



DOES THE USE OF GREEN ENERGY AFFECT ECONOMIC GROWTH? EVIDENCE OF MODERATING THE ROLE OF GOVERNANCE QUALITY IN BRICS

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Article history:	Abstract:
<p>Received: 7th April 2024 Accepted: 6th May 2024</p>	<p>The influence of green energy consumption on the economic development of the BRICS nations—Brazil, Russia, India, China, and South Africa—is the subject of this research. The quality of governance is the primary concern. From 1990 to 2020, FM-OLS regression econometric modeling was used yearly for this aim. The findings indicate that the good governance index and green energy usage have a beneficial impact on economic development. Consequently, there is a positive and substantial relationship between green energy consumption (LREC) and economic growth; for every 1% rise in LREC, there is a 0.480% gain in economic growth. Economic growth is positively and significantly impacted by good governance (GGI), and for every unit rise in GGI, there will be a 1.991 unit gain in economic growth. According to the interpretation of the data from the other control variables in this research, economic growth would rise if there is a one percent increase in carbon dioxide emissions (LCO₂), fossil fuel consumption (LFEC), gross fixed capital formation (LGFCF), inflation (LINFL), and trade openness (LTrade). (LTrade), there will be five different increases in economic growth: 0.639%, 0.018%, 0.141%, 0.205%, and 0.678%. The development of supportive policies, enhanced governance, suitable fiscal and tax frameworks, infrastructure development, international cooperation, education and awareness, research and development, promotion of foreign investment, increased coordination and collaboration between system components, and effective resource management are all areas that could use improvement, as these results demonstrate. Promote more excellent governance and the use of ecologically friendly energy to help the BRICS nations' economies flourish.</p>

Keywords: Green Energy Consumption, Economic Growth, Good Governance, BRICS Countries.

JEL Classification: O13, Q43, O55.

INTRODUCTION

The matter of greenhouse gas emissions and the use of non-renewable energy resources is of considerable importance owing to their adverse impacts on the environment, including climate change, the decline of biodiversity, and pollution. The aforementioned remark underscores the adverse ramifications associated with fossil fuel combustion and the imperative of diminishing their utilization to promote global welfare. According to Aydoğan and Vardar (2020), the proposition is made that transitioning from non-renewable energy sources to renewable energy in developing nations may result in reduced growth and development in the immediate term. Still, it can yield favorable and sustainable effects on growth and development in the long run. This

viewpoint is consistent with the recognition that the transition to renewable energy is essential to address the detrimental impacts of climate change and foster a sustainable trajectory for the future. In the immediate future, using non-renewable energy sources such as coal and natural gas has the potential to stimulate economic expansion due to their widespread accessibility and cost-effectiveness. Nevertheless, this particular methodology incurs significant environmental and public health ramifications, as shown by the extensive air pollution highlighted in the study published by the United Nations. The need for a transition to renewable energy sources is underscored by its enduring ramifications, which include the possibility of irreparable harm to ecosystems and the worsening of



climate-related predicaments. Although the shift towards renewable energy may bring early obstacles, such as the need for infrastructure expansion and possible economic adaptations, it offers a prospect for sustained progress and advancement. Renewable energy sources, such as solar, wind, hydro, and geothermal, possess a multitude of benefits, including diminished emissions of greenhouse gases, ameliorated air quality, and augmented energy security. Moreover, there has been significant progress in developing renewable energy technology, leading to enhanced cost-efficiency. Consequently, these advancements have rendered renewable energy sources increasingly feasible substitutes for non-renewable options. Through the adoption of renewable energy sources and the reduction of greenhouse gas emissions, nations have the potential to make significant contributions towards the mitigation of climate change, the preservation of ecosystems, and the promotion of sustainable development. When creating energy policies and plans, it is essential to consider the trade-offs in the near term and the long-term advantages to guarantee a sustainable and prosperous future for present and future generations.

The Sustainable Development Goals report (United Nations, 2022) indicates a notable rise of 25% in the use of renewable energy throughout the period spanning from 2010 to 2019. Nevertheless, the current proportion of renewable energy in worldwide final energy consumption is reported to be 17.7%, according to the United Nations (2022). According to a projection made by British Petroleum (2022), it is anticipated that the proportion of renewable energy on a worldwide scale will increase from 35% in 2019 to around 65% by the year 2050. Multiple scholarly investigations (Alola et al., 2022; Ayanlade et al., 2022; Ibrahim et al., 2022; Khan et al., 2022; Kirikkaleli & Adebayo, 2022)

underscore the significance of renewable energy sources in advancing environmental sustainability through the mitigation of CO₂ and other greenhouse gas emissions in the Earth's atmosphere. The implementation of this decrease is crucial in order to facilitate and maintain sustainable economic development.

The current research examines the BRICS nations: Brazil, Russia, India, China, and South Africa. These countries constitute a prominent group on the world scene, characterized by their immense natural resources, sizable populations, and substantial economic impact. However, as seen in Figure 1, the proportion of renewable energy in primary energy consumption for 2022 exhibits variation across these nations. Regarding renewable energy share, Brazil accounts for 48.74%, China for 16.02%, India for 10.4%, Russia for 6.71%, and South Africa for 3.88%. The data presented suggests a growing use of renewable energy sources in the energy portfolios of the BRICS nations. Therefore, a vital aim of this research is to investigate the influence of renewable energy consumption on the economic development of these countries.

Prior empirical research investigating the correlation between renewable energy and economic development has shown varying and inconclusive findings. Several scholarly investigations have shown renewable energy's substantial and favorable impact on economic expansion (Kahia et al., 2019; Magazzino et al., 2022; Pao & Fu, 2013). In contrast, Abbasi et al. (2020) discovered an inverse correlation between renewable energy and economic development. Apergis et al. (2010) also observed a lack of a statistically meaningful correlation between economic growth and the utilization of renewable energy.

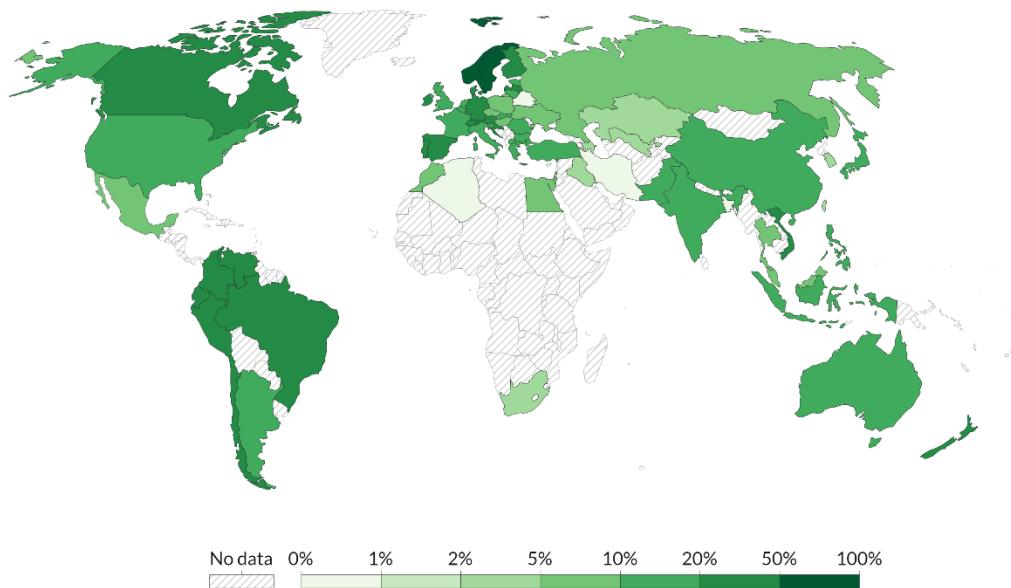


Figure (1): Share of primary energy from renewable sources, 2022

Source: <https://ourworldindata.org>

An additional aim of the current research is to examine the impact of effective governance on the economic development of the BRICS nations. Scholars, academics, and politicians have provided many definitions for the word "governance." The United States Agency for International Development (USAID) (2002) defines governance as a multifaceted framework including the interplay of structures, characteristics, and procedures emphasizing transparency, accountability, and involvement. According to the United Nations Development Programme (UNDP, 1997), governance may be defined as efficiently managing a nation's affairs at many levels, including executive, economic, and political dimensions. According to Awan et al. (2018), civil society involves complex procedures, legal frameworks, and organizational structures that enable people to articulate their viewpoints and fulfill their civic duties.

The authors, Kaufmann et al. (1999), have established a comprehensive conceptual framework encompassing several governance dimensions. Governance is often seen as a composite framework, including established customs and institutional structures that are enacted and maintained by governing bodies at the national level. This idea encompasses the ability of governing bodies to discern and execute efficient strategies and procedures to choose, oversee, and modify the administration. Furthermore, it stresses the importance of the governing body and individuals respecting the places that make business and social transactions possible. According to Quibria (2006), there was a notable

positive association identified between governance indices and per capita income throughout the period spanning from 1998 to 2008. Haggard and Tiede (2011) demonstrated that the associations between governance indicators and economic growth are much weaker in developed countries than in emerging economies. Their study results show a more vital link between the rule of law indicators and economic growth in industrialized countries than in developing economies.

The presence of inadequate governance, especially in the realm of law enforcement and maintenance of order, is a substantial impediment to economic progress in emerging nations. In his seminal work, Helliwell (1992) conducted an investigation into the correlation between economic development and democracy. The findings of this study revealed a noteworthy negative or inconsequential influence on growth within low-income nations. Nevertheless, Helliwell's research revealed a noteworthy association between economic development and democracy in high-income nations. According to a study done by Ozpolat et al. (2016), the researchers reached the conclusion that the effectiveness of the organizational structure is not a causative determinant, but rather a consequence of development. The results of the research did not indicate a positive correlation between the rule of law and economic development in nations with average and low income levels. Additionally, the importance of effective governance in fostering economic development was underscored in a research conducted by Abdeltawab Mahran (2023).



Because of these factors, looking at green energy use through the lens of sustainability and development could significantly reduce pollution and increase economic output. Nevertheless, it is crucial to acknowledge that relying on green energy consumption is insufficient. The recognition of good governance as an essential aspect of growth is necessary. The enhancement of governance positively impacts the interaction between the government and its constituents, promotes openness and accountability, protects property rights, and cultivates a conducive environment for investment. Hence, it is essential to acknowledge the importance of effective governance, focus on bolstering governance and strengthening the government in this domain, and explore aspects of green energy consumption.

This research provides a significant addition to the current body of literature by investigating the collective impact of green energy consumption, especially renewable energy consumption, and good governance on the economic development of BRICS nations. The research utilizes the FM-OLS (Fully Modified Ordinary Least Squares) econometric technique to estimate enduring associations. This approach facilitates the estimation of parameters inside a cointegrated equation. The FM-OLS method can be used to find long-run coefficients when the variables in the model are cointegrated, which means they are linked.

The present article is structured in the following manner: 1. The introduction section presents a concise summary of the study's aims and provides a structural structure for the paper. 2. Literature Review: This part looks at relevant literature about using green energy, good governance, and how these things are linked to economic growth. 3. Methodology, Variables, and Data Sources: This section will comprehensively discuss the methodologies followed, the variables evaluated, and the data sources utilized in the study. 4. Results and discoveries: This section presents the outcomes from estimating the designated model, emphasizing the significant discoveries and their consequences. 5. Discussion and Conclusion: This part will include a comprehensive analysis of the results, highlighting their relevance and contribution to the current body of knowledge. A concluding section that summarizes the critical points discussed will come after it. This essay demonstrates a proficient analysis of the interplay between green energy consumption, good governance, and economic development by adhering to a well-defined framework.

2) LITERATURE REVIEW

2.1) Theoretical Review

Energy Consumption and Economic Growth

A solid energy strategy plays a critical role in the economic growth of any nation, given the intrinsic relationship between energy and gross domestic product (GDP) output. The energy policies established in BRICS nations greatly impact the success of their separate economies. GDP acts as a macroeconomic indicator that evaluates economic activity and assesses the health of an economy by analyzing the total value of final products and services generated during a certain period. It is commonly acknowledged as a major statistic for analyzing the total size of an economy. The expansion of GDP denotes a thriving economy, reflecting increasing economic activity and productivity.

Typically, there exist three methodologies for computing gross domestic product (GDP): the value-added approach (also known as the production approach), the expenditure approach (sometimes referred to as the final output approach), and the income approach. This article examines explicitly the Gross Domestic Product (GDP) calculated using the expenditure technique, which is expressed in millions of euros and assessed at market prices. This technique facilitates the collection of diverse commodities produced inside the domestic economy. Presenting Gross Domestic Product (GDP) using current market values aids in mitigating price disparities across nations, hence facilitating the comparison of living standards and monitoring convergence patterns among BRICS countries. The essential constituents of GDP when employing the expenditure method are private consumption (C), government spending (G), gross investment (I), and net exports (exports (X) minus imports (M)). The calculation formula may be expressed as equation (1):

$$\text{GDP} = C + G + I + (X - M) \quad (1)$$

Changes in final consumption, including private consumption (C) and government spending (G), have a substantial impact on the growth and path of gross domestic product (GDP). Of these, the progression of ultimate energy consumption is especially significant, since energy plays a pivotal role in fostering economic growth and development. The link between energy and economic development is dynamic, as shown by several academics (Wada, 2017). Multiple research have investigated the correlation between GDP and energy use, producing a wide array of findings on causation. These studies have reported results emphasizing one-way causation, two-way causality, or no statistically significant connection between GDP and energy use. The nature of the link differs based on the particular setting and approach used in each research.

2.1) Empirical Review

Various studies have examined the correlation between the use of renewable energy and economic development, with diverse conclusions and suggestions.



Below are a few illustrations: Pearson (2021) investigates explicitly the relationship between renewable energy usage and economic development in Croatia. The study utilizes time-series data spanning from 1996 to 2011. The research used an autoregressive Distributed Lag (ARDL) model to establish a positive correlation between the usage of renewable energy and both short-term and long-term economic growth. Qudrat-Ullah and Nevo (2021) performed research using panel data from 37 African nations. The researchers use the Generalized Method of Moments (GMM) system estimator and discover that the implementation and advancement of renewable energy positively impact economic growth in Africa, both in the short term and the long term. In their study, Dogan and Ozturk (2017) examine the impact of real income (GDP), renewable energy consumption, and non-renewable energy consumption on carbon dioxide (CO₂) emissions in the United States. The Environmental Kuznets Curve (EKC) model was used for the period spanning from 1980 to 2014. The results indicate that during a structural break, there is a connection between CO₂ emissions, real income, quadratic real income, and renewable and non-renewable energy use. The findings from the long-term estimate suggest that a rise in the use of renewable energy leads to a decrease in environmental deterioration. In contrast, an increase in the use of non-renewable energy contributes to the release of CO₂. Moreover, the EKC theory lacks validity when applied to the United States.

The aforementioned research provides more understanding of the correlation between renewable energy use and the economy's advancement in some geographical regions. Maji et al. (2019) examined 15 West African nations using the Dynamic Ordinary Least Squares (DOLS) panel methodology. Their results indicate that the use of renewable energy has a negative impact on economic development in these nations. Nigeria was the subject of an analysis in a study by Maji (2015). The findings revealed a noteworthy inverse correlation between clean energy indicators, namely alternative nuclear energy and electricity consumption, and economic development. The Autoregressive Distributed Lag (ARDL) model was used, with data spanning from 1971 to 2011. Riti et al. (2022) performed a panel research in the southern part of Saharan Africa, using the ARDL model and utilizing data spanning from 1990 to 2018. Their research reveals a strong and statistically significant correlation between the use of renewable energy and sustained economic expansion. Furthermore, it was discovered that renewable energy has an adverse effect on greenhouse gas (GHG) emissions. Conversely, a notable positive correlation exists between real GDP, gross fixed

capital creation, and GHG emissions. These studies emphasize the varied correlation results between the use of renewable energy, economic advancement, and ecological sustainability. This shows how important it is to look at different areas and use the proper methods to fully understand how renewable energy, economic growth, and environmental effects affect each other.

The research done by Apergis and Payne (2012) examines the correlation between power usage in Central America using the Panel Error Correction Model. The results demonstrate a stable and balanced link over a long period between real gross domestic product (GDP), consumption of renewable power, consumption of non-renewable electricity, real gross fixed capital formation, and labor. The study's findings suggest that there is a positive and statistically significant relationship between renewable power usage and other factors in the long run. These findings indicate that using renewable power has a beneficial role in fostering economic development in Central America. In addition, the panel error correction model's findings show a one-way causal relationship between renewable power consumption and economic development in the near term. In the long term, there is a reciprocal relationship between the use of renewable power and economic development, where both factors influence each other. Consequently, the long-term relationship between economic development and renewable power consumption is evident, indicating that the former affects the latter. Furthermore, the findings demonstrate a reciprocal relationship between the use of non-renewable power and economic development, both in the short and long term. This suggests a reciprocal influence between the usage of non-renewable power and economic development. The study's results provide valuable insights into the precise dynamics and causal connections between renewable and non-renewable power use and economic development in Central America.

Non-renewable Energy Consumption and Economic Growth

The correlation between the usage of non-renewable energy and economic development is intricate and needs a solid agreement. Below are two studies that provide insight into this correlation: In their study, Borhan et al. (2012) investigated the influence of carbon dioxide (CO₂) emissions on the economic development of eight Asian nations. The researchers used simultaneous equation models, using pollutant intensity as a surrogate for CO₂ emissions. The results indicate a link between the environmental Kuznets curve and concavity. Consequently, the rise in non-renewable energy use may lead to increased economic growth. Nevertheless, if a specific limit is surpassed, further increments in the use of non-renewable energy



may result in reduced economic benefits or adverse impacts on growth. Ivanovski et al. (2021) examined the correlation between renewable and non-renewable energy utilization and the economy's advancement using the Least Squares Dummy Variable (LSDV) estimation technique. The researchers examined data from 1990 to 2015 in countries that included both OECD and non-OECD nations. The results suggest that using non-renewable energy has a favorable and substantial effect on economic growth in OECD nations.

However, the statistical significance of the contribution of renewable energy consumption to economic growth in these countries is not consistently supported across most studies. This suggests that the impact of renewable energy consumption on economic growth in OECD countries may be less robust or vary depending on specific factors and contexts. These studies highlight the mixed findings regarding the relationship between non-renewable energy consumption and economic growth. An environmental Kuznets curve relationship suggests that the relationship may not be linear, and the impact of non-renewable energy consumption on economic growth may diminish or become negative beyond a certain point. Additionally, the varying significance of renewable energy consumption in contributing to economic growth in OECD countries underscores the need for further research and consideration of specific factors that influence this relationship.

Nevertheless, most studies do not consistently provide statistical evidence for the impact of renewable energy use on economic development in these nations. These findings indicate that the relationship between renewable energy usage and economic development in OECD nations may be weak and might be influenced by many events and circumstances. These studies emphasize the inconclusive results about the correlation between the use of non-renewable energy and economic development. An environmental Kuznets curve connection posits that the correlation between non-renewable energy consumption and economic development may not follow a straight line and that the influence of non-renewable energy consumption on economic growth may decrease or even become negative after reaching a specific threshold. Furthermore, the differing importance of using renewable energy sources in promoting economic development in OECD nations highlights the need for further investigation and examination of particular elements that impact this correlation.

The research conducted by Sannasse (2015) specifically examined the correlation between carbon emissions and economic growth in Mauritius. The Environmental Kuznets Curve (EKC) was calculated for the period spanning from 1975 to 2009. The results

suggest a strong correlation between the trajectory of carbon dioxide (CO₂) emissions and the temporal distribution of gross domestic product (GDP). Nevertheless, the research did not identify a plausible inflection point or a "U" shaped Environmental Kuznets Curve (EKC). The study revealed a rising emission-income elasticity, indicating that as the Gross Domestic Product (GDP) expands, there is a corresponding rise in CO₂ emissions. This trend persists without reaching a point of saturation when environmental deterioration starts to decrease.

Chen and Huang (2013) performed a study examining the correlation between per capita carbon dioxide (CO₂) emissions and economic development in the N-11 nations, which are a collection of rising economies. The study analyzed data from 1981 to 2009. Their analysis used a panel heterogeneous framework. Their investigation validated an enduringly positive correlation between CO₂ emissions, electricity consumption, energy consumption, and gross domestic product (GDP). These findings indicate a positive correlation between GDP growth and the rise in CO₂ emissions, electricity usage, and energy consumption. Moreover, the analysis uncovered a bidirectional causation between CO₂ emissions and power usage, suggesting that these two variables have a mutually influencing link. These studies enhance our comprehension of the correlation between carbon emissions, economic development, and other variables in certain locations. The research on Mauritius indicates that there may not be a distinct U-shaped pattern in the correlation between economic development and carbon emissions. Conversely, the research conducted on the N-11 nations reveals a favorable and enduring correlation between CO₂ emissions and economic indices. These results emphasize the need of customized strategies and geographically-targeted measures to tackle the environmental obstacles linked to economic expansion and carbon emissions.

Good Governance and Economic Growth

The correlation between economic development and governance is a subject of substantial discourse in academic literature. Below are many significant discoveries derived from pertinent research: Singh (2022) investigated the correlation between economic development and governance using panel cointegration analysis. The research examined the influence of six governance variables on economic development in BRICS nations. The results indicate a mutually beneficial link between development and governance. The statement suggests that economic development is essential for enhancing good governance, and conversely, good governance plays a role in promoting growth. Ogbuabor et al. (2020) examined the impact of



several governance characteristics on impeding economic progress in 13 nations in West Africa. The researchers used the two-stage least squares (2SLS) regression and generalized method of moments (GMM) methodologies. The findings suggest that corruption, governmental inefficiency, lack of adherence to the rule of law, inadequate supervision quality, and political instability substantially negatively impact economic development in these nations. Beyene (2022) examined the influence of governance on economic development in 22 African nations. The research conducted a separate analysis of the impacts of each governance factor and created a composite governance index. The results indicate that the composite governance index has a beneficial influence on growth, notwithstanding the negative implications of corruption and government efficiency when considered individually. These studies jointly emphasize the importance of governance in influencing economic development results. They propose that the implementation of effective governance measures, such as transparency, accountability, adherence to the rule of law, and political stability, is essential for promoting long-lasting economic development. The results underscore the need to implement efficient governance reforms and policies to foster economic growth and alleviate the adverse effects of corruption and inefficiency in governance systems.

The aforementioned research provide other perspectives on the correlation between governance and economic development. The following are notable discoveries derived from these studies: The study conducted by Orji et al. (2022) centered on Nigeria and revealed that exerting control over corruption favorably affected economic development. According to their multiple regression models, an increase in the corruption control rate is associated with a growth rate of 0.54%. These findings indicate that by reducing corruption, it is possible to stimulate economic development inside the nation. Hamid et al. (2022) highlight the significance of effective governance, which encompasses measures to combat corruption and the advancement of democratic principles, in several facets of economic progress. According to their research, implementing effective governance practices substantially reduces carbon dioxide emissions, attracts foreign direct investment (FDI), and enhances economic development. In their study, Kesar and Jena (2022) investigated the correlation between political stability, corruption, and economic development in BRICS nations. The researchers discovered a significant correlation between political stability and economic growth, highlighting the crucial role of political stability in promoting economic development. With respect to corruption, they saw a somewhat U-

shaped phenomenon, wherein corruption first boosts economic development in certain periods but then weakens its influence in other periods. According to Olaniyan et al. (2022), enhancing governance institutions is essential for enhancing the flow of development remittances in ECOWAS nations. By improving governance structures, such as transparency, accountability, and rule of law, these nations may promote the effective movement and usage of remittance payments, thereby fostering economic growth. These studies highlight the significance of effective governance, anti-corruption measures, political stability, and enhanced institutions in fostering economic development. The text emphasizes the beneficial effects of managing corruption, implementing good governance practices, and maintaining political stability on economic progress. It underscores the need to implement effective governance changes and establish institutions that promote sustainable growth and attract investment.

Furthermore, several academics contend that the correlation between governance and economic development is contingent upon each nation's unique economic and social aspects. Fawaz et al. (2021) examined a group of 11 developing nations between 1996 and 2008 in their research. These countries were classified according to their income level, either high or low. By using the fixed effects technique, they established that in low-income nations, voice and responsibility impede economic advancement in contrast to high-income ones. A plausible reason may lie in the diminished trust of the media, regardless of its freedom, inside these nations. The report also emphasized the substantial influence of the rule of law and corruption control on economic growth. Oanh et al. (2021) used quantile regression techniques to investigate the impact of institutional quality on economic development in 48 Asian nations, with a specific focus on low-income countries. Their findings suggest that the quality of institutions has a significant influence on economic growth, which is consistent with the findings of Abdullahi et al. (2019), Fikadu et al. (2019), and Dickson et al. (2021) regarding the positive correlation between institutional quality and economic development in African nations. In addition, Helliwell (1992) examined the influence of democracy on economic development. The research found that democracy had either a negative or negligible influence on development in low-income nations. At the same time, high-income countries saw a favorable correlation between democracy and economic growth. These studies emphasize the significance of considering nations' contextual characteristics and socioeconomic levels when analyzing the correlation between governance and economic development. The results



indicate that the impact of governance on economic growth might differ depending on country-specific factors such as income levels, media credibility, and institutional quality.

3) METHODOLOGY

Since this study utilized panel data consisting of multiple countries (N) and multiple years (T), various panel data techniques such as pooled model, fixed effects (FE), random effects (RE), and fixed-effects least squares (FM-OLS) are available. The FM-OLS method produces reliable estimates, especially for small sample sizes. Different econometric techniques have been introduced to investigate long-term relationships between variables, and FM-OLS is one of the most prominent methods. This method is commonly used for panel data. The FM-OLS method has the following properties: 1) it is super consistent, 2) it is asymptotically unbiased, 3) it is asymptotically normally distributed, and 4) it

provides standardized residuals, enabling statistical inferences. In general, this method applies two corrections to the ordinary least squares (OLS) method, which are 1) the correction for heteroscedasticity and 2) the correction for contemporaneous correlation. Thus, this study will use this modeling technique to estimate the long-term coefficients.

Based on the theoretical foundations and previous studies, as well as considering the study by Mumuni & Mwimba (2023), the current research proposes a specified model to assess the impact of green energy consumption as follows:

$$\ln \text{GDP}_{it} = \alpha + \beta_1 \text{REC}_{it} + \beta_2 \text{GGI}_{it} + \beta_3 \text{CO2}_{it} + \beta_4 \text{FEC}_{it} + \beta_5 \text{GFCF}_{it} + \beta_6 \text{INFL}_{it} + \beta_7 \text{Trade}_{it} + \epsilon_{it} \quad (2)$$

Thus, the variables used in relation (1) are shown in table (1). Also, the source of each variable and the expected positive and negative effects are specified.

Table (1): Description of variables and data sources

Variable	Description	Source	Expected Sign(s)
GDP	Gross Domestic Product	World Development Indicators	/
REC	Renewable Energy Consumption (% of final energy consumed)	World Development Indicators	±
GGI	Good Governance Index	The Worldwide Governance Indicators (WGI)	+
CO2	Carbon dioxide emissions (metric tons per capita)	World Development Indicators	+/-
FEC	Fossil Fuel Energy Consumption (% of total energy consumed)	World Development Indicators	±
GFCF	Gross Fixed Capital Formation (% of GDP)	World Development Indicators	+
INFL	Inflation, Consumer Prices (annual %)	World Development Indicators	±
Trade	Trade (% of GDP)	World Development Indicators	+

Source: Research findings

As an explanation of the variables used in the corresponding modeling, the following points can be mentioned:

The Gross Domestic Product (GDP) is often used to quantify economic expansion. A rise in GDP is often linked to increased output levels, industrialization, and progress in productive areas. Nevertheless, this economic growth is sometimes accompanied by a rise in energy use, resulting in environmental contamination due to the release of carbon dioxide (CO2) from non-renewable energy sources (Borhan et al., 2012). Therefore, carbon dioxide (CO2) emissions and burning fossil fuels (FEC) are often used as substitute measures for non-renewable energy consumption. These

measures may have good and negative consequences since they can harm human health.

Conversely, renewable energy sources, such as solar, biomass, wind, geothermal, and hydropower, are essential for advancing environmental sustainability. These sources can potentially decrease CO2 emissions and other greenhouse gases, which are significant factors in global warming, rising sea levels, and other unfavorable climatic circumstances (Apergis & Payne, 2012; Riti et al., 2022). Therefore, the measurement of renewable energy consumption (REC) is often used as a gauge for green energy, and it is anticipated to have a negative correlation, suggesting a beneficial influence on environmental sustainability. To summarize, a larger



GDP is often linked to more economic activity and the use of non-renewable energy, but it may also give rise to environmental difficulties. CO₂ emissions and FEC serve as indicators of non-renewable energy usage, which may adversely impact human health. However, using renewable energy sources, represented by Renewable Energy Certificates (REC), is deemed essential to reduce CO₂ emissions and advance environmental sustainability.

Furthermore, the Good Governance Index (GGI) may have a substantial influence on the Gross Domestic Product (GDP) in addition to the aforementioned elements (Abdeltawab Mahran, 2023). It is expected that the GGI will have a beneficial impact on GDP, suggesting that improved governance practices may lead to increased economic growth. The research used many control variables to investigate this correlation, such as Gross Fixed Capital Formation (GFCF), inflation (INFL), and trade openness. The favorable effect of Gross Fixed Capital Formation and trade openness on economic growth is anticipated. Gross Fixed Capital Formation refers to the allocation of resources towards the acquisition of tangible assets, such as infrastructure

and equipment, which play a vital role in improving productivity and fostering economic growth. Conversely, trade openness allows nations to access global markets, promoting economic expansion by facilitating greater levels of both exports and imports. The effect of inflation on economic growth may be variable. Inflation may spur economic development by encouraging more spending and investment in expectation of future price increases. Nevertheless, elevated inflation may detrimentally impact economic expansion by decreasing the ability to buy goods and services and diminishing the trust of consumers and investors. The research explicitly examines the BRICS nations (Brazil, Russia, India, China, and South Africa) from 1990 to 2020, as shown in Figure 2. The research investigates the correlation between the Good Governance Index and GDP, considering other factors such as Gross Fixed Capital Formation, inflation, and trade openness. The statement acknowledges the possible beneficial influence of the Good Governance Index on economic development while also taking into account the potential impact of other variables on GDP within the context of the BRICS nations.

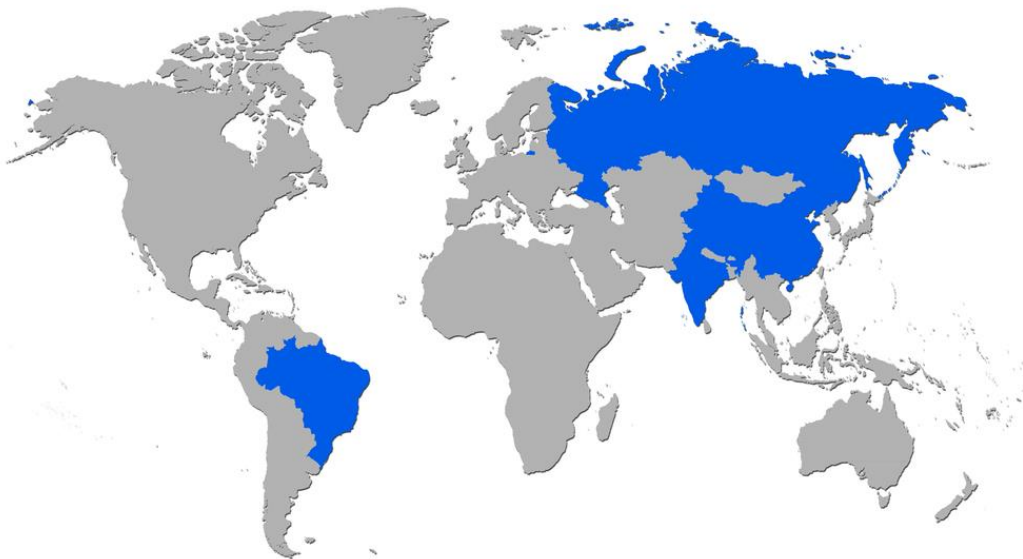


Figure (2): Study countries

The next section will focus on descriptive and inferential statistics. The present study aims to examine the research hypothesis based on the theoretical and empirical foundations mentioned: "Green energy consumption has a significant and positive impact on economic growth."

4) DATA ANALYSIS

In this section, the analysis of the research findings will be presented in two main parts: descriptive statistics and inferential statistics.

4.1) Descriptive Statistics



The descriptive statistics section provides a general overview of the variables used in the study. It includes summarizing and organizing the data in a meaningful

and comprehensible way. Descriptive statistics can calculate population parameters such as central tendencies, dispersion measures, etc.

Table (2): Descriptive statistics of research variables

	Trade	INFL	GFCF	FEC	CO2	GGI	REC	GDP
Average	44.696	5.777	25.556	77.608	5.703	-0.262	22.246	2.77E+12
Middle	46.810	5.103	21.369	86.575	6.687	-0.259	13.550	1.43E+12
maximum	65.974	15.78	44.518	92.142	11.88	0.388	50.050	1.59E+13
minimum	22.105	-0.731	13.091	51.318	0.897	-0.787	3.180	2.36E+11
Deviation from the norm	1.139	0.347	0.966	1.728	0.387	0.034	1.731	2.58E+11
Number of observations	100	100	100	65	95	100	95	100

Source: Research findings

Based on the information provided in Table (2), the mean of all variables is higher than the standard deviation. This indicates limited dispersion and limited variations in the variables. Considering the high number of countries and the number of years studied, the presentation of individual graphs for each variable has been avoided. Instead, only a summary of the descriptive statistics for each variable is provided.

However, to obtain a valid estimate of the relationships among the variables in the model, the variables included in the regression should be stationary, or a combination of them should be stationary. If the data used in a study are non-stationary, the results of the estimations will lead us to a spurious regression. The Engle-Granger (2002) test has been employed to examine the stationarity of the research variables, and the corresponding results are reported in Table (3).

4.2) Inferential Statistics

Table (3): Unit root test

Variables	t-Test	probability value	degree of stationary
GDP	-2.801	0.0025	(0)
REC	-1.919	0.0275	(0)
GGI	-3.707	0.0027	(0)
CO2	-1.747	0.0403	(0)
FEC	-1.973	0.0242	(0)
GFCF	-2.528	0.0057	(0)
INFL	-2.479	0.006	(0)
Trade	-4.123	0.0000	(0)

Source: Research findings

According to Table (4), the results of the F-test confirm that the panel regression method should be used instead of the pooled regression method. This is

because the p-value is smaller than the critical value (0.05), indicating that the null hypothesis (pooled regression) is rejected.

Table (4): The estimation results of Limer's F test for the group of innovation-oriented countries

Test statistics	The value of the statistic	Probability value
The value of the F statistic	101.052	0.000



Test statistics	The value of the statistic	Probability value
The value of the chi-square statistic	136.805	0.000

Source: Research findings

If the F-test results confirm the panel model's suitability, then the Hausman test is conducted. The Hausman test examines whether the equation should be estimated with fixed or random effects. The results of this test support the model with fixed effects because the p-value is smaller than the critical value (0.05), indicating that the null hypothesis (random effects) is rejected.

According to Table (8), one of the diagnostic tests is the test for normality of the disturbance terms. However, it should be noted that the panel quantile model is robust to the non-normality of the disturbance terms. The results of this test confirm the normality of the disturbance terms because the p-value is greater than the critical value (0.05). Therefore, the null hypothesis (normality of disturbance terms) is accepted.

Table (5): The results of the normality test of the disturbance component

Description	Value
Jarek-bra statistics	1.159
Probability value	0.560

Source: Research findings

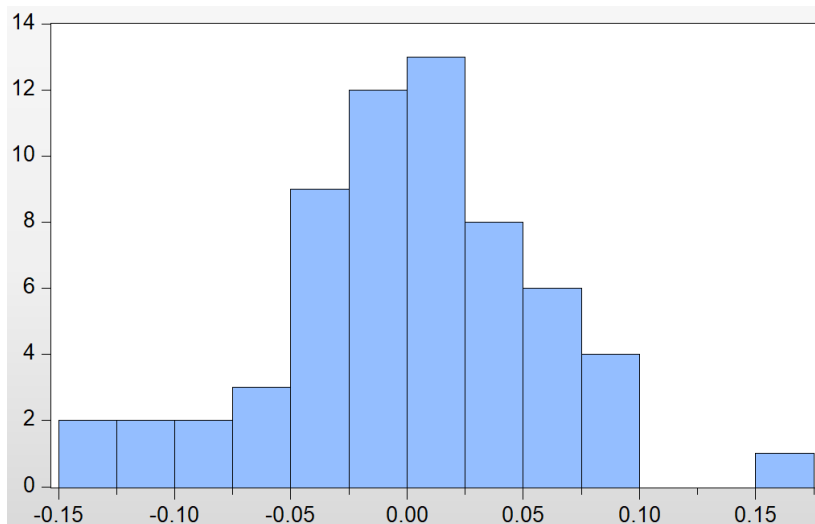


Figure 3. Showing the results of the normality test of the disturbance component

Source: Research findings

Another diagnostic test is the test for cross-sectional correlation of the disturbance terms. The results of this test indicate the presence of cross-sectional correlation because the p-value is smaller than the critical value (0.05). Thus, the null hypothesis (no cross-sectional

correlation) is rejected. Notably, a lagged dependent variable has been included in the estimation process to address the issue of cross-sectional correlation in the modeling. The final results are presented in Table (6).

Table (6): Checking the correlation between the disturbance components

Description	Value
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Brosh Pagan test	14.476
Probability value	0.1524

Source: Research findings

The subsequent discussion will focus on the cointegration test. Cointegration is a technique used to estimate the long-term equilibrium coefficients of a pattern when the variables involved have unit roots and are non-stationary. While differencing may be used to create stationarity in time series variables, it may lead to the loss of significant information on the level of the

variables. Cointegration enables us to estimate the regression model without concerns about spuriousness arising from time series variables. The Johansen test is derived from the residual-based cointegration test and has similarities with the Engle-Granger cointegration test for time series data. The Johansen cointegration test has been used in this investigation. The acquired findings are shown in Table 7.

Table (7): Checking the correlation between the disturbance components

Description	Value	probability level
ADF test statistic	-2.384	0.0085

Source: Research findings

Based on the results in Table (7) and considering the ADF statistic, which is less than 5%, it can be concluded that there are long-term relationships among the

variables in the model. With the identification of long-term relationships, the FM-OLS econometric model will be used for estimation.

Table (8): Model estimation results by FM-OLS method

Variable	Coefficient	T statistic value	probability level
LREC	0.480	2.187	0.041*
GGI	1.991	5.240	0.000*
LCO2	0.639	2.322	0.031*
LFEC	0.018	2.106	0.074**
LGFCF	0.141	2.867	0.035*
LINFL	-0.205	-1.867	0.077**
LTrade	0.678	3.240	0.004*
		R-squared	0.891
		Adjusted R-squared	0.759

Source: Research findings

* Significance at the 5% level. ** Significance at the 10% level.

Based on the results obtained from Table (8), it can be inferred that all the coefficients obtained in the long run are statistically significant at the 5% and 10% levels. Therefore, the interpretation of the results would be as follows:

Green energy consumption (LREC) positively and significantly impacts economic growth. A 1% change in green energy consumption leads to a 0.480% increase

in economic growth. Good governance (GGI) also positively and significantly impacts economic growth. A one-unit increase in good governance results in a 1.991-unit increase in economic growth. Furthermore, the interpretation of the results for other control variables in the current study is as follows: With a 1% increase in carbon dioxide emissions (LCO2), fossil fuel energy consumption (LFEC), gross fixed capital formation



(LGFCF), inflation (LINFL), and trade openness (LTrade), economic growth will increase by 0.639%, 0.018%, 0.141%, while it will decrease by 0.205% and increase by 0.678%, respectively. It is worth mentioning that the obtained results are consistent with the theoretical and empirical foundations discussed in studies such as Apergis and Payne (2012), Ivanovski et al. (2021), and Beyene (2022).

5) DISCUSSION

The results suggest that the use of renewable energy has a favorable and enduring effect on the economic expansion of BRICS nations. The favorable impact is ascribed to the substantial decrease in greenhouse gas emissions associated with the use of renewable energy sources. Renewable energy usage helps alleviate climate change and its negative impacts by minimizing the emission of greenhouse gases into the environment. These findings are consistent with prior research done in various geographical areas. Pearson (2021), Qudrat-Ullah and Nevo (2021), and Riti et al. (2022) have independently observed a favorable and enduring correlation between the utilization of renewable energy and the advancement of economies in distinct settings, namely Croatia, Africa, and South Africa, correspondingly. Furthermore, these studies highlight the capacity of renewable energy sources to stimulate economic development while simultaneously advancing environmental sustainability. In summary, the results indicate that encouraging and allocating resources to the use of renewable energy may have a beneficial and enduring effect on the economic development of BRICS nations. This aligns with the findings of other studies undertaken in different areas.

The research findings suggest that the quality of governance, as shown by the efficacy of governance institutions within societies, has a substantial and favorable influence on long-term economic development. The results align with prior research undertaken by Beyene (2022), Orji et al. (2022), Hamid et al. (2022), and Kesar and Jena (2022), who all affirm the importance of good governance in fostering economic development. Furthermore, the analysis reveals that carbon dioxide (CO₂) emissions substantially and favorably impact the economic development of BRICS nations. This outcome is anticipated since augmented production and economic activity often coincide with elevated greenhouse gas emissions. Considering that a significant proportion of energy resources in BRICS nations is obtained from non-renewable sources, it is logical to acknowledge this correlation. Aydoğan and Vardar (2020) contend that while fossil fuels, such as coal and natural gas, might foster economic expansion, they also have grave environmental ramifications. Therefore, it is essential

to minimize their use for the general ecological health of the globe. Moreover, the research demonstrates that the burning of fossil fuels (FEC) has a substantial and meaningful long-term effect on the economic development of BRICS nations. This discovery aligns with prior research was undertaken by Borhan et al. (2012), Chen & Huang (2013), Ivanovski et al. (2021), and Sannasee (2015), which have repeatedly shown a direct correlation between the use of fossil fuels and the advancement of the economy. To summarize, the research highlights the significance of effective governance institutions in promoting sustained economic development. Furthermore, it emphasizes the beneficial influence of CO₂ emissions and the burning of fossil fuels for economic development within the framework of BRICS nations. These results are consistent with prior research that substantiates the impact of effective governance and fossil fuel usage on economic growth.

6) CONCLUSION

This research investigated the influence of green energy consumption and governance quality on the economic development of BRICS nations. The study results suggest that all the factors examined, such as green energy consumption, governance index, carbon dioxide emissions, fossil fuel consumption, net fixed capital creation, and trade openness, have substantial and favorable impacts on economic development. These findings validate the significance of including green energy consumption, diminishing dependence on fossil fuels, enhancing governance quality, lowering greenhouse gas emissions, encouraging net fixed capital creation, and fostering trade openness as critical determinants in the economic success of BRICS nations.

In addition, This research investigated the influence of green energy consumption and governance quality on the economic development of BRICS nations. The study results suggest that all the factors examined, such as green energy consumption, governance index, carbon dioxide emissions, fossil fuel consumption, net fixed capital creation, and trade openness, have substantial and favorable impacts on economic development. These findings validate the significance of including green energy consumption, diminishing dependence on fossil fuels, enhancing governance quality, decreasing greenhouse gas emissions, encouraging net fixed capital creation, and fostering trade openness as essential determinants of the economic development of BRICS nations. The research indicates a significant and favorable correlation between the use of green energy, the factors under investigation, and the economic development in BRICS nations. The statement underscores the need to enhance governance quality and tackle environmental concerns



to attain sustainable economic development in these nations. The research results suggest that BRICS nations should prioritize green development, enact policies to decrease greenhouse gas emissions, increase the exploitation of clean energy resources, and improve governance quality. These actions are considered essential economic and political goals. The study has significant scholarly merit as a result of its thorough analysis, rigorous analytical techniques, and investigation of several factors. The findings have significant value for companies, politicians, and academics in the field of sustainable development and the green economy. These results may provide valuable insights for decision-making processes and facilitate the implementation of impactful policies. In summary, this research enhances our comprehension of the correlation between green energy consumption, governance quality, and economic growth within the BRICS nations. It offers valuable insights and suggestions for attaining sustainable economic development.

According to the results and substance of the paper, the following policy proposals might be highlighted and regarded as significant for BRICS countries:

1. Establishment of enabling policies: BRICS countries should devise and execute policies that provide incentives for adopting green energy and using renewable resources. This includes providing financial resources, tax benefits, and adequate infrastructure for developing businesses associated with renewable energy.
2. Enhancing governance: It is crucial to bolster governance and enhance transparency in the process of formulating and executing policies related to green energy. Governments need to build robust and autonomous monitoring systems while also strengthening transparency and accountability measures.
3. Infrastructure development: Allocating funds towards the essential infrastructure required for generating and distributing green energy promotes employment prospects and fosters the growth of associated businesses. Hence, governments must provide utmost importance to the advancement of essential infrastructure and allocate suitable funds.
4. International cooperation: Promoting collaboration and sharing experiences with other nations and global organizations in the field of green energy and sustainable development may bolster technical expertise and better policies and strategies. Education and awareness initiatives promote the consumption of green energy and sustainable development by informing and educating the public about the advantages of using green energy and associated technologies in society. Hence, it is essential to establish instructional and awareness initiatives within schools,

- institutions, and communities.
6. Effective resource allocation: The practical and optimum allocation of financial, human, and natural resources, especially energy resources, is crucial for attaining sustainable development and economic progress. Governments must develop appropriate plans and policies to enhance resource management and prioritize execution.

These policy ideas may function as solutions to influence economic development in BRICS nations by promoting green energy consumption and enhancing governance. Nevertheless, it is essential to consider each nation's unique situations and circumstances and establish suitable priorities accordingly.

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