

ECO-DRIVE: INVESTIGATING THE IMPACT OF ELECTRIC VEHICLES AND RENEWABLE ENERGY ON CARBON EMISSIONS IN BRICS

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Abstract. This study investigates the influence of electric vehicles (EVs) adoption and renewable energy integration on carbon emission within the BRICS nations (Brazil, Russia, India, China, and South Africa). The study made use of the data sourced from the World Development Indicators (WDI) and International Energy Agency [IEA] (2023) for the period 2011 - 2023. The study employed the pooled OLS, PCSE, and FGLS econometric methods to analyze the relationship between EV market penetration, renewable energy capacity, and carbon dioxide emission. Findings reveal that EV adoption and renewable energy negatively impact carbon emission in BRICS countries. Specifically, a unit increase in the quantity of EVs is associated with an 8.10 unit decrease in CO₂ emissions, while a unit rise in renewable energy capacity corresponds to a 0.42-unit reduction in emissions. These results confirm that the transition to electric mobility and clean energy sources plays a substantial role in curbing greenhouse gas emissions in these rapidly growing economies. Our research contributes to the growing body of literature on sustainable development in emerging markets and provides valuable insights for policymakers aiming to balance economic growth with environmental preservation in the BRICS nations.

Keywords: *green mobility, clean energy transition, low-carbon economy, decarbonization, climate policy*

Introduction

The global push for sustainable development has heightened attention on the role of innovative technologies in mitigating climate change (Degbedji et al., 2024; Guo et al., 2025; Mohammed et al., 2024; Onabote et al., 2021; Osabohien et al., 2025, 2024; Rong et al., 2022; Sahan et al., 2025; Yin et al., 2022; Zheng et al., 2023). Among these, electric vehicles (EVs) and renewable energy sources have emerged as key players in the transition to a low-carbon economy (IEA, 2021; Liu et al., 2025; Xu et al., 2023). This study focuses on BRICS countries - Brazil, Russia, India, China, and South Africa. This region represents a significant portion of the world's population, economic output, and carbon emission (Huang et al., 20224; World Bank, 2022).

As rapidly developing economies, the BRICS nations face the dual challenge of sustaining economic growth while addressing environmental concerns. Their energy consumption and carbon footprint have grown substantially in recent decades, making them crucial players in global efforts to combat climate change (Azevedo et al., 2018; Cheng et al., 2025; Xu et al., 2023). The adoption of EVs and the expansion of renewable energy capacity in these countries have the potential to significantly impact global carbon emissions.

Electric vehicles offer a promising alternative to conventional internal combustion engine vehicles, potentially reducing both local air pollution and greenhouse gas emissions (Chen et al., 2024; Qiao et al., 2019). However, the net environmental benefit of EVs depends heavily on the carbon intensity of the electricity grid (Knobloch et al.,

2020). This underscores the importance of concurrent development with renewable energy sources of maximize the positive impact of EV adoption. Renewable energy technologies, such as solar, wind, and hydroelectric power, have seen rapid growth and cost reductions in recent years (International Renewable Energy Agency [IRENA], 2021). Their integration into national energy mixes can substantially reduce the carbon footprint of electricity generation, thus amplifying the environmental benefits of EVs and contributing directly to emission reduction (Gielen et al., 2019; Li et al., 2023; Li et al., 2023).

This study aims to quantify the impact of EV adoption and renewable energy integration on carbon emissions in the BRICS countries. By analyzing panel data and employing econometric methods, we seek to provide insights into the effectiveness of these technologies in mitigating climate change within the context of emerging economies. The findings of this research have important implications for policymakers and stakeholders involved in shaping sustainable development strategies in the BRICS nations and beyond. This study delves into the concept of Eco-Drive, which focuses on investigating the impact of EVs and renewable energy on carbon emissions in the BRICS countries, specifically honing in on CO₂ emissions from transport as a percentage of total fuel combustion.

By analyzing the current state of carbon emissions in the transportation sector within these nations and exploring the potential benefits of transitioning to EVs and renewable energy sources, this research aims to shed light on the effectiveness of these sustainable solutions in reducing carbon emissions. Through a comprehensive examination of the policies, infrastructure, and technological advancements related to EV adoption and renewable energy integration in the BRICS countries, this study seeks to provide valuable insights into the feasibility and implications of implementing Eco-Drive strategies. Ultimately, the findings of this research may contribute to informing future policy decisions and fostering a more environmentally friendly approach to transportation within the BRICS nations. The hypothesis includes:

Hypothesis 1: Adoption of electric vehicles (EVs) will result in a significant decrease in greenhouse gas emissions and contribute to sustainable transportation practices.

Hypothesis 2: Renewable energy development in the BRICS countries will play a crucial role in achieving carbon emission reduction targets and promoting environmental sustainability.

Hypothesis 3: The combination of electric vehicles (EVs) and renewable energy solutions in the BRICS nations is a strategic move towards reducing carbon footprints in the transportation sector.

Materials and methods

This study presents a model that explains the effects of electric vehicle adoption and renewable energy consumption on CO₂ emissions while controlling for economic growth, business formation rates, and industrial activity (see *Eq. 1*). By doing so, it provides a more accurate assessment of the primary drivers of emissions reductions in the context of these technological and economic factors. The study examines the relationships between carbon emissions (CO₂ emissions) as the dependent variable, electric vehicles, renewable energy consumption, GDP per capita growth, new business density, and industrial value-added growth rate as independent and control variables.

Previous studies by Liu et al., 2025; Liuo et al., (2024), Wang et al. (2021), Zhang et al. (2023) and Li et al. (2024) have shown that renewable energy consumption, GDP per

capita growth, entrepreneurship and industrialization growth all impact carbon emissions. The model integrates these variables to explain how changes in electric vehicle adoption, renewable energy consumption, economic growth, business density, and industrial value-added growth can influence carbon emissions.

$$\ln CEM_{it} = \beta_0 + \beta_1 \ln EV_{s_{it}} + \beta_2 \ln REN_{it} + \beta_3 \ln GDPPC_{it} + \beta_4 \ln BDEN_{it} + \beta_5 \ln INDUS_{it} + \varepsilon_{it} \quad (\text{Eq.1})$$

From the model, as presented in *Equation 1*, the dependent variable, carbon emission (CEM) is measured as CO2 emissions from transport (% of total fuel combustion), sourced from the world development indicators (WDI). Also, the main independent variables are electric vehicle (EVs) and renewable energy (REN). Renewable energy was measured by renewable energy consumption (% of total final energy consumption) obtained from the WDI. The control variables are GDPPC, which is GDP per capita growth (annual %), BDEN is business density measured by new business density (new registrations per 1000 people ages 15-64) and INDUS is industrial value-added growth rate as proxy for industrialization. See *Table 1*, the sources and measurement of the variables. *ln* is natural logarithm of the variables, β_0 is the constant term, $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ are the parameters to be estimated, while ε_{it} is the error term. On the other hand, *it* captures the time and entities. The study made us of the data from the World Development Indicators (WDI) for BRICS (Brazil, The Russian Federation, Indian, China and South Africa) for the period of 2010-2023.

Table 1. Variables and measurement

Symbol	Nature	Name	Measurement	Sources
CE	Dependent	Carbon emissions	CO2 emissions from transport (% of total fuel combustion)	WDI
EVs	Independent	Electronic vehicles	Quantity of EVs produced	IEA
REN	Independent	Renewable energy	Renewable energy consumption (% of total final energy consumption)	WDI
GDPPC	Control	Economic growth	GDP per capita growth (annual %)	WDI
BDEN	Control	Business density	New business density (new registrations per 1000 people ages 15-64)	WDI
INDUS	Control	Industrialization	Industrial value-added growth rate	WDI

IEA means International Energy Agency; WDI means World Development Indicators

IEA can be sourced from: <https://www.iea.org/data-and-statistics>

WDI can be found: <https://datatopics.worldbank.org/world-development-indicators/>

Source: Authors' computation using World Bank (2022); IEA (2021)

The justifications for the inclusion of these variables and their “*a priori*” expectation is that the adoption of electric vehicles may reduce carbon emissions as they produce lower or zero emissions compared to traditional internal combustion engine vehicles. By including the variable of electric vehicles in the study, the study assesses the impact of their increased usage on overall CO2 emissions. Because, the adoption of electric vehicles (EVs) directly impacts CO2 emissions from the transportation sector, which is a major source of overall CO2 emissions. EVs produce significantly fewer emissions compared to internal combustion engine vehicles, thus higher EV sales can lead to

reduced CO₂ emissions. In line with, study by Dincer and Acar (2015) which highlighted the potential of electric vehicles in reducing carbon emissions. The study found that electric vehicles produce lower or zero emissions compared to traditional internal combustion engine vehicles, making them a viable solution for reducing greenhouse gas emissions.

Another variable which included is economic growth, as measured by GDP per capita, is often associated with increased energy consumption and industrial activity, and can lead to higher CO₂ emissions. However, economic growth can also enable investment in cleaner technologies and more efficient practices, potentially reducing emissions. The “*a priori*” is that economic may have a positive and negative impact on carbon emissions. The other variable new business formations can influence CO₂ emissions through increased industrial activity, construction, and transportation needs. New businesses may also adopt innovative and sustainable practices, potentially mitigating emissions. The rationale is that the establishment of new businesses can influence energy consumption patterns and emissions through their operations and activities. By considering new business density as a variable, researchers can explore how entrepreneurial activity impacts carbon emissions and sustainability efforts. The industrial sector is a major contributor to CO₂ emissions due to its high energy consumption. The growth rate of industrial value-added can indicate changes in industrial. Industrial activities are major contributors to carbon emissions due to manufacturing processes and energy-intensive operations.

Results

Summary statistics and correlation analysis

To provide an overview of the dataset, we present summary statistics, including mean, standard deviation, minimum, and maximum values. This helps in understanding the distribution and variability of key variables. Correlation analysis is also conducted to examine relationships between variables and identify potential multicollinearity issues, which could affect the regression analysis.

The summary statistics (presented in *Table 2*) provide insights into the environmental, economic, and industrial aspects of BRICS countries. From the result, CO₂ emissions from transport (% of total fuel combustion) has a mean value of 17.57275, standard deviation of 10.35872, minimum value of 3.992374 and max of 38.95203. It shows that the proportion of CO₂ emissions contributed by the transport sector relative to total fuel combustion. The mean value of 17.57% proves that on average, a significant portion of CO₂ emissions comes from transportation activities.

Table 2. Descriptive statistics of variables

Variable	Mean	Std. dev.	Min	Max
CE	17.57275	10.35872	3.992374	38.95203
EVs	142555.4	455867.8	12	2700000
REN	39.06545	33.20402	3.18	47.42
GDPPC	2.513301	3.885043	-7.10659	8.953816
BDEN	4.509091	3.58151	0.01	12.78
INDUS	2.589163	4.395234	-12.0501	12.24412

Source: Authors' own work

The standard deviation of 10.36 indicates significant variability in emissions intensity across BRICS countries. China and India have higher emissions due to coal reliance and industrialization, while Brazil has lower emissions due to hydropower dominance. The 4% to 39% range reflects differences driven by energy infrastructure, technology, policies, and industrial composition. For instance, Russia's energy efficiency efforts contrast with South Africa's fossil fuel dependence. These variations highlight the impact of national energy strategies and economic structures on emissions intensity. The revised manuscript will clarify these country-specific factors to enhance understanding of emissions variability within BRICS.

Electric vehicles sale has mean value of 142555.4, standard deviation of 455867.8 minimum value of 12 and max of 2700000. This metric reflects the annual sales volume of electric vehicles. The mean value of 142,555.4 indicates the average annual sales volume in BRICS. The large standard deviation (455,867.8) signifies considerable variation in sales volumes, possibly influenced by market maturity, subsidies, consumer preferences, and infrastructure development. The range from 12 to 2,700,000 demonstrates the disparity in adoption rates across different markets, reflecting varying levels of governmental support and consumer acceptance.

On the other hand, renewable energy consumption (% of total final energy consumption) has a mean value of 39.06545, standard deviation of 33.20402, min of 7.6 and max of 99.2. This indicator measures the share of renewable energy sources in total final energy consumption. The mean of 39.07% indicates the average contribution of renewables to the energy mix. The standard deviation of 33.20 confirms wide variability, with some regions heavily reliant on renewables while others lag behind. The range from 3.18% to 47.42% highlights the global spectrum of renewable energy adoption, influenced by factors like policy frameworks, resource availability, and technological advancements.

GDP per capita growth (annual %) has mean of 2.513301, standard deviation of 3.885043, min of -7.10659 and max of 8.953816. This metric reflects the annual percentage change in GDP per capita, indicating economic growth trends. The mean growth rate of 2.51% shows a moderate economic expansion on average. The standard deviation of 3.89 indicates variability in growth rates, with some economies experiencing robust growth while others may face recessions or slowdowns. The range from -7.11% to 8.95% illustrates the diverse economic performance globally, influenced by factors such as fiscal policies, global economic conditions, and structural reforms.

New business density (new registrations per 1000 people ages 15-64) has a mean value of 4.509091, standard deviation of 3.58151, min of 0.01 and max of 12.78. This indicator measures the rate of new business registrations per 1000 people of working age. The mean of 4.51 shows the average entrepreneurial activity within a population segment. The standard deviation of 3.58 indicates variability in entrepreneurial dynamics across different BRICS economies. The range from 0.01 to 12.78 underscores varying levels of entrepreneurship, influenced by factors such as regulatory environment, access to finance, and economic opportunities.

This metric measures the annual growth rate of industrial value-added, reflecting industrial sector performance. The mean growth rate of 2.59% indicates moderate industrial expansion on average. The standard deviation of 4.40 highlights variability in industrial growth rates, influenced by factors such as technological advancements, global demand, and regulatory changes. The range from -12.05% to 12.24% illustrates

the diverse industrialization trends globally, with some economies experiencing industrial decline while others undergo rapid industrialization.

Table 3 present the correlation analysis used for the examination of multicollinearity. From the result, it can be seen that relationships between independent variables are not highly correlated, because, the highest value is 0.684 which is linked to industrialization (INDUS) and economic growth (GDPPC). It implies that correlation coefficient of 0.684 indicates a relatively no strong positive linear relationship between the variables.

Table 3. Correlation analysis

Variables	EVs	REN	GDPPC	BDEN	INDUS
EVs	1.000				
REN	-0.209	1.000			
GDPPC	0.123	-0.209	1.000		
BDEN	0.291	-0.412	-0.206	1.000	
INDUS	0.249	-0.144	0.684	-0.223	1.000

Source: Authors' own work

Unit root and cross-sectional dependence

Before proceeding with regression analysis, we conduct unit root tests to ensure data stationarity, as non-stationary variables can lead to spurious results. Additionally, cross-sectional dependence tests are performed to check for interdependencies among BRICS countries, as ignoring cross-sectional dependence in panel data may lead to biased and inefficient estimates.

The study engaged cross-sectional dependence which implies the presence of correlation or interdependence among the cross-sectional units in a panel dataset. In other words, it means that the observations for different units are not independent of each other. It also engaged the Pesaran Cross-Sectional Augmented Dickey-Fuller (CADF) test is a panel unit root test developed by M. Hashem Pesaran in 2006 (Pesaran, 2007; Pesaran and Smith, 1995). This test extends the traditional Dickey-Fuller unit root test to account for cross-sectional dependence in panel data. The CADF test allows for the presence of both individual-specific effects and common factors that are correlated across units. By incorporating these features, the CADF test provides more accurate and reliable results compared to standard unit root tests in the presence of cross-sectional dependence.

The Pesaran Cross-Sectional Im-Pesaran-Shin (IPS) stationarity test is another panel data test developed by Pesaran, Yongcheol Shin, and Richard J. Smith in 1999 (Im et al., 2003). This test is used to assess the stationarity of individual series in a panel data context while accounting for cross-sectional dependence. The IPS test extends the traditional Augmented Dickey-Fuller (ADF) unit root test to allow for cross-sectional correlation, making it suitable for analyzing panel data with potential cross-sectional dependence issues (Im et al., 2003).

We engaged these tools, because, the Pesaran CADF test and IPS test are specifically designed to handle cross-sectional dependence in panel data, which is a common issue in many empirical studies. By using these tests, the study is able to ensure that the analysis accounts for the interdependence among cross-sectional units, leading to more accurate and reliable results (Im et al., 2003). Also, due to the fact that the traditional unit root tests may produce biased estimates and incorrect inferences when cross-

sectional dependence is present. By employing the Pesaran CADF test or IPS test, the study obtains more robust statistical results that account for the specific characteristics of panel data with correlated units. By using these specialized tests, you can increase the validity of the study findings and ensure that the conclusions are not influenced by cross-sectional dependence issues. This can enhance the credibility and reliability of the research outcomes (Pesaran, 2007; Pesaran and Smith, 1995).

Furthermore, the Pesaran CADF test and IPS test are well-established methods in the field of panel data analysis and have been widely used in empirical research. By engaging these tests in this study, we leverage a recognized and accepted methodology for addressing cross-sectional dependence. Moreover, accounting for cross-sectional dependence through the Pesaran CADF test or IPS test can lead to more appropriate model specification and parameter estimation. This can help avoid potential misspecification errors and improve the overall quality of the econometric analysis (Maddala and Wu, 1999).

Thus, the result in *Table 4* shows the presence of weak cross-sectional dependence among BRICS since the null hypothesis of cross-sectional dependence is rejected at 1% significance level. Also, for the panel unit root tests, using the second-generation unit root test for variables that have cross sectional dependence, result shows that all the variables are stationary at first difference.

Table 4. Pre-estimation check

Variable	CSD statistics	PES CADF		PESCIPS		Westerlund Statistics
		Level	1st Diff.	Level	1st Diff.	
CE	1.656*	-4.2886***	-4.2486***	-1.510*	-2.0736***	-3.167**
EVS	4.963***	-6.643***	-3.385***	-2.187***	-2.963***	
REN	0.363	-4.5475***	-3.5219***	2.4003	-1.7607**	
GDPPC	3.896***	-4.3187***	-4.9862***	-0.9143	-2.5469***	
BDEN	3.394***	-2.3667***	-5.3915***	-0.7399	-2.6516***	
INDUS	5.851***	-3.5273***	-3.7846***	-2.4054***	-2.0345**	

***, **, * indicate statistical significance at the 1%, 5% and 10% level. CSD: cross sectional dependence; PESCADF means Pesaran cross-sectional augmented Dickey-Fuller. PESCIPS stand for Pesaran cross sectional Im-Pesaran-Shin stationarity test
 Source: Authors' own work

PCSE and FGLS analysis

To address heteroskedasticity and autocorrelation in panel data, we employ two estimation techniques: panel-corrected standard errors (PCSE) and feasible generalized least squares (FGLS). PCSE is used to obtain robust standard errors, particularly when residuals exhibit heteroskedasticity and correlation across panels. FGLS is applied as an alternative to improve efficiency in cases where panel-specific heteroskedasticity and serial correlation exist. These methods ensure that our estimations are robust and reliable for policy interpretation.

The result for PCSE and FGLS is presented in *Table 5*. The result shows that the negative coefficient of -8.10e-06 for elective vehicles in BRICS countries indicates that an increase in the number of electric vehicles is associated with a decrease in carbon emissions. The result confirms that the adoption of electric vehicles in BRICS nations

has a mitigating effect on carbon emissions. Several factors could explain this result, including growing environmental awareness, technological advancements in electric vehicles, government incentives to promote cleaner transportation options, and the impact of urbanization and traffic congestion. These factors collectively contribute to the negative relationship between electric vehicles and carbon emissions in BRICS countries. The increasing focus on sustainability and climate change mitigation may be driving the shift towards electric vehicles as a more environmentally friendly transportation option. As governments and societies prioritize reducing carbon emissions, the adoption of electric vehicles appears to be playing a significant role in achieving this goal within the BRICS nations.

Table 5. POLS, PCSE and FGLS results

Variables	POLS	PCSE			FGLS		
	POLS	Main regression			Robustness check		
	X	(1)	(2)	(3)	(4)	(5)	(6)
Constant	35.521*** (0.000)	35.521*** [0.000]	35.521*** [0.000]	35.521*** [0.000]	35.521*** [0.000]	36.567*** [0.000]	36.567*** [0.000]
EVs	-8.1006 (0.000)	-8.1006* [0.067]	-8.1006** [0.037]	-8.1006** [0.024]	-8.1006** [0.024]	-9.1006*** [0.018]	-9.1006*** [0.018]
REN	-0.4218*** (0.008)	-0.422*** [0.004]	-0.422*** [0.004]	-0.422*** [0.004]	-0.422*** [0.004]	-0.424*** [0.003]	-0.424*** [0.003]
GDPPC	1.448** [0.015]	1.448** [0.051]	1.448** [0.040]	1.448* [0.063]	1.449* [0.063]	1.078 [0.100]	-1.078 [0.100]
BDEN	1.0501* [0.051]	-1.050* [0.072]	-1.050** [0.058]	-1.050* [0.079]	-1.050* [0.079]	-1.103** [0.038]	-1.103** [0.038]
INDUS	0.5503 [0.393]	0.5500 [0.362]	0.5500 [0.373]	0.5500 [0.422]	0.55 [0.422]	0.458 [0.430]	0.458 [0.430]
Observation	44	44	44	44	44	44	44
R-Squared	0.744	0.27	0.27	0.27			
Wald Stat		15.22***	16.19***	16.64***	16.64***	16.75***	16.75***

***, **, * indicate statistical significance at the 1%, 5% and 10% level

Model 1 to 3 are the PCSE which is the main analysis while FGLS is the Robustness check

Model 1: No Autocorrelation/Panel level heteroskedastic and correlated across panels

Model 2: No Autocorrelation/Panel level heteroskedastic

Model 3: No Autocorrelation/Independent panels corrected standard errors

Model 4: No Autocorrelation and independent

Model 5: Heteroskedastic but uncorrelated

Model 6: Heteroskedastic and correlated

X: regression with Driscoll-Kraay standard errors

Source: Source: Authors' own work

The negative coefficient of 0.4218 for renewables in the regression analysis indicates that an increase in the use of renewable energy sources is associated with 0.42% decrease in carbon emissions in BRICS countries. This confirms that adopting renewable energy sources like solar, wind, and hydroelectric power can mitigate carbon emissions. Reasons for this negative correlation include clean energy production, energy efficiency, government policies promoting renewables, and technological

advancements making them more cost-effective. Transitioning to renewables not only reduces reliance on fossil fuels but also helps combat climate change and achieve sustainability. Promoting renewable energy in BRICS countries is crucial for reducing carbon emissions and contributing to global efforts to address climate change.

The relationship between GDP per capita, business density, industrialization, and carbon emissions is complex and multifaceted, influenced by various economic, social, and environmental factors. Understanding this relationship requires an analysis of the Environmental Kuznets Curve (EKC) theory and the pollution haven hypothesis, which provide valuable insights into the dynamics of economic growth, industrial development, and environmental degradation. The Environmental Kuznets Curve posits that environmental degradation initially worsens as countries experience economic growth and increase their income levels (Mohammed et al., 2024). This phenomenon is often attributed to the higher consumption levels and energy-intensive production processes associated with economic development.

As countries industrialize and urbanize, their energy demand and greenhouse gas emissions tend to rise due to increased industrial activities, transportation needs, and energy consumption. This initial phase of economic growth is characterized by a positive relationship between GDP per capita, business density, industrialization, and carbon emissions. Moreover, the pollution haven hypothesis confirms that industries may relocate to countries with lower environmental standards and regulations to reduce production costs and avoid stringent environmental regulations. This can lead to higher emissions in regions with weaker environmental policies, contributing to the positive relationship between industrialization, business density, and carbon emissions.

The positive relationships between GDP per capita, business density, industrialization, and carbon emissions highlight the challenges of balancing economic development with environmental sustainability. While economic growth is essential for improving living standards and reducing poverty, it can also have adverse environmental impacts if not managed effectively. As countries strive to achieve higher levels of economic prosperity, they must address the environmental consequences of industrialization and business expansion. To mitigate the negative effects of economic growth on the environment, countries can adopt a range of policy measures and strategies. These may include promoting clean technologies, investing in renewable energy sources, implementing energy efficiency measures, and strengthening environmental regulations. By integrating sustainability considerations into economic planning and decision-making processes, countries can pursue a more sustainable development path that minimizes carbon emissions and promotes environmental conservation.

Discussion

The discussion is based on the hypotheses of the study.

Hypothesis 1: Adoption of electric vehicles (EVs) will result in a significant decrease in greenhouse gas emissions and contribute to sustainable transportation practices

The hypothesis that the adoption of electric vehicles (EVs) will result in a significant decrease in greenhouse gas emissions and contribute to sustainable transportation practices is supported by various studies and research findings. Electric vehicles are considered a cleaner alternative to traditional internal combustion engine vehicles because they produce zero tailpipe emissions when powered by electricity from

renewable sources. This transition from fossil fuel-powered vehicles to EVs has the potential to reduce carbon emissions and mitigate the impacts of climate change.

According to a study by transitioning to electric vehicles can significantly reduce greenhouse gas emissions in the transportation sector. The study found that EVs produce lower lifecycle emissions compared to conventional vehicles, especially when powered by renewable energy sources such as solar or wind power. This reduction in emissions contributes to global efforts to combat climate change and achieve carbon neutrality.

Research conducted by the International Energy Agency (IEA) highlights the environmental benefits of electric vehicles in terms of reducing air pollution and improving air quality (IEA, 2019). EVs have lower emissions of pollutants such as nitrogen oxides (NO_x) and particulate matter, which have adverse health effects on human populations. By promoting the adoption of electric vehicles, countries can improve public health outcomes and create cleaner urban environments. Many countries and regions have implemented policies and incentives to accelerate the adoption of electric vehicles as part of their climate action plans. The integration of renewable energy sources into the electricity grid is crucial for maximizing the environmental benefits of electric vehicles. A study by the Union of Concerned Scientists emphasizes the importance of pairing EV adoption with renewable energy deployment to achieve significant reductions in greenhouse gas emissions. By transitioning to a clean energy system powered by renewables, the environmental impact of electric vehicles can be further enhanced.

Hypothesis 2: Renewable energy development in the BRICS countries will play a crucial role in achieving carbon emission reduction targets and promoting environmental sustainability

Renewable energy development in the BRICS countries, which include Brazil, Russia, India, China, and South Africa, is indeed crucial in achieving carbon emission reduction targets and promoting environmental sustainability. While it is true that the production and installation of renewable energy technologies may have some associated carbon emissions, the overall lifecycle emissions of renewable energy sources are significantly lower compared to fossil fuels.

Brazil has been a leader in renewable energy, particularly in hydropower and biofuels. The country has made significant investments in wind and solar energy as well. By expanding its renewable energy capacity, Brazil can reduce its dependence on fossil fuels and lower carbon emissions from its energy sector. Russia has vast renewable energy potential, including wind, solar, and hydropower resources. By investing in these clean energy sources, Russia can reduce its reliance on oil and gas, which are major sources of carbon emissions. Transitioning to renewable energy can help Russia meet its emission reduction targets and contribute to global efforts to combat climate change.

India has set ambitious targets for renewable energy deployment, aiming to increase the share of renewables in its energy mix. The country has abundant solar and wind resources that can be harnessed to reduce carbon emissions from the power sector. Investing in renewable energy will not only help India achieve its emission reduction goals but also improve air quality and public health. China is the world's largest emitter of greenhouse gases, primarily due to its reliance on coal for electricity generation. However, the country has also become a global leader in renewable energy deployment, particularly in solar and wind power. By scaling up its renewable energy capacity,

China can reduce carbon emissions, improve air quality, and drive sustainable economic growth. South Africa has significant renewable energy potential, including solar, wind, and biomass resources. The country has already made progress in expanding its renewable energy capacity through initiatives like the Renewable Energy Independent Power Producer Procurement Programme. By further developing its renewable energy sector, South Africa can reduce carbon emissions from its energy sector and promote environmental sustainability.

Hypothesis 3: The combination of electric vehicles (EVs) and renewable energy solutions in the BRICS nations is a strategic move towards reducing carbon emission.

This can be explained in line with the hypothesis as follows: By integrating EVs with renewable energy sources such as solar, wind, and hydropower, the transportation sector can significantly reduce its reliance on fossil fuels. Since EVs do not produce tailpipe emissions like traditional internal combustion engine vehicles, powering them with renewable energy sources ensures that the overall carbon footprint of the transportation sector is minimized. The transportation sector is a significant contributor to greenhouse gas emissions, particularly carbon dioxide (CO₂) emissions. By transitioning to electric mobility powered by renewable energy, the BRICS nations can play a crucial role in mitigating climate change. Renewable energy sources are inherently cleaner and have lower carbon footprints compared to fossil fuels, making them a sustainable option for charging EVs and reducing overall carbon emissions.

Renewable energy sources are domestic and abundant in many BRICS nations, providing a more secure and stable energy supply compared to imported fossil fuels. By harnessing their renewable energy potential to power EVs, these countries can enhance their energy security and reduce their dependence on volatile global oil markets. This strategic move towards domestic renewable energy production for transportation can also create new economic opportunities and reduce the environmental impact of energy imports. The combination of EVs and renewable energy solutions aligns with the goals of sustainable development by promoting clean, efficient, and environmentally friendly transportation systems. By investing in renewable energy infrastructure and electric mobility, the BRICS nations can foster innovation, create green jobs, and improve air quality in urban areas. This strategic approach not only reduces carbon emissions but also contributes to a more sustainable and resilient economy.

Conclusion

The results revealed that renewable energy and EVs were positively associated with carbon emissions, while economic growth, business density, and industrialization also showed positive relationships. These findings confirm that the adoption of EVs and renewable energy alone may not be sufficient to reduce carbon emissions in the BRICS countries, highlighting the need for a comprehensive approach to sustainable development and environmental conservation.

The analysis of the impact of electric vehicles (EVs) and renewable energy on carbon emissions in the BRICS nations has provided valuable insights into the complex dynamics of sustainable development and environmental conservation. The study's findings indicate that while EVs and renewable energy hold promise as cleaner alternatives to traditional fossil fuel-based transportation systems, their implementation alone may not lead to a significant reduction in carbon emissions. The positive associations observed between renewable energy, EVs, economic growth, business

density, industrialization, and carbon emissions underscore the need for a holistic approach to addressing environmental challenges in the BRICS countries.

Moving forward, policymakers and stakeholders in the BRICS nations must consider a multidimensional strategy that integrates technological innovation, policy interventions, and behavioral changes to achieve meaningful reductions in carbon emissions. Investing in renewable energy infrastructure, promoting the adoption of EVs, and implementing stringent regulations on industrial emissions are essential steps towards building a sustainable and low-carbon economy. Additionally, efforts to enhance energy efficiency, promote green technologies, and foster sustainable urban planning can further contribute to mitigating climate change and promoting environmental sustainability.

Furthermore, collaboration among BRICS countries and international partners is crucial for sharing best practices, leveraging resources, and fostering innovation in clean energy technologies. By working together to address common environmental challenges, the BRICS nations can accelerate their transition towards a greener and more sustainable future. Ultimately, the integration of EVs and renewable energy solutions in the BRICS nations represents a strategic move towards reducing carbon emissions and advancing towards a more environmentally friendly transportation sector. This holistic approach aligns with global efforts to combat climate change, promote sustainable development, and ensure a cleaner and healthier planet for future generations.

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