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The Effect of Renewable Energy Consumption, Carbon Dioxide Emissions, and Globalization on Economic Growth in BRICS Countries

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A B S T R A C T

This study aims to investigate the impact of renewable energy consumption, carbon dioxide emissions, and globalization on economic growth in BRICS countries (Brazil, Russia, India, China, and South Africa). The data used are gross domestic product, renewable energy consumption, carbon dioxide emissions, and the KOF globalization index from 1990 to 2022, obtained from the World Bank, the Energy Institute, the European Commission, and ETH Zurich. The data were analyzed using multiple regression of panel data with a fixed-effect model. The results of the study show that renewable energy consumption, carbon dioxide emissions, and globalization simultaneously have an effect on GDP. Partially, renewable energy consumption and globalization have a significant positive effect on GDP, while carbon dioxide emissions have a significant negative effect on GDP in BRICS countries.

INTRODUCTION

The BRICS countries are currently in the spotlight due to their significant role as a driving force in the world economy, especially during the post-crisis period. According to data from the World Bank, this group of countries represents 41 percent of the world's population and accounts for 26 percent of the total Gross Domestic Product (GDP) globally in 2022. This makes them an economic force that cannot be ignored in the dynamics of the global economy (World Bank, 2024). The economic development of the BRICS countries over the past three decades cannot be separated from their dependence on fossil energy, both as a major source of domestic energy and as a strategic export commodity.

The dependence of BRICS countries on fossil energy faces major challenges in achieving the global development goals listed in the 2030 Agenda, especially in terms of environmental sustainability and carbon emission reduction. As part of a global commitment to the Sustainable Development Goals (SDGs) and the Paris Agreement, BRICS countries are faced with the need to transition their economies towards a more inclusive and environmentally friendly model (UNEP, 2023). As part of energy transition efforts, data shows that BRICS countries have experienced a significant increase in renewable energy consumption. According to the Energy Institute, BRICS countries in 2022 contributed as much as 45 percent of the total renewable energy consumption in the world. In fact, three of the five BRICS countries rank in the top 5 in the world in the use of renewable energy. China stands out as the most renewable country in the world (Energy Institute, 2024).

In line with this, the data shows a downward trend in the intensity of carbon dioxide emissions per gross domestic product, which means that BRICS countries are increasingly able to generate greater economic output value with lower carbon dioxide emissions. However, the rate and speed vary, depending on their economic structure and energy source. Brazil and India show a pattern of low emissions with a gradual and consistent decline, while China shows a major improvement in its economy due to its sharp decline from 1.29 in 1990 to 0.31 in 2022 reflecting a large energy transition. Russia experienced a sharp decline in the early 1990s due to its economic crisis until 2015, then tended to stagnate again showing limitations in improving carbon efficiency, while South Africa experienced a relatively slow decline. Even so, carbon dioxide emissions in these BRICS countries are still quite high globally (IEA-EDGAR, 2024).

BRICS countries, as a considerable contributor to world emissions and are vulnerable to experiencing large economic losses due to the impact of climate change. The damage that occurred included disruptions to the agricultural sector, increased disaster management costs, and decreased economic productivity, which cumulatively hampered economic growth in the region. Without real action, economic losses due to climate change have the potential to increase, which not only harms BRICS countries individually, but also threatens overall global economic stability and growth (Tian et al., 2020).

Global economic growth is not spared from the phenomenon of globalization that has driven economic growth through interaction and integration between countries in the economic, cultural, political, and

technological fields over the past few decades through trade liberalization, cross-border investment, and global supply chain integration which also faces challenges (June *et al.*, 2021). Globalization provides opportunities as well as challenges for BRICS countries in developing their economies. Through increased trade, foreign investment, and market integration, BRICS countries play an important role in the global economy by encouraging industrialization, increasing export competitiveness, and attracting foreign capital. This is marked by economic integration between BRICS countries also continuing to strengthen, an increase in intra-BRICS trade which reached 422 billion US dollars in the last 5 years, a significant increase of 56 percent between 2017 and 2022 (BRICS, 2023).

However, the level of globalization between BRICS countries varies, in the KOF Globalization Index data, Russia has the highest globalization score among BRICS countries with a global ranking of 48 with a score of 70, followed by South Africa with a score of 69 (ranked 50), Brazil with a score of 65 (ranked 78), China with a score of 65 (ranked 79), and India with a score of 63 (ranked 87) (KOF Swiss Economic Institute, 2024). This data shows that the benefits of globalization, such as increased trade flows, investment, and technological collaboration, have not been evenly distributed among these countries even though in some sectors each country has a leading sector.

The complexity of the relationship in the above explanation has led to the emergence of various studies that examine the relationship between these variables. Various empirical studies have been conducted to analyze the relationship between renewable energy consumption, CO_2 emissions, and globalization to economic growth, with results that vary across different countries and different time periods. For example, research from Iqbal, Tang, and Rasool (2023), shows carbon dioxide emissions, renewable energy consumption, and globalization factors such as exports and FDI have a significant long-term positive impact on economic growth. However, other factors of globalization are *trade openness,* which shows a negative influence on economic growth in BRICS countries from 2000 to 2018.

Other research from Rahmandani and Dewi (2023), showing the results of the study with a sample of OIC member countries that the consumption of renewable energy in both low- and middle-income countries has a negative and significant effect on GDP. Meanwhile, CO_2 emissions from both low and middle-income countries in OIC member countries have a positive and significant effect on GDP. The factor of FDI globalization in this study has a negative and insignificant effect on GDP in low-income countries, while in the middle-income group of countries has a positive and significant effect on GDP in OIC member countries. In contrast to research by Syafika Putri and Hendry Cahyono (2022), obtained results in his research that CO_2 emissions have a negative and significant influence on economic growth. Meanwhile, globalization factors, such as FDI, international tourism, and import and export of goods and services, have a positive and significant influence on economic growth.

From the above background, several gaps are identified between actual and ideal conditions in the BRICS countries. First, even though it contributes as a contributor to 45 percent of the world's renewable energy consumption, in some

BRICS countries there are still countries whose adoption of renewable energy is still quite low, making there a gap in technological development and innovation in BRICS countries. Second, although carbon dioxide emissions per GDP of BRICS countries show a downward trend every year, the carbon dioxide emissions of BRICS countries worldwide are still quite high, as evidenced by the many reports related to environmental damage that arise in BRICS countries. Finally, the reality of the globalization process in the BRICS countries, such as international trade and investment patterns, is still dominated by fossil energy-intensive sectors that contribute to the increase in world carbon dioxide emissions.

The complexity of the relationship between these variables is further strengthened by the results of previous studies that show inconsistencies in findings related to the relationship between renewable energy consumption, CO_2 emissions, and globalization to economic growth. Therefore, based on these gaps, this study will further address **The Influence of Renewable Energy Consumption, Carbon Dioxide Emissions, and Globalization on Economic Growth in BRICS Countries** by using data for the period 1990-2022 to provide a more comprehensive understanding of the dynamics of the relationship between these variables.

LITERATURE REVIEW

Green Economy

Green economy is a term that has been around since 1989 by a group of environmental economists in the UK (Suryandari, 2024) which then in 2008, the term *green economy* promoted by the United Nations Environment Programme (UNEP) as part of a global effort to achieve sustainable development, as well as in response to the global economic crisis of 2008 and in response to concerns about environmental degradation and climate change that increasingly threaten (Söderholm, 2020).

Energy Transition Theory

Organizations such as the International Energy Agency (IEA), the United Nations Development Programme (UNDP), and the World Energy Council (WEC) introduced energy transition models to achieve sustainability and began using the concept of low-carbon energy. To date, the energy transition continues to evolve in line with technological advances, global policies, and the need to reduce the impact of climate change

Renewable energy consumption makes a positive contribution to economic growth in the perspective of these three theories supported by previous studies by Iqbal et al., (2023); Balsalobre-Lorente & Leitão (2020); Niyonzima et al., (2022); Ningtyas & Andriyani, (2024); Zhang et al., (2023); Lankala and So (2023); and Rahman & Velayutham, (2020) who said that renewable energy consumption has a positive and significant influence on economic growth because it helps reduce environmental impact, increase efficiency, and support long-term economic sustainability.

H1: Renewable Energy Consumption has a positive and significant influence on increasing Economic Growth.

Environmental Kuznets Curve* (EKC) *Theory

In the theory of EKC, At the level *Pre-Industrial Economics*, countries with low GDP depend on the agrarian sector and the exploitation of natural resources. As industrialization progressed, the use of fossil energy for mass production and urbanization increased carbon emissions, causing environmental degradation seen on the EKC curve with an upward slope (*upward slope*). After reaching *turning point*, the negative impacts of emissions such as pollution and health costs are starting to hinder economic growth, so environmental mitigation is a priority. At the stage *Post-Industrial Economics*, the focus shifted to green technology, renewable energy, and environmental regulation. Public awareness is increasing, accompanied by investment in environmentally friendly technology. As a result, carbon emissions and environmental degradation began to decline even as GDP continued to grow, reflected in the declining EKC curve (*down slope*) reflects the pattern of negative relationships between carbon emissions and economic growth at this stage (Muhammed et al., 2023).

These theories are supported by previous studies by Niyonzima et al. (2022); Putri & Cahyono (2022) Myszczyszyn & Supron (2021); and Kang et al. (2022). which obtained results in his research that carbon dioxide emissions have a negative effect on economic growth which will cause serious environmental consequences so that preventive measures are needed to maintain sustainable and safe economic growth from the impacts of climate change.

H2: Carbon Dioxide Emissions have a negative and significant influence on increasing Economic Growth.

World-System Theory

The Modern World System Theory is a theory that explains the dynamics of globalization, economic inequality, and uneven social development between countries in the world that analyzes how global capitalism works in the modern era which is divided into three groups of countries. Countries in the core category (*core)* depending on the peripheral/peripheral country (*periphery*) for raw materials, cheap labor, and markets for their products by building global institutions such as the UN, WTO, IMF, and the World Bank that accelerate economic integration. Meanwhile, semi-peripheral countries are the balancer and liaison in global trade. This relationship is only possible through openness and interconnectedness across world borders (Mulvey, 2021).

This theory is also supported by studies Iqbal et al., (2023); Balsalobre-Lorente & Leitão (2020); Viana Espinosa de Oliveira & Moutinho (2022); Putri & Cahyono, (2022); Ningtyas & Andriyani, (2024); Adebayo (2021); Zhang et al. (2023); Xu et al. (2021); and Azam & Abdullah (2021) Because it encourages technology exchange, market integration, and increased productivity and global competitiveness that accelerate growth, especially for countries that are able to take advantage of opportunities in the global environment.

H3: Globalization has a positive and significant influence on increasing Economic Growth.

Based on the theories from the explanation above, the following is the contextual framework in this study:

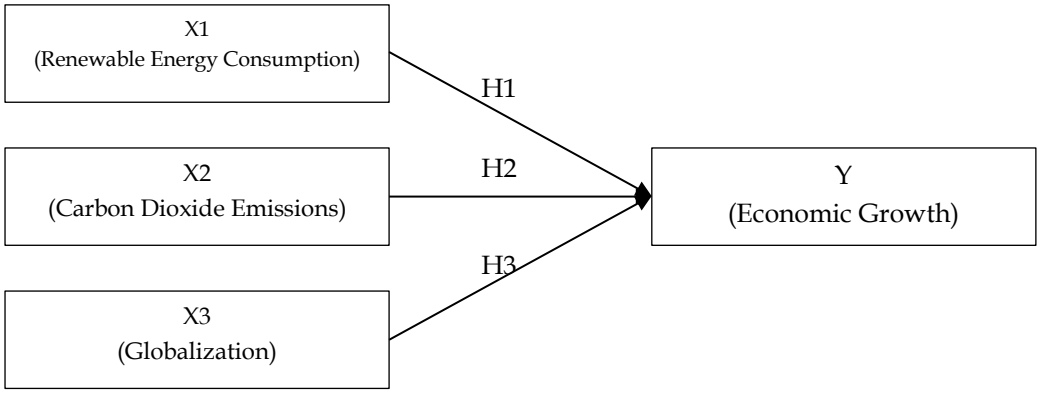

Figure 1. Conceptual Framework

METHODOLOGY

In this study, we use dependent variables of economic growth measured in real GDP USD, while there are three independent variables, namely renewable energy consumption (terawatt-hour), carbon dioxide emissions per GDP (tons per thousand USD), and globalization of the index from a score of 0-100 in 5 BRICS countries (Brazil, Russia, India, China, and South Africa). The data used is panel data that combines cross-section and time series with the period 1990-2022 obtained from the World Bank, Energy Institute, European Commission, and ETH Zurich Switzerland.

The data analysis technique used multiple regression analysis of panel data operated using E-Views. In this case, model testing is carried out to determine the right model to use between Common Effect, Fixed Effect, and Random Effect through Chow Test, Hausman Test, and Lagrange Multiplier Test. Furthermore, the classical assumption test is tested, including the normality test, the multicollinearity test, and the heteroscedasticity test. In addition, T-test, F-test, and determination coefficients are also carried out to determine the influence between independent variables and dependent variables partially and simultaneously.

The formulas used in this study include:

$$\boldsymbol{GDP_{it} = \alpha + \beta_1 REC_{it} + \beta_2 CO2_{it} + \beta_3 GLOB_{it} + \varepsilon_{it}}$$

Information:

GDP	: Gross Domestic Product
REC	: Renewable Energy Consumption
CO2	: Carbon Dioxide Emissions
X3	: Globalization Index
α	: Konstanta
β1,β2,β3	: Regression Coefficient
ε	: Error Terms
i	: Countries (Brazil, Russia, India, China, South Africa)
t	: Time (1990-2022)

RESEARCH RESULT

Determination of regression models

There are three tests in this estimation model, including *the Chow test, the Hausman test,* and the *Lagrange Multiplier test*. The following is a table of results from testing the regression estimation model in this study.

Table 1. Estimated Model Selection

Test	Probability	Result
Chow Test	0.0000	FEM
Hausman Test	0.0072	FEM
LM Test	-	-

Based on the results of the Chow Test using E-Views 12.0, in the *F cross-section* and *the chi-square cross-section* shows the number 0.0000 or < 0.05. Meanwhile, based on the results of the Hausman Test above, *the probability cross-section random* shows the number 0.0072 < 0.05. This means that the right model to use is the Fixed Effect Model (FEM), so the *Lagrange Multiplier* (LM) test does not need to be done because both tests show that the right model is FEM.

Classic Assumption Test

Normality Test

This normality test is carried out to check whether the distribution of distributed residual is normal or not. The following is a graph of the normality test results:

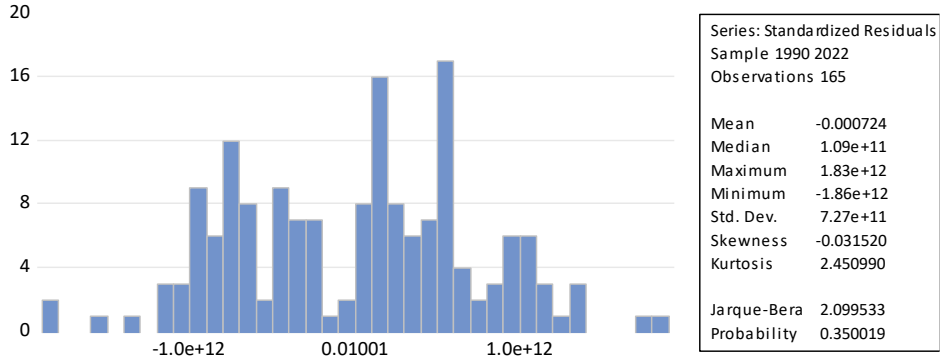

Figure 2. Normality Test

In the results of the normality test above, *the Jarque-Bera Probability* was calculated as 0.350019 > 0.05 so that it can be concluded that the data in this study is distributed normally.

Multicollinearity Test

The next classical assumption test is the multicollinearity test which is used to check whether there is a high linear relationship between independent variables and see how much VIF value there is between these independent variables.

Table 2. Multicollinearity Test

Variabel	Coefficient Variance	Uncentered VIF	Centered BRIGHT
C	1.42E+23	43.60809	ON
REC	1.80E+16	1.556809	1.058209
CO2	5.29E+22	4.298566	1.030902
GLOB	3.62E+19	38.37332	1.079095

Based on the table above, the results of the multicollinearity test on *Centered VIF (Variance Inflation Factors)* show that the VIF for the variables REC, CO2, and GLOB are 1.058209; 1.030902; and 1.079095 or < 10 which means that there are no symptoms of multicollinearity among the independent variables (independent variables) in this study.

Heteroscedasticity Test

Heteroscedasticity tests occur when the variance from residual or error is not constant for all meaningful observations, the model's prediction error fluctuates depending on the value of independent variables.

Table 3. Heteroscedasticity Test (REABS)

Variabel	Coefficient	Std. Error	t-Statistic	Prob.
C	2.07E+11	2.67E+11	0.777330	0.4381
REC	99057909	82298758	1.203638	0.2305
CO2	-1.71E+11	2.75E+11	-0.623804	0.5337
GLOB	2.81E+09	2.89E+09	0.970212	0.3334

Based on the results of the heteroscedasticity test above, the regression of the panel data using the FEM model with reabs showed the probability values of independent variables, such as REC of 0.2305, CO2 of 0.5337, and GLOB of 0.3334 or greater than 0.05 which means that it has met the heteroscedasticity-free assumption.

FEM Panel Data Regression Estimation Results

In this model, a panel data regression equation can be formulated which aims to estimate the influence on dependent variables if independent variables are increased or decreased. The following is a table of results from the regression of panel data using *the Fixed Effect Model* (FEM).

Table 4. Uji Hypothesis

Variabel	Coefficient	Std. Error	t-Statistic	Prob.
C	2,263397	4.61E+11	0,490629	0,6244
REC	6,811116	1.42E+08	47,86491	0,0000
CO2	-2,216427	4.75E+11	-4,663723	0,0000
GLOB	1,112244	5.00E+09	2,222527	0,0277
R-Squared	0,981652			
Adjusted R-Squared	0,980834			
F-Statistic	1199,948			
Prob. (F-Statistics)	0,000000			

Based on the results of the estimation of the table above, the following regression equation is obtained:

GDP = 2,263397 + 6,811116 REC – 2,216427 CO2 + 1,112244 GLOB + e

Partial Test (t-test)

Based on the table, the results show that in the variable of renewable energy consumption (REC) shows a t-count (t-statistic) of 47.86491 > t-table (df = 161, α = 0.05) of 1.65437, and a p-value (Prob.) of 0.0000 < 0.05 which can be concluded that renewable energy consumption has a positive and significant effect on economic growth.

The next variable is carbon dioxide (CO2) emissions which shows t-calculation (t-statistic) |-4.663723| > t-table 1.65437, as well as p-value 0.0000 < 0.05 it can be concluded that carbon dioxide emissions have a negative and significant effect on economic growth.

The globalization variable (GLOB) shows a t-count (t-statistic) of 2.222527 > t-table of 1.65437, and a p-value of 0.0277 < 0.05 which can be concluded that globalization has a positive and significant effect on economic growth.

Simultaneous Test (F-Test)

Based on the results of the study, the F-statistical value (F-calculated) was obtained of 1199.948 > F-table (df1 = 3, df2 = 161; α = 0.05) of 2.66 and the probability value (p-value) of 0.000000 < 0.05. Since the F-statistical value is much greater than the F-table and the p-value is smaller than 0.05, it can be concluded that the regression model studied is significant simultaneously which means that the variables of Renewable Energy Consumption (REC), Carbon Dioxide Emissions (CO2), and Globalization (GLOB) together have a significant influence on Economic Growth (GDP) in BRICS countries.

Coefficient of Determination

Based on the results of the research obtained from the output *of E-Views* 12.0, the *R-Squared* value of 0.981652 shows that as much as 98.17 percent of the variation in the GDP (economic growth) variable can be explained by three independent variables, namely renewable energy consumption, carbon dioxide emissions, and globalization. Meanwhile, the *Adjusted R-Squared* value of 0.980834 indicates that after correcting for the number of variables and observations, there is still 98.08 percent variation in dependent variables or economic growth that can be explained by the model. Thus, this regression model has a very strong explainability, and only about 1.92 percent of economic growth is influenced by factors other than the research model used.

DISCUSSION

Based on the results of the study, it shows that the variable of renewable energy consumption has a positive and significant effect on economic growth. This can be seen from the coefficient value of 6.811116 which indicates the direction of a positive relationship, as well as a probability value of 0.0000 which is smaller than the significance level of 5% (0.05). Thus, the hypothesis that renewable energy consumption has a significant effect on economic growth is accepted. The results of the study are also supported by several previous studies, including, research by Iqbal et al., (2023); Balsalobre-Lorente & Leitão (2020);

Niyonzima et al., (2022); Ningtyas & Andriyani, (2024); Zhang et al., (2023); Lankala and So (2023); and Rahman & Velayutham, (2020) who say that renewable energy consumption has a positive and significant influence on economic growth because it helps reduce environmental impact and supports long-term economic sustainability. This result is in line with the concept *green economy* or green economy, which is an economic development approach that aims to create growth by prioritizing the principle of environmental sustainability.

In the results of the regression panel data, carbon dioxide emissions showed a negative influence on economic growth with a coefficient value of -2.216427 and a probability value of 0.0000. This means that carbon dioxide emissions have a real detrimental effect on economic activity in the long run. In this case, the negative coefficient findings indicate that the BRICS countries (Brazil, Russia, India, China, South Africa) that were the object of the study have passed or are at the top of the EKC (*turning point*) or *decreasing emissions with continued growth*, namely the impact of emissions on the economy began to turn negative due to the increasing burden of environmental externalities. Other previous research results that show a negative relationship of carbon dioxide emissions to economic growth, namely Putri & Cahyono (2022) Myszczyszyn & Supron (2021); and Kang et al. (2022).

In the results of the regression data panel, the globalization variable using the globalization index showed a positive and significant influence on economic growth, with a coefficient value of 1.112244 and a probability value of 0.0277. The positive coefficient means that every increase in one globalization index score will increase the Gross Domestic Product (GDP) by $1.112244, assuming the other variables remain the same. While a probability value below 0.05 indicates that this relationship is statistically significant, so it can be concluded that globalization really has a real impact on the economic growth of the observed countries, namely the BRICS (Brazil, Russia, India, China, and South Africa). Research according to Xu, Abbas, Sun, Gillani, Ullah, and Raza (2021), found that globalization has a positive influence on economic growth, especially in several developing countries in Asia that are starting to be actively involved in free trade and international cooperation.

CONCLUSIONS AND RECOMMENDATIONS

Based on the discussion of the results of multiple regression of the panel data above, renewable energy consumption has a positive and significant influence on economic growth in BRICS countries which shows that renewable energy consumption is a commitment to the global agenda in the openness of investment space and green technology innovation to reduce the cost of negative externalities and environmental damage.

Then, the carbon dioxide emission variable has a negative and significant influence on economic growth in BRICS countries, because high emissions will not only worsen air pollution and climate change but will also create social and economic costs due to environmental damage caused by high emissions. The finding that carbon dioxide emissions negatively impact economic growth supports the validity of the *Environmental Kuznets Curve* (EKC) theory, BRICS

countries are in a phase where economic growth still produces negative externalities to the environment and need to pass the stage towards the turning point of the EKC in order for sustainability to be achieved.

Furthermore, globalization has a positive and significant influence on economic growth in BRICS countries. This is because globalization encourages the exchange of technology and information, market integration, and global competitiveness to increase the productivity of each BRICS country.

Based on the conclusions described above overall, this study shows that the variables studied have a significant influence on economic growth in BRICS countries. These results confirm the importance of the role of renewable energy, carbon dioxide emissions, and globalization in encouraging or hindering economic growth.

ADVANCED RESEARCH

The focus of the research is only on five BRICS countries, namely Brazil, Russia, India, China, and South Africa. Meanwhile, there are still six other BRICS countries that are not included in this study, so further research is needed to see the overall economic growth conditions of BRICS member countries.

This study has not explicitly distinguished between the short-term and long-term effects of independent variables on economic growth. In this case, the energy transition and globalization have effects that are usually different from the short term.

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