG's as well as intensifying the issue of climate change. **(Geels ; 2011)** in his work aims to understand the role of Multi- Level perspective (MLP) for facilitating socio-technical transitions to sustainability. The study agrees with the fact that the debates regarding transitions sum up as one of the most complicated and multifaceted ones. The work concludes that although sustainability has made certain progress but, there is much more way to go with the subsequent passage of time.

(Krishna et al., 2015) in their work aim to emphasize the need for increasing the supply of renewable energy on account of its role in mitigating climate change and attaining the SDGs utilizing a mixed method approach comprising desk research along with semi-structured interviews and snowball data collection techniques to facilitate the collection of qualitative and quantitative information. The study concludes that the major factors that influence the adoption of Renewable Energy regimes in the Indian context include the Policies of the Union and State Government, the Role of Political Class, and the Role of Manufacturers**.**

(Mahajan et al; 2014) in their study aim to highlight key regulatory and governance issues in the Renewable Energy Sector. The study collects information through secondary sources of data such as journals, policies, and peer-reviewed publications, as well as through interviews with several stakeholders and Renewable Energy Experts. The work highlights key aspects of governance in the renewable energy sector in India, such as capacity and supporting infrastructure, institutional capacity data availability, and social and environmental issues. The study supplements several ways forward in order to fill several gaps, which include sound enforcement of the policies formulated, ramping up manufacturing in the sector, Increasing Penetration of Renewables in the Electricity mix, and increasing budgetary allocation**.**

(Zarnic et al.; 2013) In their work, they aim to identify and address knowledge-related gaps in the theory of green growth and its practice. The study highlights the complicated nature of the concept of Green Growth and its implementation. The work highlights challenges of the Green Economy, such as the need for harmonization of the data collected, poor integration of economic and environmental data, the need for improvisation of data collection techniques, the need for convergence of data, and challenges pertaining to the construction of indicators.

(World Bank et al. 2013) Their study highlights the transition of Indonesian households in the context of cooking fuels. It states that the switch from conventional sources to newer ones such as LPG and electricity can pave the way for achieving clean cooking solutions; however, the expensive nature of the fuels makes it not reachable for rural households. The work throws light upon the issues, especially in the supply of stoves, such as the prevalent cook stove market and Production capacity, the production costs, and the knowledge towards the stoves, which act as a major hindrance in the adoption of clear energies. The work recommends policies that can facilitate Universal Access to Clean Cooking.

(Diop et al., 2014) the study critically evaluates the policy of reduction of Energy Subsidies in Indonesia. The work showcases the historical evolution of energy subsidies and the role they played in the nation's development. The work concludes that the energy subsidy reform shall shield vulnerable households from the negative impacts of sudden surges in the prices of energy on account of the elimination of Energy Subsidies.

(Myhrvold et al; 2012) In their study, they emphasize the need for a shift away from coal-based electricity generation mechanisms and toward low-GHG energy generation practices in order to lessen the effects of long-term climate change. The study uses straightforward mathematical models to examine the short-term impacts of energy system transitions on a number of different areas, including global mean temperature changes, radiation forcing, and greenhouse gas emissions. The study concludes that there exists a necessity for the generation of 10-30 T.W. of carbon-neutral thermal energy in order to balance the global demand as well as ensure sustained growth.

(Philibert et al. 2017in their study highlight the problems that act as a barrier to the adoption of Renewable Technology regimes and supplement data regarding the most difficult obstacles in the energy transformation process. The study concludes that although challenges are indeed multiple when the emerging sector is taken into consideration, however, certain way forwards exist, such as enhancement of the energy supply regulatory regime, Encouragement of Investments, proper evaluation of the Return on Investment, Technological Awareness, and most importantly harmonizing operability and integration.

(Qazi et al., 2019) their study aims to highlight the world's energy requirements for renewable technologies for domestic usage, as well as determine public opinions on renewable energy technologies. The major findings of the study state that out of the numerous technologies available in the current scenario, Solar Energy serves as a major substitute for fossil fuel-driven technologies. The study concludes that in order to facilitate sustainable development with the due passage of time, it becomes quite essential to raise awareness regarding Renewable Energy Technologies**.**

(Okeke; 2021) in a study aimed to determine the sustainable nature of the practices adopted by the oil and gas companies across Europe, Asia as well as America by analyzing 150 annual reports of 15 companies spread across the three continents. Highlighting the importance that the companies give in putting forward the sustainability dimension in their respective annual reports. It concludes that among the 15 companies spread over the respective continents, the companies operating in Europe give more emphasis on social, environmental, and economic aspects of sustainability in comparison with their Asian and American counterparts. the work also opines that with the passage of time, focus on sustainability by the major players would pave the way for facilitating energy transitions.

(Jarboui ; 2021) the study aims to examine the operational and environmental efficiency of 45 Oil and Gas Companies during the time period of 2000-2018 using the True Fixed Effect Model as well as determine the impact of Renewable Energy on the efficiencies. The major findings of the study reveal that the total production of renewable energy, along with biomass energy, has a negative impact on the operational efficiency of the Oil and Gas Companies, but they have a positive impact on environmental efficiency. (Boulaire et al; 2019) their study aims to develop a model that would determine the benefit to both customers and the distribution grid when the households or a community battery without a central control is set up, focusing mainly upon the dwelling of Townsville, Australia. It concludes that in the particular case study, either individual or shared batteries would enable the generalization of operational savings to several customers. (Smith et al. 2017) in their study seek to demonstrate the interlinkages across three key areas, i.e., across sectors (finance, agriculture, energy, and transport), societal sectors (local authorities, government agencies, private sector, and civil society) and among low, medium as well as high-income countries. The study highlights the role of the Sustainable Development Goals in promoting holistic development. It recommends seven-way forwards supplementing information regarding improvisation of the interlinkages at global and national levels. The study concludes by supplementing brief ideas about the achievement of the various SDGs through properly integrated implementation plans.

(Delmotte et al., 2021) (The IPCC Team), in their study, aims to undertake a full and comprehensive assessment of the physical science basis of climate change, laying an emphasis upon the data of 14,000 scientific publications. It highlights the role of innovation in facilitating virtual collaborations, incorporating various aspects such as extra support and training for participants and facilitators, additional advance preparation, the necessity of more focused meetings with clear agendas, and facilitating stable internet connectivity.

(Merello et al; 2018) By utilizing Logit and Linear Panel Data to identify the driving forces behind the decisions, the study's goal is to investigate the relationship between the corporate variables and two crucial decisions: reporting carbon emissions and the impact of carbon emissions' evolution. Listed South American firms with a minimum market capitalization of $2500 million are included in the sample. The work concludes that a positive correlation exists between the size of the company, the presence of a CSR Committee, the publication of a CSR Report, and the likelihood of disclosing data about CO2 emissions.

The above review of the literature reveals that most of the available studies are based on either a single country or a group of countries other than BRICS. The majority of the works have been concentrated around the European Union, Nordic Nations, Scandinavian Countries, and, to be more specific, revolving around the major Western Economies. Therefore, the present study attempts to investigate the current status of carbon emissions, i.e., CO_2 Emissions and renewable energy consumption in the context of BRICS nations, and to investigate the effect of renewable energy on air pollution and carbon emissions.

III. DATA AND METHODOLOGY

A. Data

The purpose of this study is to verify how green energy use affects economic and environmental results. We examined annual time series data spanning from 1990 to 2020 for the BRICS nations—Brazil, Russia, India, China, and South Africa. We picked the time period based on the availability of a full series for the variables under consideration. Furthermore, absolute green energy consumption in a million tones, such instrumental variables broadly confirmed by various empirical analyses (Lin and Moubarak, 2014; Shahbaz et al., 2015), are commonly used to calibrate the uses of green energy. On the other side, as an instrumental variable of carbon emission, we looked at CO2 emissions in million tonnes. All relevant statistics on green energy consumption and CO2 million tonnes emissions are accessible on the Organization for Economic Co-operation and Development (OECD) website and can be accessed from https://data.oecd.org/air/air-and-ghg-emissions.htm. We extracted related data from the OECD's website.

B. Methodology

a) ARDL Model for Analysis

For analysis of CO_2 emissions renewable energy usage in Brazil, Russia, India, China, and South Africa, the Auto Regressive Distributed Lags (ARDL) econometrics model has been applied. For the purpose of predicting the magnitude of the connection between a dependent variable and a set of variables that are independent and would not always be incorporated in the same sequence, Pesaran et al. (2001) devised this robust econometric technique. When there is a mixture of stationary and non-stationary series, the ARDL model allows for simultaneous estimating of the long- and short-term relationships and enables consistent estimation for observations with small or finite sample sizes (Pesaran et al., 2001). To address spurious estimation related to time series data, a unit root test via the Augmented Dickey-Fuller and Philip Perron stationarity testing approaches is conducted. This confirms that none of the variables are I(2) or beyond, which is a requirement for the mixture of the series.

b) Model Specification

$$\boldsymbol{CO = \alpha + \sum_{i=1}^{q} \partial CO_{t-i} + \sum_{i=1}^{q} \beta Renergy_{t-i} + e} \quad \textbf{(1)}$$

From the above ARDL model, it can be seen that carbon emission (C.O.) is dependent upon the past lag of its own as well as the past lag of independent variables, which includes renewable energy consumption (Renergy). On the other hand, $\boldsymbol{\alpha}$ is a constant term where $\boldsymbol{\partial}$ ***and*** $\boldsymbol{\beta}$ are the coefficients of the model, which show the impact of explanatory variables on the explained variable. Finally, $\boldsymbol{e}$ is a white noise error term, which is assumed to be IID.

The above model can be written in the error correction form below.

$$\boldsymbol{\Delta CO = \alpha + \sum_{i=1}^{q} \partial \Delta CO_{t-i} + \sum_{i=1}^{q} \beta \Delta Renergy_{t-i} + \eta_1 CO_{t-1} + \eta_2 Renergy_{t-i} + \mathcal{E}} \quad \textbf{(2)}$$

$\boldsymbol{\alpha}$ is a constant term where ∂**s** and $\boldsymbol{\beta}$ coefficients show the short-run relationship. On the other hand, $\boldsymbol{\eta}$ are the coefficient of error correction term, which shows the speed of adjustment towards the equilibrium. The null hypothesis of the cointegrating relationship between carbon emission and renewable energy is detected by testing the F-statistic bound test for **H0:** $\boldsymbol{\eta_1 = \eta_2 = 0}$, against the alternative **H1:** $\boldsymbol{\eta_1 \neq \eta_2 \neq 0}$. If the tested F-statistic value lies below the lower bound critical value, then the null hypothesis of no cointegrating relationship cannot be rejected, and if it exceeds the respective upper bound critical value, the null hypothesis is rejected. If the tested F-statistic value falls within the lower and upper critical value bounds, the inference is inconclusive.

The above model can be simplified as below:

$$\boldsymbol{\Delta CO = \alpha + \sum_{i=1}^{q} \partial \Delta CO_{t-i} + \sum_{i=1}^{q} \beta \Delta Renergy_{t-i} + \eta_1 CO_{t-1} + \psi \chi_{t-1} + \epsilon} \quad \textbf{(3)}$$

Where $\boldsymbol{\psi}$ is the coefficient of error correction term, which shows the speed of adjustment towards the equilibrium, and it is expected to be negative.

IV. FINDINGS AND DISCUSSIONS

A. Descriptive Statistics

Table 1: CO_2 Emissions (in million tonnes) of BRICS Countries

Countries	Brazil	Russian Federation	India	China	South Africa
Mean	325.38	1586.13	1282.84	5731.81	349.99
Median	314.12	1537.18	1074.99	5407.40	374.18
Standard Deviation	86.93	184.89	590.21	2931.64	74.32
Kurtosis	-1.03	4.62	-1.32	-1.70	-1.57
Skewness	0.05	2.23	0.44	0.20	-0.30
Range	296.88	756.94	1786.38	7992.48	207.94
Minimum	184.76	1406.59	530.12	2088.85	235.39
Maximum	481.64	2163.53	2316.50	10081.34	443.33

From the above table, it can be inferred that the average CO_2 Emissions of Brazil during the time frame stood at 325.38 million tons, whereas in the case of Russia, it was placed at 1586.13 million tons. In the context of India, the average emissions pointed to an amount of 1282.84 million tons annually, while the figures in the case of China were placed at 5731.81, and finally, South Africa emitted 349.99 million tons of CO_2 on an average basis during this time frame. Coming into the context of the Standard Deviation, from the above table, it can be stated that the maximum deviation with regard to CO_2 emissions was witnessed in the case of the emissions of China, followed by India, Russia, Brazil, and South Africa with figures of 2931.64, 590.21, 184.89, 86.93 and 74.32 respectively. When the skewness of the dataset is taken into consideration, from the table, it can be stated that apart from the figures as shown by South Africa, all other nations' datasets are skewed towards the right.

Table 2: Renewable Energy Usage in Thousand Tonnes

Countries	Brazil	Russian Federation	India	China	South Africa
Mean	95185.15	19641.71	153751.92	231384.03	9252.07
Median	92532.33	18763.90	145613.17	217790.58	9022.27
Standard Deviation	24162.70	2676.43	32108.97	37170.71	1834.84
Kurtosis	-1.58	1.57	-0.58	3.69	-1.48
Skewness	0.18	1.64	0.71	2.07	0.14
Range	71387.81	9238.29	107399.78	147432.62	5488.54
Minimum	65619.67	17234.25	114137.73	203002.61	6683.00

From the above table, it can be inferred that the average Renewable Energy Usage of Brazil during the time frame stood at 95,185.15 (000 toe), whereas in the case of Russia, it was placed at 19,641.71. In the context of India, the average Renewable Energy Usage pointed to an amount of 153,751.92 (000 toe) annually. At the same time, the figures in the case of China, the mean figure was placed at 231,384.03, and finally, South Africa utilized 9252.07 (000 toe) of Renewable Energy on an average basis during this time frame. Coming into the context of the Standard Deviation, from the above table, it can be stated that the maximum deviation with regard to Renewable Energy Usage was witnessed in the case of the emissions of China, followed by India, Brazil, Russia, and South Africa with figures of 37,170.71, 32,108.97, 24,162.70, 2,676.43 and 1,834.84 respectively. When the skewness of the dataset is taken into consideration, from the table, it can be inferred that the dataset of all the BRICS nations is skewed towards the right.

Table 3: Unit Root Test Results

	Unit Root test at level		Unit Root test at first difference level	
Countries	CO_2 Emission	Renewable Energy	CO_2 Emission	Renewable Energy
Brazil	-1.53	0.99	-4.25***	-3.87***
Russia	-1.97**	-2.74	-2.92***	-4.94***
India	-0.58	3.39**	-2.67**	-3.64**
China	-0.43	0.05	-2.96**	-2.96**
South Africa	-1.35	-0.56	-4.91***	-3.55***

*Note: *** is significant at 1% and ** at 5%*
Source: Researcher Calculation

The outcomes of the ADF unit, the root test in Table 3, reveal that all the variables are non-stationary at the level, except for the carbon emission in Russia and the green energy uses in India. However, the results also show that, at the 1% or 5% significance level, the initial differences in the variables remain stationary. We use the bound test to examine the long-run relationship between carbon emission and green energy in the BRICS countries after verifying the stationarity characteristic of the variables. Table 4 below displays the results of the binding test.

Table 4: Results of Bound Test

ARDL Long Form and Bounds Test				
Country	F Statistic	Significance	I(0)	I(1)
Brazil	2.63	10%	3.02	3.51
		5%	3.62	4.16
		1%	4.94	5.58
Russian Federation	12.16***	10%	3.02	3.51
		5%	3.62	4.16
		1%	4.94	5.58
India	9.43***	10%	3.02	3.51
		5%	3.62	4.16
		1%	4.94	5.58

China	5.14**	10%	3.02	3.51
		5%	3.62	4.16
		1%	4.94	5.58
South Africa	5.31**	10%	3.02	3.51
		5%	3.62	4.16
		1%	4.94	5.58

*Note: **** is significant at 1% and ** at 5%*
Source: Researcher Calculation

The bound test results demonstrate that there is a long-run relationship between carbon emission and green energy consumption in all selected BRICS nations except Brazil. In the Bound test, the value of the F statistic is greater than the aforementioned critical threshold at all levels of significance, rejecting the null hypothesis of no co-integration between carbon emission and green energy uses (see table no 4). We estimated the Long and short-run coefficients using the ARDL model after receiving a significant result from the bound test. The country-wise outcome of the long and short-run coefficient has been presented below. The lag length of the above ARDL model has been selected based on the Akaike Information Criterion (AIC).

Table 5: Long Short and Short Run Outcome of Brazil

Long Run			
Variable	**Coefficient**	**t stats**	**p-value**
Carbon Emissions	-0.17	-1.68	0.1
Renewable Energy	0.0005	1.23	0.22
Short Run			
δ Renewable Energy	0.0003	0.29	0.76
δ_1 Renewable Energy	-0.002	-1.58	0.12
Error Correction Term	-0.58		0.25

*Note: *** is significant at 1% and ** at 5%*
Source: Researcher Calculation

From Table 05, it can be mainly inferred that in the context of Brazil, it is being witnessed that the t value shows insignificance in the case of both the variables, and there exists no co-integration among the variables. On the other hand, the result coefficient of the error correction term is highly insignificant, which is not desirable for a good model fit. It is evident from the bound test outcome that there is no long-run relationship between carbon emission and green energy consumption, which also pertains to the outcome of the error correction term. On the other hand, the result also shows that none of the coefficients are significant at either 1 percent or a 5 percent level of significance. This further reveals that green energy uses do not seem fruitful to mitigate carbon emissions from the Brazilian perspective.

Table 6: Long Short and Short Run Outcome of Russian Federation

Long Run			
Variable	**Coefficient**	**t stats**	**p-value**
Carbon Emissions	-0.26	-1.97**	0.05
Renewable Energy	-0.005	-0.52	0.6
Short Run			
δ Renewable Energy	0.004	0.38	0.7
δ_1 Renewable Energy	0.01	2.1**	0.04
Error Correction Term	-0.365**	0.03	

*Note: ** is significant at 5%*
Source: Researcher Calculation

In the context of the Russian Federation, from Table 06, it can be inferred that the t value shows a mixed type of response in the case of both the variables taken into consideration and there exists co-integration among the variables. The error correction term's result, which is -0.365 and significant at the five percent significance level, shows that any differences in the long-run equilibrium from the previous lag period are corrected at a rate of 36% in the present period in order to bring the system closer to equilibrium. On the other hand, the outcome long run coefficient reveals that there is no significant impact of renewable energy consumption on carbon emission in Russia. However, because renewable energy consumption has a significant coefficient, the short-term coefficient shows that using renewable energy results in a decrease in carbon emissions. It can further be inferred that a 1000-ton increase in renewable energy consumption leads to a fall in carbon emission by 0.01 million tonnes.

Table 7: Long Short and Short Run Outcome of India

Long Run

Variable	Coefficient	t stats	p-value
Carbon Emissions	0.43	4.69***	0.001
Renewable Energy	-0.1	-4.4***	0.0002
Short Run			
δ Renewable Energy	0.001	0.29	0.77
δ_1 Renewable Energy	0.02	4.16***	0.0003
Error Correction Term	-0.46**		0.05

*Note: *** is significant at 1% and ** at 5%*
Source: Researcher Calculation

Table 07 provides insight into the term for error correction in the Indian context. It is -0.46, which is significant at the 5 percent significance level, meaning that any discrepancy in the long-term equilibrium from the previous lag time frame is adjusted at a rate of 46% in the current period and leads to equilibrium. On the other hand, the outcome long-run coefficient reveals that there is a significant impact of renewable energy consumption on carbon emission in India as the coefficient of renewable energy consumption is significant. The outcome of the long run coefficient shows that a 1000-tone increase in renewable energy consumption leads to a 0.1 million tone fall in carbon emission in India. On the other hand, the short-run coefficient exhibits that renewable energy consumption leads to a fall in carbon emissions, as the coefficient of renewable energy consumption is significant. It can further be inferred that a 1000-tone increase in renewable energy consumption leads to a fall in carbon emission by 0.02 million tonnes. Hence, it can be inferred that renewable energy consumption is pertinent in the context of India to mitigate carbon emissions.

Table 8: Long Short and Short Run Outcome of China

ARDL Test Results of China			
Long Run			
Variable	**Coefficient**	**t stats**	**p-value**
Carbon Emissions	-0.17	-1.68	0.1
Renewable Energy	0.0005	1.23	0.22
Short Run			
δ_1 Carbon Emissions	0.41	1.86	0.07
δ_2 Carbon Emissions	-0.23	-1.23	0.23
δ Renewable Energy	-0.01	-1.56	0.13
δ_1 Renewable Energy	-0.004	-0.4	0.68
δ_2 Renewable Energy	-0.03	-3.36**	0.003
δ_3 Renewable Energy	-0.01	-1.28	0.21
Error Correction Term	-0.65***		0.01

*Note: *** is significant ** at 5%*
Source: Researcher Calculation

In the context of China, the outcome of Table 8 shows a mixed type of response of renewable energy consumption on carbon emission in the short and long-run perspective. However, the error correction term's outcome is -0.65 and significant at the 1 percent significance level, meaning that any difference in the long-run equilibrium from the previous lag period is corrected at a rate of 65% in the present period in order to reach equilibrium. On the other hand, the outcome long-run coefficient reveals that there is no significant impact of renewable energy consumption on carbon emission in Russia. Alternatively, the short-run coefficient exhibits that renewable energy consumption over the past two periods of time leads to a fall in carbon emission, as the coefficient of renewable energy consumption is significant. It can further be inferred that a 1000-tone increase in renewable energy consumption leads to a fall in carbon emission by 0.03 million tonnes.

Table 9 Long Short and Short Run Outcome of South Africa

Long Run			
Variable	**Coefficient**	**t stats**	**p-value**
Carbon Emissions	-0.07	-0.43	0.66
Renewable Energy	0.002	0.32	0.75
Short Run			
δ_1 Carbon Emissions	-0.24	-0.98	0.34
δ_2 Carbon Emissions	-0.23	-1.23	0.23
δ_3 Carbon Emissions	-0.45	-2.22**	0.03
δ Renewable Energy	0.001	0.18	0.85
δ_1 Renewable Energy	0.02	0.007	0.25

δ_2 Renewable Energy	0.01	1.61	0.12
δ_3 Renewable Energy	-0.02	-3.95***	0.001
Error Correction Term	-0.59		0.00

*Note: *** is significant at 1% and ** at 5%*
Source: Researcher Calculation

Table 9 indicates a mixed kind of reaction of renewable energy consumption on carbon emissions in the short and long term in the context of South Africa. The outcome of the error correction term, on the other hand, is -0.59 and significant at the 1% level of significance, indicating that any disparity in long-run equilibrium in the previous lag period is adjusted at the pace of 59% in the present period and reaches equilibrium. On the other hand, the long-term coefficient demonstrates that renewable energy use has no substantial influence on carbon emissions in Russia. Alternatively, the short-term coefficient shows that renewable energy usage during the past three periods renewable energy consumption has resulted in a decrease in carbon emission as the coefficient of renewable energy consumption is significant. It can further infer that a 1000-tone increase in renewable energy consumption leads to a fall in carbon emission by 0.02 million tonnes respectively.

V. CONCLUSION AND POLICY IMPLICATION

The study findings bring forth a compelling conclusion regarding the relationship between renewable energy consumption and carbon emissions in the context of BRICS countries, with the exception of Brazil. The research establishes a strong and consistent long-run association between these variables, suggesting that as renewable energy consumption increases, carbon emissions tend to decrease across most BRICS nations. However, upon delving into individual country cases, the results showcase intriguing variations. In the case of Brazil, unlike its BRICS counterparts, no significant long-run or short-run relationship is observed between renewable energy consumption and carbon emissions. This divergence in Brazil's trajectory highlights the complexities inherent in the relationship between renewable energy adoption and carbon emission mitigation, calling for further investigation into the unique factors influencing this phenomenon in the country. For Russia, China, and South Africa, the study reveals a noteworthy long-run dissociation between renewable energy consumption and carbon emissions. Despite this, the short-run analysis indicates that these nations experience a temporary reduction in carbon emissions with an increase in renewable energy consumption. This short-term effect implies that while immediate progress may be achieved in carbon emission mitigation, a more sustained approach is required for long-term gains. India, on the other hand, emerges as a compelling case study. The research highlights a significant and consistent relationship between renewable energy consumption and carbon emissions, both in the short run and long run. This indicates that India's adoption of renewable energy sources yields tangible and persistent reductions in carbon emissions. Thus, a strategic emphasis on enhancing renewable energy usage in the Indian context could prove instrumental in combating carbon emissions and fostering sustainable development. Given the study's insightful findings, it is crucial for BRICS countries to devise comprehensive policies that prioritize the sustainable utilization of renewable energy as a viable alternative to reduce carbon emissions. However, it is essential to discern whether the current renewable energy usage truly contributes to carbon emission reduction or if policy redesign is imperative to maximize its potential impact. Therefore, further research is warranted, delving into component-wise analyses of renewable energy sources and their individual roles in curbing carbon emissions. This targeted investigation will enable policymakers to fine-tune their strategies, fostering effective and context-specific policies for a greener and more sustainable future. In conclusion, the study's nuanced findings open avenues for deeper exploration and informed policy formulation, ultimately steering BRICS nations towards a greener, cleaner, and more resilient energy landscape.

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