Environmental Cost of Economic Development, Trade Openness, And FDI: Empirical Evidence from BRICS Economies

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Abstract

The balance between economic and ecological well-being has become one of the primary concerns of the governments in the world. The need to achieve sustainable growth is emphasized in the contemporary world economies and especially those that are underdeveloped. This paper investigates the dynamic impacts of the Foreign Direct Investment (FDI), economic growth (EG), the consumption of renewable energy (RE) and trade openness (TO) on the environmental degradation (CO2 emissions) in the BRICS countries (Brazil, Russia, India, China, South Africa). The analysis that will be conducted utilizes annual panel data covering the years 1995 to 2023 to implement the Panel Autoregressive Distributed Lag (ARDL) methodology to analyse the short and long-term correlation.

We are all paying the opportunity cost of economic development by accelerated environmental degradation all over the world. In order to curb the devastating realities of climate change and save nature, countries need to reshape their energy usage policies through renewable energy technologies and research, thus creating sustainable development in the world. The findings show that economic growth has a significant positive impact on the increase in CO2 emissions in the long-run and the use of renewable energy has significant positive impact on the reduction of the CO2 emissions in short and long-term. The effect of Foreign Direct Investment (FDI) is dynamic, increasing emissions over the short term and decreasing them significantly over time, therefore, supporting the Pollution Halo Hypothesis in the long term. The openness to trade showed a statistically significant yet insignificant positive impact on the long-term emissions. These findings bring about the need to develop renewable energy and wisely utilize foreign direct investment coupled with green growth strategies to reduce environmental degradation as well as develop the economy of the BRICS countries.

Keywords: *Economic Development, Trade Openness, Foreign Direct Investment, Renewable Energy Consumption, CO2 Emission, BRICS.*

Introduction

A global agenda on Sustainable Development Goals (SDGs) has been offered in 2015 United Nations general Assembly (UNGA) to achieve a sustainable future. The name "Agenda 2030, " includes 17 SDGs, consisting of 169 targets to help eradicate poverty, combat injustice and inequality and protect the global environment. The key success factor of Agenda 2030 is Sustainable Energy. The SDGs-7 is the objective of the world to have reliable, sensible, and convenient access to promote energy services to improve sustainability as the share of renewable energy in the world rises. Which will ensure the world is more energy-efficient.Multiple studies were made in order to narrow the SDGs-7 towards explaining its input into other SDGs. Gielen et al.,2019)

Most countries have a significant contribution towards GDP due to energy and its existence. This multidimensional sector aids the production of a great variety of goods and services and actively contributes to the improvement of the standard of living, increasing efficiency and productivity and promoting the entrepreneurial activity and the work of investors. Nevertheless, the environment is also affected by such activities significantly (Bekun et al., 2019). The energy sector has a close dependence with real GDP per capita based on the facts mentioned above of both the consumption of energy and the real GDP. The relationship between the use of energy and GDP has been explained in a variety of studies (Amri, 2018).

The global warming associated with the greenhouse gases and energy shortage is two major threats to the global financial system. CO2 emission is the most significant variable of greenhouse gas approximately 72% of emitted greenhouse gas. (Adams and Acheampong 2019). The paper examines the impact of FDI on the emission of CO2 in the BRICS countries. It is argued that the BRICS nations are perceived to be the driver of development in the world at the future. The term BRICS denotes the group of nations (Brazil, Russia, India, China and South Africa).

The research will seek to measure and describe the results of the current data sample and determine the effects of Economic Development, Trade Openness, Foreign Direct investment and Renewable Energy Consumption on the Environmental Degradation in BRICS countries. The use of renewable energy is viewed as the answers to this dilemma as a replacement of fossil fuels; however, the relationship between renewable energy and economic development is not always direct. Studies show that the correlation might not be linear meaning that the effect might change over time when a country advances and reaches different levels of wealth. Poor countries might have difficulties with the implementation of renewable energy at first, yet rich countries always have the advantage of a steadily positive economic impact related to this practice (Ullah et al.,2021). Empirical reviews done in the past have made diverse conclusions concerning the validation of the findings of this study. Thus, we paid attention to the effect of the economic development, trade liberalisation, foreign direct investment, the economic growth, and the use of renewable sources of energy on the environmental degradation in the framework of BRICS countries.

Literature Review

The Environmental Kuznets Curve (EKC) is an idea that explains the U-shaped nature of the economic development and environmental degradation. The economic deterioration occurs when people are aware of the harmful effects of such economic activities on the environment and, therefore, the economic growth sharply decreases. The Environmental Kuznets Curve (EKC) explains the relationship because there is an increase in environmental pressure as the economy expands leading to emission of pollutants due to the overuse of technology and processes that cause severe environmental damages. This environmental destruction is experienced at the earlier stages of economic development as such a method has negative effects on the environment. Later on in the stages, the impacts are reversed as explained in the EKC cycle as a result of the heightened awareness of the environmental degradation as a result of these economic activities. As a result during the following stages the economy suffers whereas the environment takes time to reclaim itself. This particular cycle repeats itself, and the correlation is reversed as explained and studied by the Kuznets Curve theory (Maneejuk et al., 2020).

Empirical Studies

Carbon emission, FDI, and financial inclusion in the BRICS through renewable energy and agricultural production. It is a non-linear relationship that is estimated by the use of a Panel Smooth Transition Regression (PSTR) model with data that spans 1995-2019. Agribusiness was boosted by renewable energy, the FDI, and financial inclusion. But the carbon emissions are the scourge. The report recommends that BRICS farmers should be encouraged to use clean energy and also a better access to financial services to make farming sustainable (Raza et al., 2025). The results suggest that economic development is not bad, but it often leads to the destruction of the environment unless alleviated by sustainability policies. The study recommends sustainable industrial processes and agricultural practices that are resistant to climate change in order to achieve environmental goals (Raihan, 2023).

According to research, FDI has the ability to reduce the CO2 emissions, especially in labour-intensive and technology advanced industries, through the introduction of cleaner and more efficient technologies. It is in favor of Pollution Halo Hypothesis. The EKC was also supported by the inverted U-shaped relationship between growth in GDP and the emissions by the authors. The researchers determined that FDI and technology innovation enhance the environmental performance (Yi, Hou, and Zhang, 2023). The analysis established that there is a high degree of correlation between the FDI inflows and the CO2 emission particularly with time, and this implies that foreign investment causes degradation of the environment. The growth in the economy leads to higher emissions, particularly in fast industrialising economies. Through the quantiles, FDI and growth do not influence emissions in equal measures which indicates that there is an asymmetry in the effects. The findings regarding the influence of sector mix. FDI will lower the intensity of capital-intensive industries on pollution, which is in favour of the Pollution Halo Hypothesis. According to the Pollution Haven Hypothesis, the FDI increases the emission level of pollution-intensive variables. The environmental implication of FDI is dependent on the industry, and the

regulatory environment as cleaner technologies are more willing to be applied in highly regulated sectors with high capital (Boohene and Darkwah, 2023).

The long-term relationship between economic growth on the one hand and CO2 emissions on the other hand was analyzed by the ARDL model. Studies have shown that as the economy expands, CO2 emissions also increase, which held the theory of the Environmental Kuznets Curve (EKC). This is such that the emissions increase at an early stage of economic development but could decrease at a certain income level provided that cleaner technologies and green policies are implemented. This demonstrates the fact that sustainable solutions should be incorporated in economic planning (El-Halafawy et al., 2022). This paper will look at the effects of FDI, renewable energy and green financing on CO2 emissions. The paper stated that FDI leads to emission growth in the short run because of the industrial activity and a decrease in the long run through the introduction of cleaner technology and efficient production methods. The results suggest that governments ought to channel FDI in green industries to cut the pollution (Wei et al., 2022).

This paper provides an exclusive observation of the relationship between CO2 emission and economic growth in Singapore. Contrary to previous research, the DOLS study established that a percentage point growth in the economy reduces CO2 emissions by 0.99 percent. Green technology adoption and energy efficiency as well as stringent environmental regulations can decouple economic development in Singapore with regard to carbon emissions. The emission increases with energy consumption, urbanisation, and tourism, and the sustainability appears to be improved with economic expansion (Raihan and Tuspekova, 2022). To analyze the non-linear association between the renewable energy, financial inclusion, foreign direct investment, carbon emission, and agricultural productivity of the BRICS countries in 1995-2019. According to the PSTR method, it was found that the use of renewable energy, foreign direct investment (FDI) and financial inclusion have a positive and significant impact on agricultural productivity in low and high contexts. On the other hand, carbon emissions were also established to have a negative impact on agricultural productivity. The findings show that encouraging the use of clean energy, the inflow of foreign capital, and greater access to financial services can make agriculture in the BRICS countries more sustainable and productive (Ullah et al., 2022).

The research established a positive correlation of an economic growth and CO2 emission in the long term and proved that the growth of the GDP resulted in the increase of the emissions. Despite the short-term forces in favor of an Environmental Kuznets Curve (EKC), long run growth in the economy does not exclusively lower emissions. Egyptian economic development does not benefit the environment by significantly altering the structure or technology (Bekhet and Othman, 2021). This paper analyzed the top 15 countries that consume renewable energy in the world to determine the presence of a non-linear relationship between the use of renewable energy, revenues obtained through the use of natural resources, and the ecological footprint, which is used to point out environmental degradation. Based on the PSTR model, it was established that in every case, the greater the dependence on renewable energy, the worse the ecological footprint, which means that less harm was caused to the environment. On the other hand, the reliance on the income of the

natural resources was positively associated with the ecological footprint, which made the situation worse. The report recommends increased investment in the renewable energy technology by countries in order to support sustainable development (Ullah et al., 2021).

Adams and Acheampong (2019) expose the impact of democracy and renewable energy on the carbon emission of 46 African nations and used GMM (generalized - method of the moment) on unbalanced data between 1980 and 2015. The outcome of the study is that renewable energy and democracy were involved in order to decrease the CO2 emissions. CO2emissions affected FDI, GDP, population and trade openness. The policy implication to the policymaker as part of the research recommendation is to lay greater emphasis on the implication of modern technologies to mitigate the emission of CO2 in sub-Saharan African nations. Canh et al. (2019) focus on how income level, industrialization, urbanization, public spending, energy intensity, trade openness, FDI inflows, and shadow economy, in particular, impact on total greenhouse outflows. This paper employed the model of STIRPAT and the hypothesis of EKC to examine the economic aspects of the outflows in the world. The study applied the data on 106 economies during the period 1995-2012. The research suggests that the larger shadow economy raises higher total greenhouse emission omissions (CO2). The shadow economy has marginal differences on the outflows at the three income levels. The shadow economy is a good phenomenon which affects all three income levels and industrialization is the key to all the outflows except (N2O) and outflows except CH4 have direct impacts. Moreover, trade openness and FDI inflows cause an increase in the total greenhouse emissions CO2 but it has no effect on the reduction of CH4 and N2O emissions. Cheng et al.(2019) investigate the impacts of GDP, renewable energy, export, and environmental patents on the carbon dioxide discharge per capita. The analysis involved the panel quantile regression technique and panel OLS technique when analyzing the BRICS countries between 2000 and 2013. The research finding implies that renewable energy exerts an inverse effect to CO2 outflows per capital whereas the relation between exports and discharge of CO2 is positive, but insignificant, however, FDI and DCP exert an inverse effect on CO2 discharge per capital. Additionally, it has also a direct and significant impact on the CO2 outflows through environmental patents as well as GDP. The general research implies that BRICS states pay more attention to the use of high technologies.

Research Methodology

This study utilises a quantitative approach to analyse secondary panel data from 1995 to 2023 for the BRICS nations. Data has been gathered from several sources, including the World Bank (WDI), UNCTAD, and national statistics agencies.

Model

The Panel Autoregressive Distributed Lag (ARDL) model is a suitable approach for analysing the relationships between variables in a panel dataset. Here's the general form of the panel ARDL equation:

$$\Delta CO2it = \alpha I + \Sigma\beta j\Delta CO2it\text{-}j + \Sigma\gamma j\Delta REit\text{-}j + \Sigma\delta j\Delta FDIit\text{-}j + \Sigma\theta j\Delta TOit\text{-}j + \Sigma\varphi j\Delta GDPit\text{-}j + \lambda 1CO2it\text{-}1 + \lambda 2REit\text{-}1 + \lambda 3FDIit\text{-}1 + \lambda 4TOit\text{-}1 + \lambda 5GDPit\text{-}1 + \varepsilon it$$

Whereas CO2: CO2 emissions (Environmental Degradation), RE: Renewable energy, FDI: Foreign Direct Investment, TO: Trade openness, GDP: Gross Domestic Product, i: Country index (BRICS countries), t: Time index, Δ: First difference operator, αi: Country-specific fixed effects, εit: Error term." Parameters and assumptions: βj, γj, δj, θj, φj: Short-run coefficients and λ1, λ2, λ3, λ4, λ5: Long-run coefficients. The variables are integrated of order I(1) or I(0). The panel ARDL model assumes a linear relationship between the variables. The panel ARDL model can be estimated using the Pooled Mean Group (PMG) estimator or the Mean Group (MG) estimator. The PMG estimator assumes that the long-run coefficients are homogeneous across countries, while the MG estimator allows for heterogeneous long-run coefficients. The coefficients of the panel ARDL model can be interpreted as "Short-run coefficients (βj, γj, δj, θj, φj): Represent the short-term effects of the independent variables on CO2 emissions. Long-run coefficients (λ2, λ3, λ4, λ5): Represent the long-term effects of the independent variables on CO2 emissions. By estimating the panel ARDL model, you can analyse the short-run and long-run relationships between CO2 emissions and the independent variables (renewable energy, FDI, trade openness, and GDP) for the BRICS countries.

Discussion and Analysis

Stationarity Analysis (Unit Root Tests)

On empirical studies that use time series or panel data, before analysis, it is first necessary to check the stationarity of such variables. Unit root tests identify the presence or absence of a long-term mean and a long-term variable variance of a variable. In this case, the Im, Pesaran, and Shin (IPS) test is used, which is suitable when working with panel data as it allows varying cross-sectional results to be equalised in average across the individual Augmented Dickey-Fuller (ADF) tests.

Table 1
Stationarity Test Results

Variables	**ADF test**			
	I(0)		I(1)	
	t-stats	Prob.	t-stats	Prob.
CO2	1.37	0.91	-6.07	0.00
FDI	-1.65	0.05	-	-
GDP	4.33	1.00	-5.31	0.00
RE	0.69	0.24	3.33	0.00
TO	0.56	0.29	5.20	0.00

Source: Author's Estimation

The stationarity analysis indicates that the variables display mixed orders of integration: FDI is I(0), but CO2, GDP, RE, and TO are I(1). This discovery is essential for choosing the proper

econometric model for subsequent study, indicating that models such as ARDL, capable of accommodating mixed orders of integration, are appropriate.

Autoregressive Distributed Lag (ARDL) Model

The Panel ARDL technique is suitable in this case because it allows the integration of variables of different degrees of integration, i.e. I(0), I(1), as revealed through the unit root tests wherein FDI was at the same level, and rest of the variables were at the same level after first difference. It also simultaneously tests the short and long term relationships among the variables on a single equation basis. It is capable of effectively addressing the endogeneity issue and the autocorrelation problem by including lags of the dependent and independent variables.

To determine the short-run and long-run effect of foreign direct investment (FDI), renewable energy (RE), trade openness (TO) and GDP (Economic Growth) on CO2 emission (Environmental Degradation) in BRICS panel, taking into consideration the dynamic temporal effect. The model that was selected based on Akaike Information Criterion (AIC) was ARDL (4, 2, 2, 2, 2) which shows that the dependent variable (CO2) uses four lags, whereas the independent variables use two delays.

Table 2
Panel ARDL Model Estimation

Long Run Equation				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.***
FDI	-0.07	0.02	-4.93	0.00
RE	-0.02	0.00	-4.35	0.00
TO	0.00	0.00	2.02	0.05
GDP	0.00	0.00	13.79	0.00
Short Run Equation				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.***
COINTEQ01	-0.28	0.23	-1.21	0.23
D(CO2(-1))	-0.12	0.08	-1.40	0.16
D(CO2(-2))	-0.07	0.22	-0.31	0.76
D(CO2(-3))	-0.18	0.17	-1.06	0.29
D(FDI)	0.04	0.02	2.17	0.03
D(FDI(-1))	0.00	0.04	-0.09	0.93
D(RE)	-0.08	0.03	-2.91	0.00
D(RE(-1))	0.00	0.14	-0.03	0.98
D(TO)	0.00	0.01	0.64	0.52
D(TO(-1))	0.00	0.00	-0.95	0.35
D(GDP)	0.00	0.00	0.86	0.39
D(GDP(-1))	0.00	0.00	0.40	0.69

C	0.42	0.33	1.29	0.20
Mean dependent var	0.09	**S.D. dependent var**		0.28
S.E. of regression	0.14	**Akaike info criterion**		-1.18
Sum squared resid	1.48	**Schwarz criterion**		0.24
Log likelihood	154.31	**Hannan-Quinn criterion.**		-0.60

Source: Author's Estimation

Long-Run Equation

The coefficient of the long-run is -0.074060, which is statistically non-significant (p=0.0000). This implies that an increase in foreign direct investment (in units) by one unit over time leads to a decrease in environmental degradation (in units) of 0.074, which supports the Pollution Halo Hypothesis of BRICS in the long-run. The coefficient of the long-run is -0.015126 which is very significant (p=0.0000), meaning that one unit change in the consumption of renewable energy leads to a change of 0.015 units in the environmental degradation. In the long run, and thus, ratifies the ecological advantages of renewable sources of energy. The coefficient of the long-run is 0.002987 which is statistically significant (p=0.0466). This implies that an increase in one unit of trade openness is associated with a negligible (0.003 unit) increase in environmental degradation in long-run. This is a desirable effect, relative to the fixed effects result, but it is not large. The long-run coefficient is found to be 0.000522 which is also statistically significant (p=0.0000). This indicates that an increase in GDP per capita by one unit will lead to an increase in environmental degradation by 0.052 units in the long run, and this confirms the hypothesis that economic growth and emissions are positively related in the BRICS countries.

Short-run equation (Error Correction Model)

The error correction term (COINTEQ01) coefficient is equal to -0.278754, though, statistically insignificant (p=0.2294). This is one of the most significant findings as a large Error Correction Term (ECT) is the main indicator of a well-established long-term relationship. The low error correction term means that there is not much evidence of cointegration between the variables in this panel with this specification. Since the environmental and economic growth policies are strategic and need time before being implemented and in addition, they vary, depending on governance structures.

Discussion and Conclusion

Discussion

Environmental Degradation and Foreign direct investment in BRICS countries.

The panel ARDL model results indicate that the relationship between the Foreign Direct Investment (FDI) and CO2 emission is dynamic and important in the BRICS countries. The long-term analysis shows that the effect of foreign direct investment (FDI) on CO2 emission is statistically significant which is estimated at -0.074060 (p=0.0000). This is a long-term observation in favour of the Pollution Halo Hypothesis, which posits that foreign direct investment

(FDI) has the potential to encourage the export of cleaner technologies and other environmental sustainable practices to the host countries. This is in line with the results of Rafique et al. (2020) that reported a negative long-term relationship between FDI and CO2 emissions in BRICS, and Yi et al. (2023), who found a negative effect of FDI on manufacturing emissions in China, on average. In the light of the sustainable development goals, the long-term beneficial impact of foreign direct investment on the reduction of the emissions may make a substantial contribution to SDG 13 (Climate Action) as it may help the BRICS nations reduce their carbon footprint.

BRICS countries Economic growth (GDP per capita) and Environmental Degradation.

The output of the ARDL model results of Economic Growth (EG) in terms of the GDP per capita proves that the long-term coefficient is significant (0.000522) with its p-value of (0.0000). This finding is in line with much of the available literature, such as those by Adedoyin et al. (2020) and Fu et al. (2021), who also find a positive relationship between economic growth and environmental degradation in BRICS and other emerging countries. This highlights a persistent issue, namely, how to foster economic growth without contributing to environmental pressure. It shows how these countries face difficulties in attaining the SDG 13 (Climate Action) as they work towards attaining SDG 8 (Decent Work and Economic Growth) at the same time.

Green energy (RE) and Environmental Degradation in BRICS.

The use of Renewable Energy (RE) has a significant negative environment degradation (CO2 emissions) in a long run with a coefficient of -0.015126 (p=0.0000). The outcome is hugely consistent with theoretical predictions and most of the empirical studies reviewed such as Saba et al. (2024), Imran et al. (2024) and Grodzicki & Jankiewicz (2022) that confirm the emissions-reducing role of renewable energy sources. This explains the critical importance of renewable energy adoption as a core approach that BRICS countries can use to achieve their green goals to support SDG 7 (Affordable and Clean Energy) directly and contribute significantly to SDG 13 (Climate Action).

Environmental Degradation in BRICS countries and Trade openness (TO).

The results of this study show that there is a significant long-run effect of Trade Openness (TO) on CO2 emissions, but which is complex. TO has a positive and statistically significant long-run coefficient, 0.002987 (p=0.0466), but the value is insignificant. This result is aligned with the findings of Rafique et al. (2020) regarding BRICS.

Conclusion and Recommendations

The overall objective of the study was to investigate how the Foreign Direct Investment (FDI), economic growth (GDP), renewable energy use (RE) and trade openness (TO) relate to environmental degradation as depicted by the CO2 emission levels in the BRICS states. The study used annual panel data (1995- 2023). To be able to capture both short-run and long-run dynamics, a quantitative method was used based on the Panel Autoregressive Distributed Lag (ARDL) model.

The results show that the further development of the economy remains the initial trigger of the CO2 emissions in BRICS countries. However, renewable energy and, in the long run, foreign direct investment with a long-term strategic approach can give a great solution to relieve the load on the environment. The openness to trade has lost its relevance, but requires careful administration. These results explain why there is a need to align economic and investment policies with the Sustainable Development Goals, namely SDG 7, SDG 8, SDG 12, and SDG 13, to create a more balanced and sustainable path to development.

Recommendations

The 2024 reports of the IEA have ranked China to be the largest carbon emitter in the world and within the BRICS group, China ranked the highest with 12.6 gigatons of carbon dioxide emissions, equivalent to one-third of the worldwide emissions. This is because of the fact that China consumes large amounts of coal in its industry because of high level of emissions. After China, India is the second-largest BRICS emitter and third in the world with 3.0 gig tons of CO2 being emitted in 2024. In India, the emissions are increasing with the growth in development though there are attempts towards renewable energy. Russia is the third largest BRICS emitter and fourth in the world, which is dependent on natural gas and coal. The emissions in Brazil and South Africa are smaller in comparison with the other BRICS countries, yet the economic growth is placing strain on the energy needs. The five initial BRICS nations, Brazil, Russia, India, China and South Africa produce 42 percent of all carbon emissions in the world.

Promote green growth: Economic growth aggravates environmental degradation as time goes, thus BRICS countries need to put up tangible measures such as prices on carbon or specific energy consumption targets amongst large scale industries in order to uncouple economic growth with environmental degradation. Circular economy models can be implemented in reducing resource wastage. These activities would be in favor of SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action). Accelerate the switch to renewable energy: The governments must offer tax rebates and quicker licenses of solar and wind developments to build on their success and achieve SDG 7 (contributing to SDG 7: Affordable and Clean Energy) and SDG 8: Decent Work and Economic Growth by generating employment and enhancing energy security. Manage Foreign Direct Investment Strategically: FDI has a dual effect and therefore policies are to attract quality FDI that will contribute to the achievement of sustainable development objectives especially SDG 13. These involve environmental screening conditions to inbound investments, incentives to invest in green technologies and research and development, and stringent environmental laws so that member of the BRICS are not transforming into pollution haven. The long-term environmental benefits (pollution halo effect) of FDI could be maximised through enhancing the domestic absorptive ability (technological) capability. Add to Trade Policy Environmental Concerns: TO was not highly influential, but its long-term positive impact on emissions is worth research. One should not use environmental deregulation to enhance the competitiveness of trade. They ought to encourage trading in environmental products and services, trade agreements that contain environmental requirements and cooperate on an international level to reduce carbon leakage (in

case the emissions are directed to countries with weaker constraints). This strategy supports the SDG 12 and SDG 17 environmental aspects.

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