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The relationship between access to electricity, CO_2 emissions, and economic growth in BRICS

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Abstract. *This study examines the relationship between Access to Electricity, CO_2 Emission, and Economic Growth in BRICS. This study uses secondary data sourced from the World Bank with the period 2000 to 2021. The analysis technique in this study uses panel data regression and graanger causality. The conclusion of this study confirms that increased access to electricity has a significant impact on economic growth in BRICS countries. Strong investment in energy infrastructure, including efforts to expand access to electricity, has proven to encourage sectors of the economy that rely on reliable energy.*

Keywords: access to electricity, CO_2 emission, economic growth, BRICS.

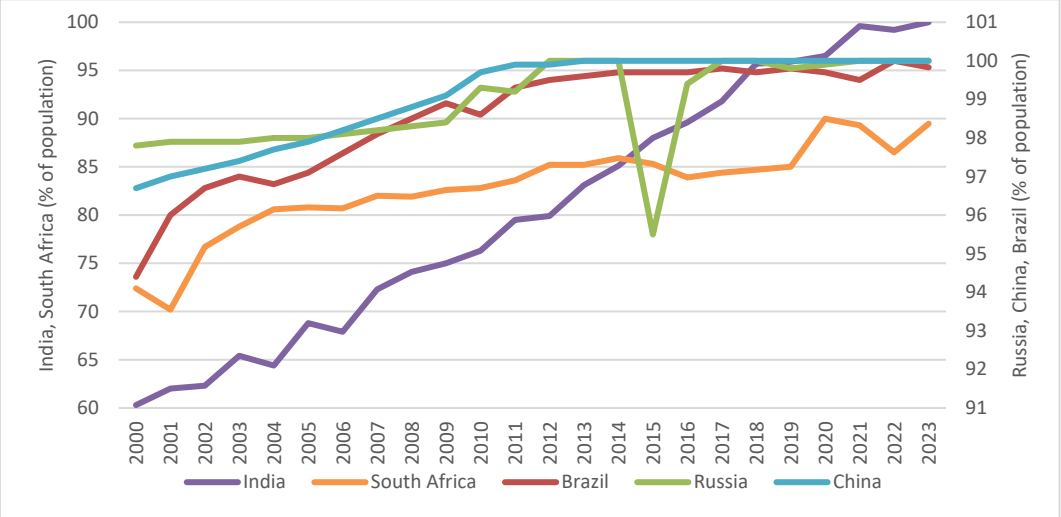
JEL Classification: O44, Q53.

1. Introduction

The BRICS, which consists of Brazil, Russia, India, China, and South Africa, is a group of countries with significant economic influence in the world (Lumumba-Kasongo, 2015). Since its inception, BRICS has been the center of attention in many economic, environmental, and energy-related research. These countries have an important role in the global economy, not only because of their large populations but also because of their rapid economic growth and abundant natural resources (Danish et al., 2019). One of the important aspects of economic development is access to electricity, which is the foundation for the development of industry, education, health, and daily life (Burke et al., 2018). On the other hand, increased economic activity is often accompanied by an increase in CO_2 emissions, which has an impact on global climate change.

Access to electricity is an important indicator of a country's infrastructure development and quality of life (Ahlborg et al., 2015). In BRICS countries, increased access to electricity has become a priority to support economic development and improve the quality of life (Gu et al., 2018), reflected in Figure 1. Adequate access to electricity allows for increased industrial productivity, increased efficiency in the agricultural sector, and expanded access to education and health services (Riva et al., 2018). However, the supply of electricity is often linked to the burning of fossil fuels that produce CO_2 emissions (Shahsavari & Akbari, 2018). CO_2 emissions are a major concern because of their contribution to global warming and climate change.

Figure 1. *Access to Electricity in BRICS*



Source: World Bank, data processed, (2024)

Sustainable economic growth in BRICS countries is the main focus in achieving various Sustainable Development Goals (SDGs) (Ali et al., 2018). The SDGs emphasize the importance of inclusive and sustainable economic growth, which supports the creation of decent jobs (SDG 8), reduces economic inequality (SDG 10), and improves access to basic services such as education and health (SDG 3). However, rapid economic growth is often

accompanied by environmental challenges, especially greenhouse gas emissions such as CO_2 (Liu et al., 2019). An uncontrolled increase in CO_2 emissions can lead to negative impacts on the environment, such as rising global temperatures, changing weather patterns, and an increase in the incidence of natural disasters (Rajak, 2021). Therefore, understanding the relationship between access to electricity, CO_2 emissions, and economic growth is crucial to formulating sustainable policies.

Research on the relationship between access to electricity, CO_2 emissions, and economic growth in the BRICS has very important relevance in today's global context. First of all, access to electricity plays a crucial role in economic and social development, affecting people's productivity, health, and education. However, this increased access often impacts CO_2 emissions, which are a major contributor to global climate change and environmental balance. This study not only explores the causal dynamics between these variables through the panel data regression method, but also uses the Granger causality approach to understand the direction and strength of the relationship between them empirically. The contribution of this research lies in developing a theoretical and empirical understanding of how energy and economic policies can be designed to achieve sustainable economic growth while reducing negative environmental impacts. The results of this study are expected to provide guidance for policymakers in formulating sustainable development strategies in BRICS countries and around the world.

2. Data and Methods

This study examines the influence and causality relationship between access to elecricity, CO_2 emissions, and economic growth, the operational definition of the variable is described in Table 1. This study uses BRICS, namely Brazil, Russia, India, China, and South Africa as the research population. This study uses a type of secondary data taken from the World Bank with the period 2000 to 2023. The analysis technique in this study uses the panel regression described in equation 1.

$$EG_{it} = \beta_0 + \beta_1 ATE_{it} + \beta_2 CO2_{it} + \varepsilon_{it} \quad (1)$$

GDP is the real GDP per capita for economic growth; CO_2 emissions measured by CO_2 emissions (metric tons per capita); ATE is access to electricity; i is cross section; t is the time series; and e is the error term.

This study uses a panel data regression method, considering three different approaches: the Common Effects Model (CEM), the Fixed Effects Model (FEM), and the Random Effects Model (REM). Next, to choose the best method between the three using the chow, hausman, and lagrange multiplier tests.

Table 1. *Variable Operational Definition*

Variable	Description	Source
Economic Growth	GDP per capita, PPP (current international $)	World Bank
Access to electricity	Access to electricity (% of population)	World Bank
CO_2	CO_2 emissions (metric tons per capita)	World Bank

Source: Author Compilation, (2024)

The analysis technique in this study also used Pairwise Dumitrescu Hurlin Panel Causality Tests type granger causality panels. The model of the granger causality equation is described as follows:

$$\Delta EG_{it} = \beta 1 + \beta 2_{it} + \delta ATE_{it} - 1 + \sum_{i=1}^{m} \alpha i \Delta CO2_{it} - 1 + \varepsilon_{it} \quad (2)$$

$$\Delta ATE_{it} = \beta 1 + \beta 2_{it} + \delta EG_{it} - 1 + \sum_{i=1}^{m} \alpha i \Delta CO2_{it} - 1 + \varepsilon_{it} \quad (3)$$

$$\Delta CO2_{it} = \beta 1 + \beta 2_{it} + \delta EG_{it} - 1 + \sum_{i=1}^{m} \alpha i \Delta ATE_{it} - 1 + \varepsilon_{it} \quad (4)$$

Equation (2) tests whether changes in access to electricity (ATE) and changes in CO_2 (CO_2) emissions affect economic growth (EG). Equation (3) tests whether changes in economic growth (EG) and changes in CO_2 (CO_2) emissions affect access to electricity (ATE). Equation (4) tests whether changes in economic growth (EG) and changes in access to electricity (ATE) affect CO_2 (CO_2) emissions. Overall, the Granger causality model aims to identify whether changes in one variable can be used to predict changes in other variables by taking into account time lag. It is important to understand the causal dynamics between access to electricity, CO_2 emissions, and economic growth in BRICS countries.

3. Results and Discussion

3.1. Model Selection

Table 2 shows the results of the best model selection test using the Chow Test and the Hausman Test. In the Chow Test, a probability value of 0.000 indicates that the Fixed Effect (FEM) model is better compared to the Pooled OLS model, with a significant result at a significance level of 1%. Similarly, in the Hausman Test, a probability value of 0.000 indicates that the Fixed Effect (FEM) model is more suitable compared to the Random Effect (REM) model, with a result that is also significant at a significance level of 1%. Therefore, these two tests consistently indicate that the Fixed Effect model is the best choice for this data analysis.

Table 2. *Best Model Selection Test*

Test	Prob	Selected Methods
Chow Test	0.000	Fixed Effect Model
Hausman Test	0.000	Fixed Effect Model

Source: Author Calculation, (2024)

Table 3 shows the regression results of panel data with dependent variables of economic growth plotted by GDP per capita, as well as independent variables of CO_2 emissions and access to electricity (ATE). Constant (C) has a coefficient of 5.003619 and is significant at a significance level of 1%, indicating that the base value of GDP per capita is 5.003619 when the other independent variables are zero. CO_2 emissions (CO_2) have a coefficient of 0.309066 and are significant at a significance level of 1%, indicating that every increase in CO_2 emissions will increase GDP per capita by 0.309066 units, ceteris paribus. Access to electricity (ATE) has a coefficient of 0.027198 and is also significant at a significance level of 1%, suggesting that every increase in access to electricity will increase GDP per capita by 0.027198 units, ceteris paribus. Overall, the results of this regression show that both

CO_2 emissions and access to electricity have a positive and significant effect on economic growth as measured by GDP per capita.

Table 3. *Panel Data Regression Results*

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.003619	0.319956	15.63845	0.0000
CO_2	0.309066	0.024264	12.73766	0.0000
ATE	0.027198	0.003595	7.565455	0.0000
C	5.003619	0.319956	15.63845	0.0000
Cross Section Effect				
_Brazil	1.194258			
_Russia	-1.291271			
_India	0.779205			
_China	-0.467071			
_South Africa	-0.215121			
R-squared	0.878589	Mean dependent var		9.268153
Adjusted R-squared	0.872143	S.D. dependent var		0.665019
S.E. of regression	0.237792	Akaike info criterion		0.021720
Sum squared resid	6.389574	Schwarz criterion		0.184323
Log likelihood	5.696827	Hannan-Quinn criter.		0.087754
F-statistic	136.2874	Durbin-Watson stat		0.128434
Prob(F-statistic)	0.000000			

Source: Author Calculation, (2024)

The regression results show an R-squared value of 0.878589, which means that 87.86% of the variation in GDP per capita can be explained by this model. An adjusted R-squared of 0.872143 indicates a good adjustment for the number of independent variables in the model. The standard error of regression (S.E. of regression) of 0.237792 indicates the accuracy of the model's prediction. An F-statistic of 136.2874 with a probability of 0.000000 indicates that the model as a whole is significant at a significance level of 1%.

The regression results with the Fixed Effect (FEM) model provide insight into the unique variation between the BRICS countries (Brazil, Russia, India, China, and South Africa) in their contribution to GDP per capita, after taking into account independent variables such as CO_2 emissions and access to electricity. The cross-section effect in this model shows specific values for each country, reflecting different structural characteristics and economic conditions. Brazil has a positive cross-country effect of 1.194258, which suggests that specific factors in Brazil make a significant positive contribution to GDP per capita, beyond the influence of independent variables. In contrast, Russia showed a negative cross-country effect of -1.291271, indicating that specific factors in Russia have a negative impact on GDP per capita. India, with a cross-country effect of 0.779205, showed a positive contribution of its unique factors, while China, with a cross-country effect of -0.467071, and South Africa, with -0.215121, showed the negative impact of their specific factors on GDP per capita.

3.2. Granger Causality Results

In the causality analysis using the homogeneity test, the findings showed a significant pattern of relationships between the variables in the model. In particular, the results show a strong two-way causal relationship between CO_2 emissions and GDP (Table 4). A significant probability indicates that changes in CO_2 emissions may affect changes in GDP,

and conversely, changes in GDP also affect CO_2 emissions. These findings are consistent with the literature highlighting the reciprocal relationship between economic growth and emission levels in a global context.

Table 4. *Granger Causality Results*

Null Hypothesis:	W-Stat.	zbar-stat.	Prob.
CO_2 does not homogeneously cause GDP	4.81962	2.20235	0.0276
GDP does not homogeneously cause CO_2	6.11509	3.31992	0.0009
ATE does not homogeneously cause GDP	5.12368	2.46466	0.0137
GDP does not homogeneously cause ATE	3.79925	1.32211	0.1861
ATE does not homogeneously cause CO_2	2.23685	-0.02572	0.9795
CO_2 does not homogeneously cause ATE	2.71113	0.38343	0.7014

Source: Author Calculation, (2024)

Furthermore, there is strong evidence for a one-way causal relationship of access to electricity (ATE) to GDP, with a probability of 0.0137 suggesting that increased access to electricity contributes positively to economic growth as measured by GDP. However, there is no evidence to suggest that economic growth significantly affects the level of access to electricity in this model (probability 0.1861).

However, in the relationship between access to electricity (ATE) and CO_2 emissions, as well as between CO_2 and ATE emissions, the findings suggest that there is no significant causal relationship. The high probability suggests that changes in access to electricity or CO_2 emission levels do not significantly affect each other within the framework of the tested model.

3.3. Discussion

The results of the analysis show that increased access to electricity (ATE) has a significant positive impact on economic growth, an important finding in the context of BRICS countries. The study supports previous findings suggesting that a strong energy infrastructure, including better access to electricity, can be a key driver for sustainable economic development (Bhattacharya et al., 2015); (Burke et al., 2018). Researchers have identified that among BRICS countries, there is variation in the level of access to electricity and its impact on their respective national economies. India and South Africa face greater challenges in improving access to electricity in rural or remote areas, affecting their potential to achieve more inclusive economic growth (Singh et al., 2015); (Almeshqab & Ustun, 2019). On the other hand, China has shown a strong commitment to energy infrastructure, including programs to expand access to electricity at large, which has contributed significantly to their economic growth in recent decades (Geng et al., 2016).

The importance of access to electricity is not only limited to increasing the productivity and competitiveness of industrial and service sectors, but also in creating conditions that support investment in technological and infrastructure innovation (Osano & Koine, 2015). At an increasingly connected global level, the ability to address inequalities in access to electricity between urban and rural areas, as well as between BRICS member countries, will be key to ensuring sustainable and inclusive economic growth in the future. Therefore, public policies that prioritize investment in energy infrastructure, including renewable

energy sources and energy efficiency, will play an important role in shaping the economic future of the BRICS countries and maintaining their global competitiveness.

In this analysis, the results show that increased CO_2 emissions have a significant impact on economic growth, an interesting finding to consider in the context of global economic development. In some countries, especially in the early stages of their economic development, increases in CO_2 emissions often occur in tandem with the growth of the industrial and infrastructure sectors, which in turn can provide an initial impetus for broader economic growth (Sarkodie et al., 2020). For example, in the industrialization phase, countries could experience a spike in CO_2 emissions as a result of energy-intensive manufacturing activities, which could ultimately contribute to GDP growth and job creation (Avenyo & Tregenna, 2022).

BRICS countries are major producers of global CO_2 emissions due to energy-intensive industrial activities and rapid infrastructure growth (Baloch et al., 2020). China, as the largest member of the BRICS in terms of population and economy, has experienced a significant spike in CO_2 emissions over the past few decades in line with its rapid economic growth (Fu et al., 2021). Increased CO_2 emissions in cases such as China and India are often closely linked to the growth of industries that utilize fossil resources to meet their energy and infrastructure needs. While this can provide an initial boost to economic growth through job creation, infrastructure development, and industrialization, its long-term impact can be a serious challenge. Climate change induced by CO_2 emissions can threaten environmental and social sustainability, affecting sectors such as agriculture, health, and critical infrastructure (Kumar et al., 2021).

The results of causality analysis show that in the context of BRICS countries, there is a complex pattern of relationships between CO_2 emissions, access to electricity (ATE), and economic growth (GDP). The findings show a strong two-way causal relationship between CO_2 emissions and GDP, confirming that an increase in CO_2 emissions can affect economic growth, and conversely, economic growth can also affect CO_2 emission levels over a period of time. Previous research such as that conducted by (Wang et al., 2016); (Mardani et al., 2019) has shown that rapid economic growth is often associated with increased CO_2 emissions, indicating a two-way relationship between these two variables at the global level.

In addition, there is a significant one-way causal relationship of ATE to GDP. These findings show that increased access to electricity contributes positively to economic growth in BRICS countries. Although the level of access to electricity still varies among these countries, efforts to improve its accessibility have proven to have a positive impact on the development of economic sectors that rely on reliable energy infrastructure. Research by (Javid et al., 2021) shows that increasing access to electrical energy in developing countries can improve people's productivity and quality of life, which directly supports inclusive economic growth.

However, the results of the analysis also showed that there was no significant causal relationship between CO_2 emissions and access to electricity in the BRICS countries. Although the link between CO_2 emissions and access to electricity has not been shown to

be causal significant in the context of BRICS, this study highlights the importance of reliable energy infrastructure in supporting sustainable economic growth. This is in line with environmental economics theory which emphasizes the importance of sustainability in the use of resources and energy policies to reduce the negative environmental impact of economic growth (Stern, 2019).

4. Conclusion

The study reveals that in the context of BRICS countries, increased access to electricity has a significant positive impact on economic growth. These findings suggest that investment in adequate energy infrastructure, including efforts to improve electricity accessibility, can spur sectors of the economy that rely on reliable energy. While there are still challenges in addressing unequal access to electricity in rural or remote areas, China has shown that its commitment to energy infrastructure can have a significant positive impact on its economic growth. The implication of this study is the need for public policies that focus more on the development of sustainable energy infrastructure, taking into account the variety of unique needs and challenges faced by each BRICS country.

To support inclusive and sustainable economic growth in the future, BRICS countries need to increase investment in renewable energy and energy efficiency. These measures will not only help reduce the negative impact on the environment, but also strengthen their economic competitiveness at the global level. Additionally, it is important to continue to conduct research and development in innovative energy technologies, which can help address energy infrastructure challenges and improve electricity accessibility at large. Thus, BRICS can play a more active role in achieving sustainable development goals globally, while maintaining a balance between dynamic economic growth and sustainable environmental protection.

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