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## The Effect Of Green Innovation, Co2 Emissions, Foreign Direct Investment, And Trade Openness On Gross Domestic Product In Brics Countries

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### Abstrak

Penelitian ini bertujuan untuk menganalisis pengaruh Green Innovation, emisi CO<sub>2</sub>, Foreign Direct Investment, dan Trade Openness terhadap produk domestik bruto (PDB) di negara-negara BRICS. Dalam penelitian ini, data panel dari 5 negara di BRICS periode 2002-2021 dianalisis menggunakan Analisis Regresi Berganda dengan metode Ordinary Least Square (OLS) dengan Fixed Effect Model. Hasil penelitian menunjukkan bahwa green innovation dan foreign direct investment berpengaruh positif dan signifikan terhadap produk domestik bruto di negara-negara BRICS, emisi CO<sub>2</sub> berpengaruh negatif dan signifikan terhadap produk domestik bruto di negara-negara BRICS, dan trade openness berpengaruh negatif terhadap produk domestik bruto di negara-negara BRICS. Dalam mencapai tujuan pembangunan berkelanjutan (SDGs), negara-negara BRICS harus memprioritaskan dan mengintegrasikan pertimbangan lingkungan dalam kegiatan ekonominya.

Kata kunci: *BRICS, Emisi CO<sub>2</sub>, Foreign Direct Investment, PDB, Green Innovation, Trade Openness*

### Abstract

This study aims to analyze the effect of green innovation, CO<sub>2</sub> emissions, foreign direct investment, and trade openness on gross domestic product (GDP) in BRICS countries. In this study, panel data from 5 countries in BRICS for the period 2002-2021 were analyzed using Multiple Regression Analysis with the Ordinary Least Square (OLS) method with a Fixed Effect Model. The results show that green innovation and foreign direct investment have a positive and significant effect on gross domestic product in BRICS countries, CO<sub>2</sub> emissions have a negative and significant effect on gross domestic product in BRICS countries, and trade openness has a negative effect on gross domestic product in BRICS countries. Towards achieving sustainable development goals (SDGs), BRICS countries should prioritize and integrate environmental considerations in their economic activities.

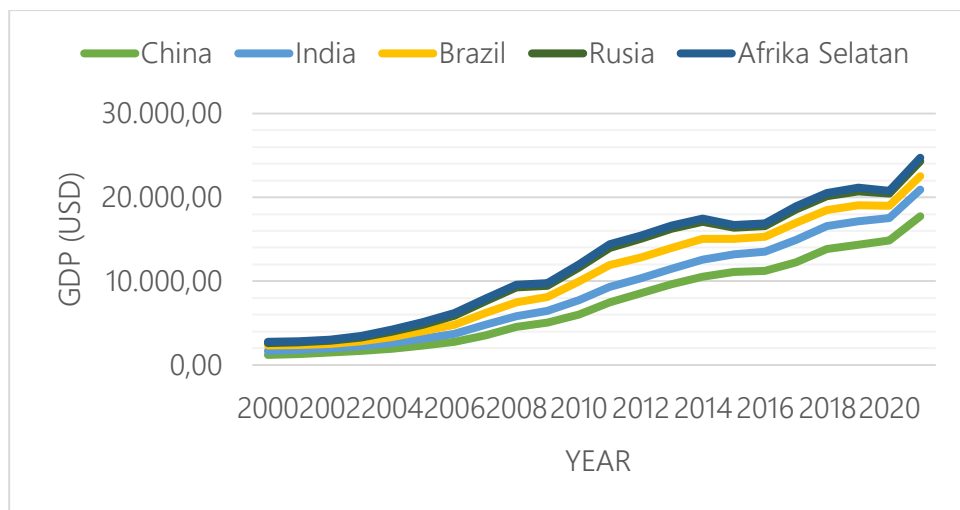
Keywords: *BRICS, CO<sub>2</sub> Emissions, Foreign Direct Investment, GDP, Green Innovation, Trade Openness.*

## INTRODUCTION

In the early stages of development, countries tend to focus more on increasing GDP than caring for the natural environment (Lowe, 2016). Economic growth is the expansion of a country's economic activities, leading to an increase in the production of goods and services, which in the long run improves people's welfare and becomes an indicator of a country's development (Marselina, 2021). Economies of scale and increased production capacity, which may reflect the growth of the economic strength of a country or region. Conditions in each region have unique characteristics (Usman et al., 2022). However, emissions tend to increase despite the fact that increased economic activity fosters economic growth through the production of more goods and services (Aida et al., 2022). The pollution haven hypothesis (PHH) states that due to weak environmental regulations in the host country, some industries with high levels of contamination and consumption will be relocated from other countries through FDI and trade, causing a significant increase in pollutant emissions (Savona & Ciarli, 2019; Stef & Jabeur, 2020). High economic growth increases productivity, one of which will depend on the availability of natural resources and environmental quality. Trade expansion is one of the main reasons for the difficulty of improving energy conservation and regulating high energy consumption in China (Chen et al., 2022). In addition, the trade surplus in India is the main cause of the sharp rise in CO<sub>2</sub> emissions (Jiao et al. 2022).

BRICS, which is a multilateral cooperation organization whose name is the acronym of the member countries, namely Brazil, Russia, India, China and South Africa, has been considered as the five leading emerging economies in the world. The BRICS countries (Brazil, Russia, India, China and South Africa) position themselves as the most growing economies (Zhang & Wang, 2019). They have had significant economic growth in recent decades and contribute to the dynamics of the global economy. One of the main objectives of BRICS is to strengthen economic cooperation among its member countries. This includes trade, investment, and collaboration in economic sectors such as technology, industry, and energy among themselves and have changed their political systems to embrace global capitalism.

Figure 1. BRICS Gross Domestic Product (GDP) from 2000 to 2021 (in USD)



Source: International Monetary Fund (2022)

According to data from the International Monetary Fund (2022) China has the largest GDP of the BRICS countries, at 16.86 trillion USD in 2021, while the others are all under three trillion. The combined BRICS bloc had a GDP of over 24.73 trillion US dollars in 2021, slightly more than the United States. India has a GDP of 3.2 trillion USD in 2021. Brazil has a GDP of 1.6 trillion USD in 2021. Russia has a GDP of 1.8 trillion USD in 2021. Furthermore, South Africa has a GDP of 419 billion USD in the same year. Since the beginning of the 21st century, the BRICS countries have been considered the world's five leading emerging economies. The BRICS countries are known as countries with rapidly growing economies. These countries also have a stake in environmental issues, including climate change, natural resource management, and sustainability. The group can work together to find common solutions to global environmental challenges. An overview of environmental conditions in BRICS countries in recent years, generally experiencing water and wastewater pollution problems, as well as air pollution especially in urban areas, around industrial and mining areas. According to British Petroleum (BP) statistics in 2019, the carbon dioxide emissions of BRICS countries reached 14,781 billion tons, which is about 43.19% of the world's total CO<sub>2</sub> emissions. The countries, such as China, India, Russia, and Brazil are among the top seven countries by CO<sub>2</sub> emissions and environmental damage (Khan et al., 2020). The increasing economic trend of BRICS countries has negatively impacted environmental damage and climate disruption (Su et al., 2021). Natural resource extraction is worsening the environment in BRICS countries as the burning of fossil fuels for energy is a significant contributor to CO<sub>2</sub> emissions which is a major cause of climate change (Wang & Huang, 2023). The increasing demand for resources and energy has led to increased pollution and deforestation, which negatively impacts the environment and human health (Scott et al., 2017). In addition, BRICS countries should promote clean FDI flows by reducing environmental damage, and investing

countries should be assessed based on environmental damage in the host country (Apergis et al., 2023).

Green innovation has become a popular technique to achieve environmental conservation and economic well-being (Karimi Takalo et al., 2021). In addition, green innovation lowers environmental costs and introduces environmentally friendly technologies that ensure environmental safety by reducing environmental damage (Ekins et al., 2021). In the context of climate change and high-quality economic growth, green innovation is essential for achieving sustainable economic development. (Nan et al., 2022). The long run of positive and significant environmental innovation and patents can ensure that environment-related technologies are helpful in achieving green growth economy in BRICS countries (Chen et al., 2023). In general, all BRICS countries are facing pressure to adopt green innovation due to sustainability demands and increasing awareness of environmental impacts such as efforts to reduce CO2 emissions.

## RESEARCHER METHODS

The data used in this study is an annual data that was collected in BRICS countries namely Brazil, Russia, India, China and South Africa from 2002 to 2021. The variables used in this study are Gross Domestic Product, Green Innovation, CO2 Emissions, Foreign Direct Investment, and Trade Openness. The data was obtained from the World Bank, Organization for Economic Cooperation and Development Database (OECD) and Our World in Data which was then analyzed with the E-views 12 tool.

The following panel data regression equation model is used:

$$LN\text{GDP}_{it} = \beta_0 + \beta_1\text{GI}_{it} + \beta_2\text{CO2}_{it} + \beta_3\text{FDI}_{it} + \beta_4\text{TO}_{it} + \varepsilon_{it}$$

Description:

$\text{GDP}_{it}$  = Gross Domestic Product in country i in year t (in trillion USD)

$\text{GI}_{it}$  = Green Innovation in country i in year t (in percent)

$\text{CO2}_{it}$  = Carbon dioxide emissions in country i in year t (in percent)

$\text{FDI}_{it}$  = Foreign Direct Investment in country i in year t (in percent)

$\text{TO}_{it}$  = Trade Openness in country i in year t (in percent)

## RESULT AND DISCUSSION

Table 1. Panel Data Regression Model Selection

Test	Prob.	Decision
Chow	0.0000	FEM
Hausman	0.0000	FEM
LM	0.0000	REM

Source: Eviews 12 output

From the model test above, the best model chosen is the Fixed Effect Model (FEM) compared to the Random Effect Model (REM) and the Common Effect Model (CEM).

Table 2. Panel Data Regression Estimation Results with FEM

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.720735	0.521615	10.96736	0.0000
GI	0.141719	0.030792	4.602486	0.0000
CO2	-0.010186	0.008543	-1.192238	0.2363
FDI	0.114080	0.047259	2.413946	0.0178
TO	0.008362	0.009969	0.838798	0.4038
<b>Effects Specification</b>				
<b>Cross-section fixed (dummy variables)</b>				
R-squared	0.715485	Mean dependent var	7.275700	
Adjusted R-squared	0.690472	S.D. dependent var	1.080632	
S.E. of regression	0.601212	Akaike info criterion	1.905951	
Sum squared resid	32.89249	Schwarz criterion	2.140417	
Log likelihood	-86.29756	Hannan-Quinn criter.	2.000844	
F-statistic	28.60527	Durbin-Watson stat	0.564436	
Prob(F-statistic)	0.000000			

Source: Eviews 12 output

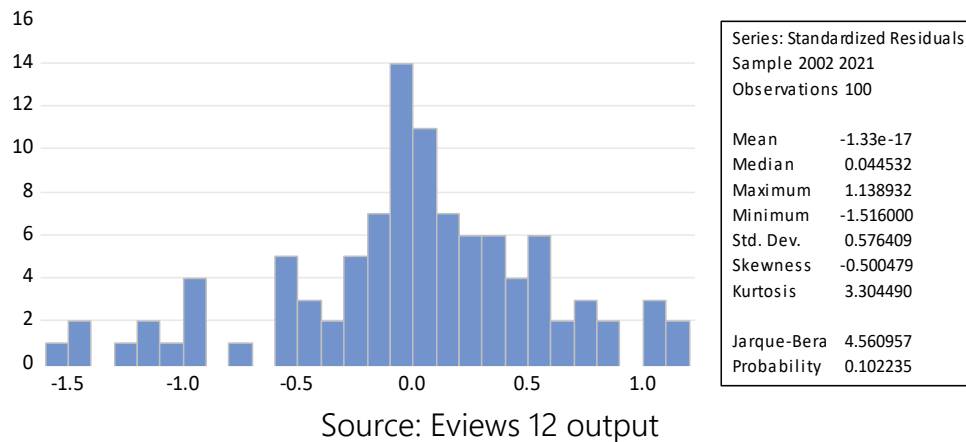
Based on the estimation results in Table 2, the regression equation with a significance of  $\alpha = 5\%$  is obtained as follows:

$$LNGDP = 5.720735 + 0.141719GI_{it} - 0.010186CO2_{it} + 0.114080FDI_{it} + 0.008362TO_{it}$$

The estimation results above show the effect of each regression coefficient of the independent variable on the dependent variable. The constant value (C) is positive at 5.720735 which means that if Green Innovation (GI), CO2 emissions (CO2), Foreign Direct Investment (FDI), and Trade Openness (TO) are equal to zero, then the amount of GDP value formation in BRICS in 2002-2021 is 5.72% assuming *ceteris paribus*.

## Classical Assumption Testing

Figure 2. Normality Test Results.



Based on the figure above, it is known that the probability value of Jarque-Bera  $> \alpha$  5% or  $0.102235 > 0.05$ , so the residuals are normally distributed.

Table 3. Multicollinearity Test Results, Correlation

	GI	CO2	FDI	TO
GI	1.000000	-0.308424	0.044418	-0.018022
CO2	-0.308424	1.000000	-0.104665	0.269283
FDI	0.044418	-0.104665	1.000000	-0.254292
TO	-0.018022	0.269283	-0.254292	1.000000

Source: Eviews 12 output

Based on the table above, the correlation value is not more than 0.85. This means that this model is not affected by multicollinearity problems.

Table 4. Results of Heteroscedasticity Test

Variable	Prob.
C	0.5371
GI	0.8952
CO2	0.8958
FDI	0.3012
TO	0.6801

Source: Eviews 12 output

Based on the table above, it is known that the probability value of each independent variable is greater than  $\alpha = (5\%)$ . This means that this model is free from heteroscedasticity problems.

Figure 3. Durbin-Watson test results

Positive Autocorrelation	dL	dU	No Autocorrelation	4-dU	4-dL	Negative Autocorrelation
0	1.5795	1.7546	1.9791	2.2454	2.4205	4

Source: Eviews 12 output

Based on the Durbin-Watson test using the First Difference data transformation, it is known that the DW value is 1.9791, with  $k = 4$ ,  $n = 95$ , dL value = 1.5795, dU value = 1.7546, 4-dU value = 2.2454, and 4-dL value = 2.4205. Therefore, the results of this autocorrelation test are  $dU < d < 4-dU$  and it can be concluded that this study is not infected with autocorrelation problems.

### Hypothesis Test

Table 5. Partial Test Results (t test)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.720735	0.521615	10.96736	0.0000
GI	0.141719	0.030792	4.602486	0.0000
CO2	-0.010186	0.008543	-1.192238	0.2363
FDI	0.114080	0.047259	2.413946	0.0178
TO	0.008362	0.009969	0.838798	0.4038

Source: Eviews 12 output

Based on Table 11, the t-test results on the Green Innovation (GI) variable show that the t-count value of 4.6024 is greater than the t-table of 1.9852 with a probability value of 0.000 less than  $\alpha = 5\%$  ( $0.000 < 0.05$ ). This means that  $H_0$  is rejected and  $H_a$  is accepted. So it can be concluded that Green Innovation has a positive and significant effect on Gross Domestic Product in BRICS countries in 2002-2021. The t-count value of CO2 emissions is known to be -1.1922 less than the t-table with a probability value of 0.2363 greater than  $\alpha = 5\%$  ( $0.2363 > 0.05$ ), this means that  $H_0$  is accepted. So it can be concluded that CO2 emissions have a negative and significant effect on Gross Domestic Product in BRICS countries in 2002-2021. The t-count value of Foreign Direct Investment (FDI) is known to be 2.4139 greater than the t-table with a probability value of 0.0178 less than  $\alpha = 5\%$  ( $0.0178 < 0.05$ ) This means that  $H_0$  is rejected and  $H_a$  is accepted. It can be concluded that Foreign Direct Investment has a positive and significant effect on Gross Domestic Product in BRICS countries in 2002-2021. Then the t-count value of the Trade Openness (TO) variable is known to be 0.8387 less than the t-table with a probability value of 0.4038 greater than  $\alpha = 5\%$  ( $0.4038 > 0.05$ ), this means that  $H_0$  is accepted.

So it can be concluded that Trade Openness has a negative but insignificant effect on Gross Domestic Product formation in BRICS countries in 2002-2021.

Table 6. Simultaneous Test Results (F-Test)

F-Statistics	Prob.
28.60527	0.000000

Source: Eviews 12 output

Based on Table 12, the F-count of 28.6052, is greater than the F-table of 0.000 with a probability value smaller than  $\alpha = 5\%$  ( $0.000 < 0.05$ ). This means that  $H_0$  is rejected and accepts  $H_a$ . It can be concluded that Green Innovation, CO<sub>2</sub> emissions, FDI, and Trade Openness simultaneously affect gross domestic product in BRICS countries in 2002-2021.

#### Determination Coefficient Test (R<sup>2</sup>)

The coefficient of determination or R<sup>2</sup> is 0.715485. This means that Green Innovation, CO<sub>2</sub> emissions, Foreign Direct Investment, and Trade Openness can explain 71.54% of the formation of gross domestic product in BRICS member countries in 2002-2021, while the remaining 28.46% is explained by other variables not included in the model in this study.

#### 1. The Effect of Green Innovation on Gross Domestic Product Formation in BRICS

Based on the estimation results of the Fixed Effect Model, the results are in accordance with the hypothesis. Where the results of this study are the formation of GDP which is influenced by green innovation has an influence with a positive and significant direction in BRICS member countries for the period 2002-2021. These results indicate that if there is an increase in the green innovation variable, there will be an increase in GDP in BRICS. The regression results show that the green innovation coefficient is 0.141719. This shows that if there is an increase of 1% in green innovation, it will increase gross domestic product by 14.17% with the assumption of *ceteris paribus*. This research is in line with research conducted by Karimi Takalo et al (2021); Huang (2024); Nan et al (2022); and Ogiemwonyi et al (2023) where green innovation has a positive effect on economic growth and reduces environmental pollution using environmentally friendly technology. In addition, Chen et al (2023) in their research stated that the long-term estimation of innovation and technology patents related to the environment has a significant positive effect and is very helpful in achieving a green growth economy in BRICS countries. Social, economic, and environmental factors also significantly generate green innovation in the long run in BRICS (Qi, & Yang, 2023). Technological innovation is an endogenous and fundamental factor in determining economic quality that promotes

sustainable economic growth (Ghisetti & Quatraro, 2017). Brazil has abundant natural resources, including natural resources that can support green innovation, such as bioenergy. If the demand for these products increases, it will increase GDP in Brazil while reducing environmental problems can be achieved so that the ecosystem can be maintained. Russia has shown support for diversification of energy sources to reduce dependence on fossil fuels. Green innovation in India includes the development of solar energy and other clean energy programs to address sustainability issues and reduce carbon emissions. The Chinese government has implemented pro-green policies and major investments in green innovation to reduce serious air pollution and other environmental problems. The South African government is creating renewable energy through green technology to improve the economy and environmental quality.

## 2. Effect of CO<sub>2</sub> Emissions on Gross Domestic Product Formation in BRICS

Based on the estimation results of the Fixed Effect Model, the results are in accordance with the hypothesis. The t-count value of CO<sub>2</sub> emissions is known to be -1.1922 smaller than the t-table with a probability value of 0.2363 greater than  $\alpha = 5\%$  ( $0.2363 > 0.05$ ), this means that H<sub>0</sub> is accepted. So it can be concluded that CO<sub>2</sub> emissions have a negative and significant effect on the formation of Gross Domestic Product in BRICS countries in 2002-2021. The regression results show that the coefficient of CO<sub>2</sub> emissions is -0.010186. This shows that if there is an increase of 1% in CO<sub>2</sub> emissions, it will reduce gross domestic product by 0.1% assuming ceteris paribus. This is in line with research by Shahbaz et al (2021) which states that in the long run low CO<sub>2</sub> emissions contribute positively to economic growth. The increasing economic trend of BRICS countries has negatively impacted environmental damage and climate disruption (Su et al., 2021). Some BRICS countries have a high dependence on fossil energy sources, such as coal and oil. The extraction of natural resources is worsening the environment in BRICS countries as burning fossil fuels for energy is a significant contributor to CO<sub>2</sub> emissions which is a major cause of climate change (Wang & Huang, 2023). In addition to the high level of CO<sub>2</sub> emissions, especially from the energy and industrial sectors and the impact of global trade activities such as in China, India and Russia. CO<sub>2</sub> emissions in China are increasing as a result of environmentally unfriendly technological advances (Yu & Du, 2019) and industrial expansion (Wen et al., 2020) causing massive infrastructure development that requires more fuel, and consequently increasing the amount of carbon emissions. CO<sub>2</sub> emissions in Brazil are due to the country's increased energy demand (Sharif et al., 2022). This climate change can have a direct impact on key sectors such as agriculture, water resources, and infrastructure, which in turn can affect GDP. In the context of a global economy increasingly focused on sustainability, BRICS countries that are able to adopt sustainable economic models

and reduce CO<sub>2</sub> emissions can find advantages in international trade and investment. Zhang (2021) mentioned that the level of technological innovation has not helped BRICS countries to decouple economic growth from CO<sub>2</sub> emissions, but it has contributed to reducing CO<sub>2</sub> emissions.

### 3. Effect of Foreign Direct Investment on Gross Domestic Product Formation in BRICS

Based on the estimation results of the Fixed Effect Model, the results show results that are in accordance with the hypothesis. Where the results of this study obtained a t-test where the t-count of 2.4139 is greater than the t-table with a probability value of 0.0178 smaller than  $\alpha = 5\%$  ( $0.0178 < 0.05$ ). So that FDI has a positive and significant effect on GDP formation in BRICS member countries for the period 2002-2021. The regression results show that the FDI coefficient is 0.114080. This shows that if there is an increase of 1% in FDI, it will increase gross domestic product by 11.40% with the assumption of *ceteris paribus*. Ali et al (2019); Dinh et al (2019); and Udi et al (2020) mention that Foreign Direct Investment is referred to as a tool for economic growth that is able to create jobs and become a channel for technology transfer to the host country. Foreign Direct Investment can help BRICS countries to diversify their economic structure. The BRICS have seen FDI flows and their share in global flows increase substantially over the last 20 years. This is true for all countries in BRICS, even taking into account China and India as global investment destinations. While FDI in BRICS was negatively impacted by the COVID-19 pandemic, these five countries showed better resilience compared to others. BRICS recovered well in 2021 reaching record highs for both FDI inflow and outflow. BRICS countries have adopted a number of important initiatives to strengthen cooperation, such as promoting intra-group investment in recent years, particularly given the impact of the pandemic and the increasing uncertainty in the world economy and related challenges faced by the group (UNCTAD, 2023). While FDI can provide great benefits, BRICS countries must also ensure that these investments also consider environmental impacts so that they are in line with their long-term development policies and economic sustainability.

### 4. Effect of Trade Openness on Gross Domestic Product Formation in BRICS

Trade openness refers to the level of dependence of a country on international trade, especially exports and imports. Based on the estimation results of the Fixed Effect Model, it is known that the t-count of 0.8387 is smaller than the t-table with a probability value of 0.4038 greater than  $\alpha = 5\%$  ( $0.4038 > 0.05$ ), this means that  $H_0$  is accepted. So, it can be concluded that Trade Openness has a negative but insignificant effect on Gross Domestic Product formation in BRICS countries in 2002-2021. The regression results show that the trade openness coefficient is 0.008362. This shows that if there is an increase of 1% in trade openness, it will reduce gross domestic product by 0.08% assuming *ceteris paribus*. Export-dependent BRICS

countries can experience significant economic growth through trade openness. With increased global demand for their goods and services, they can experience economic expansion. Shah et al (2022) also stated that trade openness has a positive effect on carbon dioxide emissions. Trade openness can attract non-renewable or scarce natural resources that are expensive to produce domestically. An imbalance between exports and imports can affect economic stability and cause environmental degradation due to exploitation of natural resources which can affect GDP in BRICS. The expansion of energy-intensive industries has led to high fossil fuel energy use in China (Feng and Wang, 2019). Trade expansion is one of the main reasons it is difficult to improve energy conservation and regulate high energy consumption in China (Chen et al., 2022). The trade surplus in India is the main cause of the sharp rise in CO<sub>2</sub> emissions (Ren et al 2014). The need for a balance between Trade openness and economic sustainability in the long run. Awareness of the risks and appropriate policies are essential to optimise the positive impact of trade openness on GDP.

## CONCLUSION

The conclusions in this study include that green innovation and foreign direct investment have a positive and significant effect on gross domestic product, CO<sub>2</sub> emissions has a negative and significant effect on gross domestic product, and trade openness has a negative effect on gross domestic product in BRICS countries for the 2002-2021 period. BRICS includes countries with diverse economies, from the world's largest economy like China, to emerging economies like Brazil and India. The combination of market size and significant economic growth makes BRICS have a major impact on the global economy. The role of government in public policy can vary depending on the political system, government ideology, and country-specific circumstances so it is necessary to consider the externalities of all economic activities in the BRICS member countries. Regarding environmental issues, BRICS has shown concern for environmental and sustainability issues. China and India, in particular, have increased their investment in renewable energy such as solar power, wind power, and bioenergy. Each BRICS country has unique challenges and priorities in managing CO<sub>2</sub> emissions according to their domestic conditions. Stricter regulations can help control pollution, promote sustainable resource management, and encourage the use of clean technology to ensure economic growth without harming the environment.

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