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# Exploring the Drivers of Carbon Emissions: Panel Evidence from BRICS Countries

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**Abstract: The BRICS countries, like Brazil, Russia, India, China, and South Africa confront major obstacles related to climate change and environmental sustainability as a result of swift economic expansion and increasing energy needs. The growing energy demand resulting from economic growth significantly affects carbon emissions. Consequently, it is crucial to examine the factors influencing carbon emissions in these economies. This research examines how significant economic factors, like energy consumption, trade openness, industrial value added, and GDP per capita affect carbon emissions. This study employs panel data covering a period of 20 years i.e., from 2003 to 2022 for the BRICS nations. A panel regression model has been utilized to meet the goals of the research. The data is assessed by employing several econometric methods, which include descriptive statistics, correlation analysis, and diagnostic evaluations like panel unit root tests and tests for multicollinearity. Additionally, the Hausman specification test is employed to identify the better suited model between fixed effects and random effects panel regressions. The empirical findings show that energy usage positively and significantly affects carbon emissions, illustrating that greater energy consumption results in environmental harm. CO2 emissions and economic growth are positively and statistically significantly correlated. This result supports the claim that growth is still energy-intensive and environmentally costly in the chosen countries since it shows that emissions tend to rise as economies grow. The effects of industrial value added and trade openness on emissions are deemed statistically insignificant. To cut carbon emissions without hurting economic growth, energy regulations and new technology really matter. This research points out that BRICS countries need to boost renewable energy, use energy more efficiently, and shift to sustainable industrial methods if they want real, long-term environmental progress.**

***Keywords:*** *Carbon Emissions, BRICS Countries, Energy Consumption, Economic Growth, Panel Data Analysis, Environmental Sustainability.*

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## I. INTRODUCTION

Environmental sustainability has been a large global concern in recent decades. It is generally accepted that the primary driver of climate change and Global Warming is the unprecedented growth in carbon emissions due to rapid industrialization, growing economic activity and higher consumption of energy. The prominent usage of fossil fuels for energy production leads to considerable carbon dioxide emissions that suppresses environmental degradation and disturbs ecological stability.

The BRICS countries — Brazil, Russia, India, China and South Africa — have seen exponential growth in industrial production, and to support that production, they consume large amounts of energy and raw materials, leading to an increase in the proportion of solid, liquid, and gaseous wastes. In particular, a large proportion of gaseous waste (e.g., carbon) contributes to greenhouse gas emissions, and the nation's people are facing global warming-related problems. We know that every great thing comes with a cost, and here the cost comes in the form of climate change, an increase in the proportion of $CO_2$ in the atmosphere, which is ultimately the result of various industries and their waste management, because technological advancement and material well-being need to be improved in this competitive edge of the modern era. Without modern industry and its production, it is quite a difficult task to take the country into the global competitive market, and that comes at the cost of $CO_2$ and other gaseous emissions.

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One of the main causes of carbon emissions is energy usage. Fossil fuels, such as coal, oil, and natural gas, continue to be crucial to the industrial output and economic activity of many developing and growing economies. Pollution levels usually grow as energy demand rises. But economic expansion can also lead to advancements in technology and energy efficiency, which could eventually lessen environmental stresses. Beyond energy consumption, environmental outcomes are also significantly affected by trade and industrial growth. Global trade promotes economic expansion and makes it easier for new technology to spread, yet increasing output frequently results in higher energy consumption and pollution levels. In a similar vein, industrialization raises energy consumption and carbon emissions, especially in rapidly developing economies.

Given these dynamics, it is important to understand the interrelation between economic growth, energy use, and environmental quality. Which ultimately help policymaker to design better strategies that will assist a balance development with sustainability. The BRICS countries offer a useful case for such analysis because of their growing role in the global economy and their remarkable contribution to carbon emissions. Through the use of panel data analysis this study tries to explore which key factors influencing carbon emissions in these nations. More especially, it scrutinizes how energy consumption, trade openness, industrial value added, and GDP per capita affect emission levels. The goal is to identify the main economic drivers behind environmental sustainability in these rapidly developing countries.

The paper is organized as follows: the next section reviews existing studies in this area, followed by the objectives of the research. The hypotheses are then presented, along with the methodology used for analysis. After that, the findings are discussed, and the paper concludes with final observations and implications.

## II. SURVEY OF EXISTING LITERATURE

Environmental issues, particularly the rise in carbon dioxide ($CO_2$) emissions, have become a significant global concern. Numerous studies have examined the impacts of economic growth, energy consumption, trade, and industrialization on the environmental carbon dioxide ($CO_2$) emissions.

In their working study paper "Economic growth and environmental quality: Time-series and cross-country evidence," **Shafik and Bandyopadhyay** (1992) examined the relationship between environmental quality and the growth of the economy through cross-country data. On the report of their findings, the Environmental Kuznets Curve (EKC) displays a pattern in the shape of an inverted U for some variables, such as access to sanitary facilities and clean water, but not for others, especially those emitted by carbon. These findings imply that environmental advancement cannot be ensured by economic expansion alone. The researchers emphasize the significance of strong institutions, sensible policies, and environmental laws, especially in emerging economies where industrialization based on fossil fuels frequently propels economic expansion.

**Soytas and Sari** (2009), in their paper “Energy consumption, economic growth, and carbon emissions: challenges faced by an EU candidate member” adopt a multivariate time series framework based on the Toda and Yamamoto technique to evaluate the long-run causal links linking energy consumption, CO2 emissions, and income in Turkey from 1960 to 2000 using data from World Development Indicators. The findings show that there is little evidence of long-term causality between earnings, emissions, or energy use, implying that Turkey may be capable of reducing emissions while maintaining development of the economy. Furthermore, there is a considerable short-term interaction across variables, with shocks in one variable impacting the others.

**Alkhathlan and Javid** (2013) examined how economic growth, energy use, and carbon emissions are interconnected in Saudi Arabia through their paper titled “Energy consumption, carbon emissions and economic growth in Saudi Arabia: An aggregate and disaggregate analysis”. They have employed time-series data spanning 1980 to 2011 to establish the relation. By applying the autoregressive distributed lag (ARDL) approach, Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) statistics, and the Granger causality test, it depicts strong evidence that the short as well as long-term gas usage has a negative income elasticity of carbon emission, whereas they are positive for the aggregate of oil and electricity models. Furthermore, there is monotonicity in Saudi Arabia, where an increasing interrelation exists between per capita earnings and emissions of carbon, which implies EKC does not hold in this context. It also proves that electricity is less polluting than oil and gas.

In the paper "Modeling energy consumption, carbon emission and economic growth: Empirical analysis for Pakistan," **Ali et al.** (2015) attempted to investigate the interrelation between carbon emissions, energy consumption, and economic growth as well as the empirically analyzed existence of EKC in the short and long run over a time period from 1980 to 2012 using secondary data from World Development Indicators, 2013. The results were obtained by first using the ADF test, which showed that they are all stationary at first difference; second using VAR lag order selection criterion to find out lag length, which yields 3; and third using the Johansen maximum likelihood method, where maximum eigenvalue values demonstrate the existence of a long-term relationship among variables, where a 1% increase in energy consumption will result in a 0.78% increase in emissions. On the other hand, emissions typically rise by 0.12% for every 1% growth in financial development. The EKC is similarly invalid in the short term when using ECM, which shows only short-term carbon emissions influenced by energy use.

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**Long et al.** (2015) addresses by virtue of their paper titled "Non-renewable energy, renewable energy, carbon dioxide emissions and economic growth in China from 1952 to 2012" where they want to figure it out how economic growth as well as carbon emission impacted by the way of energy consumption along with interrelation between them, during a period of 1952 to 2012 by using secondary data. Where Granger causality analysis reveals a positive, reciprocal interrelation linking economic growth and CO2 emission, nonetheless, the unit root test demonstrates that the above variables with energy consumption are nonstationary. While Static and dynamic regression analysis revealed that using coal had created a much more impact on economic growth and CO2 emissions than nuclear and hydroelectricity.

**Mesagan** (2015) embarked a study on "Economic growth and carbon emission in Nigeria" to find out is there any interrelation exists between carbon emission and economic growth in Nigeria from 1970 to 2013 through the use of secondary data collected from WDI and by using variables like carbon emission, real GDP, capital investment, along with trade openness (net export divided by GDP). By using the Error correction model, he concluded that in the first period, if they allow GDP to grow uncontrollably, then emissions will also tend to increase uncontrollably, but later it will be negatively impacted by GDP. Furthermore, trade openness and capital investment positively impact carbon emissions in Nigeria.

**Lu** (2017) employed time series data of 24 Asian countries from WDI & Environmental Protection Department in the Government of Hong Kong Special Administrative Region to find out the association between green energy use, emission of carbon, as well as economic growth of these countries in their paper titled "Renewable energy, carbon emissions, and economic growth in 24 Asian countries: evidence from panel cointegration analysis". By applying advanced econometric techniques, i.e., panel cointegration tests, panel VECM model, together with Granger causality analyses, he emphasizes that, particularly in some specific countries, green energy consumption is positively influenced by $CO_2$ emissions which reflects a unidirectional causality from GDP to $CO_2$ emissions, which clearly refers to the fact that the growth of the economy tends to lead to emissions. However, approximately 0.66% higher intake of sustainable energy is observed for a 1% increase in GDP, indicating income-driven demand for renewables.

**Waheed et al.** (2019) dug up both single-country and multi-country research papers up to the period of 2019 by using various econometric techniques such as the Granger and Toda-Yamamoto procedures, VECM, PAVR & ADRL models, and panel cointegration to discover if there is any relation that exists between economic growth, energy usage, and carbon emissions in their paper titled "The survey of economic growth, energy consumption and carbon emission". The findings show that, for economic growth and carbon emissions, there is a positive relationship that exists for developing countries, but for developed countries, the connection isn't clear among the variables because these nations reduce their emissions without compromising growth by employing better policies and by switching to renewable energy sources.

**Begum et al.** (2020) analysed "Dynamic impacts of economic growth and forested area on carbon dioxide emissions in Malaysia" by employing secondary data from the WDI Dataset over the period 1990 to 2016 to understand the relationship between the variables, namely forests, economic growth, and CO2 emissions in Malaysia. For this study, they applied the unit root test by DOLS, an expanded equation of ordinary least squares estimation, Dickey-Fuller (ADF), and Dickey-Fuller generalized least squares (DF-GLS), and to identify the causalities between the variables, Granger causality tests were used. The results clearly indicate that CO2 emissions have a positive relationship with the GDP, which is significant at the 1% level, meaning a rise of CO2 emissions of 0.931 kt is associated with an increase of RM 1 million in GDP. Being a tropical country with 67.55% of forested area, it will have to implement effective policy measures by decreasing deforestation and by doing reforestation to achieve sustainable forest management and long-term economic growth in Malaysia.

In early studies, **Nawaz et al.** (2021) dug up in their paper titled "Trilemma association of energy consumption, carbon emission, and economic growth of BRICS and OECD regions: quantile regression estimation" by utilizing secondary data for the OECD and BRICS countries between 1980 and 2016 to identify the association among GDP growth, NRE and RE usage, and $CO_2$ emissions. By employing the QARDL model through the use of panel data, it was found that long-run NRE and GDP growth have significantly influenced carbon emissions, but in the short run, $CO_2$ emissions rise through the consumption of NRE. Whereas an increase in gross capital formation tends to reduce $CO_2$ emissions, trade openness does not have any significant effect on them.

**Sharif and Tauqir** (2021) in their paper "The effects of infrastructure development and carbon emissions on economic growth" look at how economic growth and the environment, were affected by road infrastructure especially carbon emissions from transport. By employing econometric techniques like FMOLS and DOLS to analyze data collected from WDI Database for a time period spanning 1972 to 2017, which focuses on Pakistan's road length, carbon emissions and their effects on economic growth. The findings confirm a positive relationship between road infrastructure and economic growth, which indicates that through the expansion of road networks leads to higher income and productivity. Besides, carbon emissions, have a negative impact on economic growth, which reflects environmental costs associated with infrastructure expansion. The analysis also confirms a cointegrating relationship among the variables, suggesting long-term equilibrium associations.

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**Wang and Zhang** (2021) in their paper titled "The effects of trade openness on decoupling carbon emissions from economic growth–evidence from 182 countries" By using secondary data of 182 countries for a period from 1990 to 2015, through the Tapio decoupling model combined with econometric panel data techniques (unit root tests, cointegration analysis, fixed effects, and FMOLS), it wants to find out how trade openness influences carbon emissions across countries of different income levels (high-income, upper-middle-income, lower-middle-income, and low-income). Global decoupling of growth from emissions is weak, with significant differences across income groups, but rich countries have effectively decoupled growth from emissions, with trade openness aiding this process. Whereas, in poorer countries, trade openness often leads to higher emissions due to weaker environmental standards. Some factors, like renewable energy adoption and higher oil prices, facilitate decoupling universally.

**Jiang and Yu** (2023) looked into "Carbon emissions and economic growth in China: Based on mixed frequency VAR analysis," the relationship between carbon emissions and economic development by taking total domestic carbon emissions of China from 1992 to 2018 from the World Bank and Wind database. Variables like growth rate, carbon emissions, coal and crude oil price were taken for the study. To check the reliability of data and to confirm whether data are stationary, they have applied the ADF and PP unit root tests. The findings revealed that economic growth increases alongside rising carbon emissions, indicating a positive relationship between the two. Moreover, Granger causality tests were performed, in which the MF-VAR model shows a strong association between carbon emissions and economic growth; however, the LF-VAR model shows that carbon emissions have no effect on the GDP growth rate at the 5% and 10% significance levels.

**Raihan** (2024) in his paper titled "Influences of foreign direct investment and carbon emission on economic growth in Vietnam", where he assess the interrelationship between the rate of GDP growth, CO2 emissions, and FDI in Vietnam by complying secondary data from World Development Indicators for a period of 1992 to 2021, and by employing unit root tests including ADF, DF-GLS, and P-P tests to determine the stationarity properties of the individual series which is essential to avoid spurious regressions. Moreover, the Autoregressive Distributed Lag (ARDL) bounds testing approach is used, where it is clearly shown that a 1% rise in CO2 emissions leads to a 1.11% and 0.29% rise in the long run & short run increase in GDP.

Despite ample research, the relationship between trade openness and industrialization remains unclear, especially for panel data sets including emerging economies. Additionally, a lot of research focuses on cross-sectional or time-series data, which leaves room for more thorough panel data analysis. In order to lock this gap, this study looks at the factors that influence CO2 emissions using panel data for BRICS nations.

➢ *Objective of the Study*

This study examines how key economic factors—energy consumption, trade openness, industrial value added, and GDP per capita—impact carbon emissions across BRICS countries.

➢ *Hypothesis of the Study*

To accomplish the above-stated goal of the study, the following null hypothesis is formulated:

Energy consumption, trade openness, industrial value added, and GDP per capita do not significantly correlate with carbon emissions.

Rejection of the null hypothesis indicates that energy consumption, trade openness, industrial value added, and GDP per capita significantly correlate with carbon emissions.

## III. DATABASE AND METHODOLOGY OF THE STUDY

This article is purely based on secondary data, and all the required facts & figures are congregated from the World Bank (World Development Indicators) Database. This examination focuses on the BRICS economies—Brazil, Russia, India, China, and South Africa. These countries contribute significantly to both global economic output and carbon emissions, and they are among the emerging economies with the fastest growth rates. The study spans 20 years, from 2003 to 2022. The relationship between carbon emissions and key economic factors, including energy consumption, trade openness, industrial value added, and GDP per capita, is assessed using panel data analysis. Analysis of differences between nations and over time is made possible by panel data, which combines cross-sectional and time-series observations.

To investigate the relationship between carbon emissions and the explanatory variables, the study employs following panel data regression model.

$$CO2_{it} = \alpha + \beta_1 EC_{it} + \beta_2 TO_{it} + \beta_3 IND_{it} + \beta_4 GDP_{it} + \mu_i + \varepsilon_{it}$$

Where, $CO2_{it}$ = Carbon emissions for country i at time t
$EC_{it}$ = Energy consumption for country i at time t
$TO_{it}$ = Trade openness for country i at time t
$IND_{it}$ = Industrial value added for country i at time t
$GDP_{it}$ = GDP per capita for country i at time t
$\mu_i$ = Country-specific effects
$\varepsilon_{it}$ = Error term

Where $\alpha_i$ is the intercept term, and the parameters $\beta_1, \beta_2, \beta_3$ *and* $\beta_4$ are coefficient of independent variables that measure the impact of the explanatory variables on carbon emissions.

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In this study, carbon dioxide has been treated as the dependent variable. It is measured in metric tons per capita and reflects the level of environmental pollution resulting from economic activities. Among the independent variables, energy consumption (kg of oil equivalent per capita) represents the total amount of energy utilized for economic and industrial activities within a country. Trade openness (% of GDP) is measured as the ratio of exports and imports to GDP. It gauges the extent to which a country is integrated with the global economy. Industrial Value Added (% of GDP) reflects the contribution of the industrial sector to the national economy. GDP per Capita (current US$) serves as an indicator of economic growth and income levels.

## IV. EMPIRICAL FINDINGS OF THE STUDY

### *A. Descriptive Results*

Table 1: Descriptive Statistics of Independent and Dependent Variables

| Variable [Abbreviation] | N | Mean | Std. Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| $CO_2$ Emissions (metric tons per capita)[CO2] | 100 | 6.310 | 4.148 | 0.968 | 14.040 |
| Energy Consumption (kg of oil equivalent per capita) [EC] | 100 | 2233.494 | 1504.277 | 399.699 | 5681.392 |
| Trade Openness (% of GDP) [TO] | 100 | 44.741 | 11.215 | 22.106 | 65.974 |
| Industry Value Added (% of GDP) [IND] | 100 | 29.527 | 7.534 | 18.188 | 46.8865 |
| GDP per Capita (current US$) [GDP] | 100 | 6731.370 | 4057.601 | 544.143 | 15941.45 |

Table 1 summarizes the descriptive statistics of variables used in the study. This statistics portray the information about the average, variations and ranges of the data. Descriptive statistics reflects approximately 6.31 metric tons average per capita carbon emission in BRICS countries. In comparison, a high standard deviation indicates significant variation in emission levels across different countries and years. Significant differences in energy consumption are also noted, which reflect differences in economic activity and energy demand among the different countries. The BRICS nations appear to have a moderate level of engagement with international trade, a fact substantiated by an average 'trade openness' figure of 44.741 percent of GDP. The significance of industrial activity in these economies is demonstrated by the fact that the industrial sector typically contributes close to 29.527% of GDP. GDP per capita varies greatly, reflecting the disparities in economic development among the study's participating nations.

### *B. Model Diagnosis*

- ➢ *Panel Unit Root Test and Cointegration Test*

Table 2: Panel Unit Root Test

| Variable | At Level | | | At 1st Difference | | |
|---|---|---|---|---|---|---|
| | Test Statistic | p-value | Result | Test Statistic | p-value | Result |
| $CO_2$ Emissions (metric tons per capita)[CO2] | -1.614 | 0.053 | Non-Stationary | -3.646 | 0.000 | Stationary |
| Energy Consumption (kg of oil equivalent per capita) [EC] | -0.708 | 0.239 | Non-Stationary | -4.167 | 0.000 | Stationary |
| Trade Openness (% of GDP) [TO] | -0.547 | 0.292 | Non-Stationary | -3.088 | 0.001 | Stationary |
| Industry Value Added (% of GDP) [IND] | 0.000 | 0.500 | Non-Stationary | -3.780 | 0.000 | Stationary |
| GDP per Capita (current US$) [GDP] | 0.322 | 0.626 | Non-Stationary | -4.939 | 0.000 | Stationary |

The stationarity qualities of the study's variables—CO2 emissions, energy consumption, trade openness, industrial value added, and GDP per capita—were assessed using the panel unit root test (Levin, Lin & Chu t*). The findings show that every variable is non-stationary at the level form. The p-values, which are higher than the generally acknowledged significance limit of 5%, make this clear. For example, the p-values for CO2 emissions are 0.053, energy consumption is 0.239, trade openness is 0.292, industrial value added is 0.500, and GDP per capita is 0.626. These values demonstrate that the series are not stationary in their original form and imply that the null hypothesis of a unit root cannot be rejected at levels.

However, all variables become stationary after the first difference is taken. The associated p-values are all identical to or extremely close to 0.000, much below the 5% significance level, and the test statistics at first difference are noticeably more negative. The null hypothesis of a unit root at first difference for all variables is thus rejected.

To determine whether there is a long-run equilibrium relationship between the variables, it is acceptable to test for cointegration because all of the variables are stationary at first difference. A long-run model, like an Error Correction Model (ECM), can be used if cointegration is found; if not, the analysis would concentrate on short-run dynamics utilizing differenced variables.

Table 3: Pedroni Residual Cointegration Test

| **Panel Statistic (within-dimension)** | | | | |
|---|---|---|---|---|
| | **Statistic** | **Prob.** | **Weighted Statistic** | **Prob.** |
| Panel v-Statistic | 0.378502 | 0.3525 | 0.455666 | 0.3243 |
| Panel rho-Statistic | 0.401633 | 0.6560 | 0.796854 | 0.7872 |
| Panel PP-Statistic | -0.976766 | 0.1643 | 0.061214 | 0.5244 |
| Panel ADF-Statistic | 0.898690 | 0.8156 | 1.374561 | 0.9154 |
| Group Statistic (between-dimension) | | | | |
| | Statistic | Prob. | | |
| Group rho-Statistic | 1.785112 | 0.9629 | | |
| Group PP-Statistic | 0.792200 | 0.7859 | | |
| Group ADF-Statistic | 2.349789 | 0.9906 | | |

In order to determine whether there is a long-term equilibrium relationship between the variables CO2 emissions (CO2), energy consumption (EC), economic growth (GDP), industrialization (IND), and trade openness (TO) across the chosen panel of countries between 2003 and 2022, the Pedroni Residual Cointegration Test was used. The test's null hypothesis is predicated on the idea that the variables do not cointegrate.

The null hypothesis cannot be rejected, according to the findings from both the within-dimension (panel statistics) and between-dimension (group statistics) techniques. In particular, all of the panel statistics' probability values—including the panel v-statistic, panel rho-statistic, panel PP-statistic, and panel ADF-statistic—are higher than the standard significance levels of 5%. The lack of cointegration is further supported by the group statistics, such as the group rho, group PP, and group ADF statistics, which likewise have strong p-values. Consequently, the results imply that the variables under investigation are not long-term cointegrated. Applying a long-run equilibrium model like the Error Correction Model (ECM) would therefore be inappropriate. Thus, we are utilizing first-differenced variables for panel regression models.

➢ *Correlation Matrix and Multicollinearity Test*

Table 4: Correlation Matrix of the Variables

| **Variables** | **dCO2** | **dEC** | **dTO** | **dIND** | **dGDP** |
|---|---|---|---|---|---|
| dCO2 | 1 | | | | |
| Dec | 0.679** | 1 | | | |
| Dto | 0.253* | 0.212* | 1 | | |
| Dind | 0.360** | 0.327** | 0.477** | 1 | |
| dGDP | 0.465** | 0.442** | -0.048 | 0.169 | 1 |

** Significant at 0.01 level, * Significant at 0.05 level

The correlation matrix for the first-differenced variables—CO2 emissions (dCO2), energy consumption (dEC), trade openness (dTO), industry value added (dIND), and GDP per capita (dGDP)—is shown in Table 4. The preceding unit root results, which verified that all variables are stationary at first difference, are consistent with the use of differenced variables. The findings show that while the strength of these correlations vary, the majority of factors show a positive link with one another. Significantly, at the 1% level, there is a robust and statistically significant positive association (0.679) between CO2 emissions and energy consumption. This implies that short-term increases in carbon emissions are strongly connected to increases in energy consumption.

At the 1% level, there is a considerable positive association (0.465) between CO2 emissions and GDP per capita. Industry value added, at the 1% level, likewise has a strong moderate connection with GDP (0.360). Therefore, as economies expand and industrial activity increases, emissions typically increase as well. Although the correlation between trade openness (dTO) and CO2 emissions is not as strong (0.253), it is still significant at the 5% level. The same tendency can be seen in energy use. It has a positive correlation with GDP per capita (0.442) and Industry Value Added (0.327) at the 1% level. This demonstrates that increased economic activity and industrial growth are often correlated with increased energy consumption. There is a moderately favorable correlation (0.477) between trade openness and industry value added. In general, trade-opening nations typically have higher levels of industrial activity. There is no real relationship between GDP and trade openness – statistically, at -0.048, the relationship is almost non-existent.

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Multicollinearity is not a problem here, as none of the correlations go above 0.80. Therefore, it is fine to use these variables together in a regression model. To be thorough, a multicollinearity test was run to cross verify everything.

Table 5: Multicollinearity Test

| **Variables** | **dEC** | **dTO** | **dIND** | **dGDP** |
|---|---|---|---|---|
| Variance Inflation Factor (VIF) | 1.38 | 1.35 | 1.41 | 1.29 |
| Tolerance | 0.724 | 0.739 | 0.709 | 0.773 |
| Mean VIF = 1.36 | | | | |

Variance Inflation Factor (VIF), along with tolerance values for every variable used in this study, is portrayed in Table 5. It is evident from the table that, for every variable, the tolerance values lie between 0.709 and 0.773, while the VIF values range from 1.29 to 1.41, indicating the absence of multicollinearity among the independent variables. In particular, the results presented fall well within the generally accepted requirements of a VIF below 10 and a tolerance above 0.1. The lack of multicollinearity is further supported by the mean VIF of 1.36.

### *C. Regression Results*

The factors influencing CO2 emissions in the BRICS countries have been examined using both the fixed effect model and the random effect model. The estimation results for the FE and RE models are shown in Tables 6 and 7, respectively.

Table 6: Determinants of CO2 Emissions: Fixed Effect Estimates

| **Dependent Variable dCO2** | **Coef.** | **Std. Err.** | **T** | **P>\|t\|** | **[95% Conf. Interval]** | |
|---|---|---|---|---|---|---|
| *Explanatory Variables* | | | | | | |
| dEC | 0.00115** | 0.00023 | 5.00 | 0.000 | 0.00069 | 0.00161 |
| dTO | 0.00991 | 0.00628 | 1.58 | 0.118 | -0.00258 | 0.02240 |
| dIND | 0.04554 | 0.02628 | 1.73 | 0.087 | -0.00673 | 0.09776 |
| dGDP | 0.00005** | 0.00002 | 2.84 | 0.006 | 0.00001 | 0.00009 |
| C | 0.0175 | 0.0234 | 0.75 | 0.457 | -0.02903 | 0.06404 |
| Number of Observations | 95 | | | | | |
| Number of Countries | 5 | | | | | |
| R-Square | 0.5153 | | | | | |
| Prob [F Statistics] | 0.0000 | | | | | |

**Significance at 0.01 level

Table 7: Determinants of CO2 Emissions: Random Effect Estimates

| **Dependent Variable dCO2** | **Coef.** | **Std. Err.** | **Z** | P>\|z\| | [95% Conf. Interval] | |
|---|---|---|---|---|---|---|
| *Explanatory Variables* | | | | | | |
| dEC | 0.00139** | 0.00023 | 6.14 | 0.000 | 0.00095 | 0.00184 |
| dTO | 0.00775 | 0.00632 | 1.23 | 0.220 | -0.00463 | 0.02014 |
| dIND | 0.03117 | 0.02665 | 1.17 | 0.242 | -0.02107 | 0.08342 |
| dGDP | 0.00005** | 0.00002 | 2.66 | 0.008 | 0.00001 | 0.00009 |
| C | 0.00961 | 0.02429 | 0.40 | 0.692 | -0.03799 | 0.05721 |
| Number of Observations | 95 | | | | | |
| Number of Countries | 5 | | | | | |
| R-Square | 0.5221 | | | | | |
| Prob [chi-sq. Statistics] | 0.0000 | | | | | |

**Significance at 0.01 level

Both the Breusch-Pagan Test and the Redundant Fixed Effects Test reject their null hypotheses, so the Hausman test needs to be conducted. This one helps figure out if the fixed effects model or the random effects model fits better. The Hausman Test findings are shown in Table 8. The Random Effects Model is the best option for this investigation, based on the test's p-value of more than 0.05.

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Table 8: Hausman Test

| chi-sq. Statistics | chi-sq. df | Prob>chi-sq. |
|---|---|---|
| 2.28 | 4 | 0.6846 |

The findings of the random effects regression model, in which the dependent variable is the first difference of CO2 emissions (dCO2), are shown in Table 7. The model looks at the relationship between CO2 emissions and changes in energy consumption (dEC), trade openness (dTO), industrialization (dIND), and economic growth (dGDP). The findings show that energy consumption (dEC) significantly and favorably affects CO2 emissions. The results demonstrate that CO2 emissions rise in direct proportion to increases in energy use. With solid statistical support, the figure, 0.00139, which is statistically significant at 1% level, indicates that emissions increase by about that amount for each additional unit of energy used. It is quite evident that increased energy consumption, particularly from fossil fuels, exacerbates environmental harm. Similarly, economic growth (dGDP) also shows a positive and statistically significant relationship with $CO_2$ emissions at the 1% level (coefficient = 0.00005). This finding indicates that as the economy expands, emissions tend to increase, supporting the argument that growth is still energy-intensive and environmentally costly in the selected countries. Trade openness and industrialization do increase CO2 emissions somewhat, but the numbers just do not support this; the p-values (0.220 and 0.242) are far too high to call these effects statistically significant. It's true that the positive coefficients suggest higher emissions, but it can't say that these variables have a significant impact without sufficient statistical support.

## V. CONCLUSION

The study aimed to assess the factors influencing carbon emissions in the BRICS nations—Brazil, Russia, India, China, and South Africa. The study concentrated on examining the connection between carbon emissions and important economic factors such as energy consumption, trade openness, industrial value added, and GDP per capita. The effect of several economic factors on CO2 emissions was evaluated using panel data analysis techniques. The study's conclusions provide significant new insights into the economic factors affecting carbon emissions in the BRICS economies. The empirical study leads to the conclusion that energy consumption is a significant factor in influencing carbon emissions in the BRICS nations. Energy consumption and CO2 emissions are positively and significantly correlated, which emphasizes how critical it is to promote cleaner energy sources and lessen reliance on fossil fuels. CO2 emissions and economic growth are positively and statistically significantly correlated. This result supports the claim that growth is still energy-intensive and environmentally costly in the chosen countries since it shows that emissions tend to rise as economies grow. The results indicate that trade openness and industrial value-added do not have a significant impact on carbon emissions—at least not directly, according to this model. This research underscores the point that if BRICS nations wish to expand their economies without causing environmental damage, they must adopt prudent and sustainable solutions. By promoting renewable energy, enhancing energy efficiency, and taking environmental policies seriously, they can make substantial progress. In this way, they can reduce carbon emissions and achieve sustained growth.

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