The Impact of GDP Per Capita, Trade Openness, Environmental Policy Stringency, Population, and Renewable Energy Consumption on Carbon Emissions in The BRICS, 1990-2020

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Abstract. BRICS countries collectively account for about 38% of global carbon dioxide emissions and significantly contribute to global carbon emission levels. This study aims to analyze the impact of GDP per capita, Trade Openness, Environmental Policy Stringency, Population, and Renewable Energy Consumption on Carbon Emissions in BRICS countries from 1990-2020 in the long run. FMOLS analysis is used in this study to see the long-term impact between variables. The results show that GDP per capita and population positively and significantly impact carbon emissions in the long run. Renewable energy consumption negatively and significantly impacts carbon emissions in the long run. Trade openness and environmental policy stringency have a negative and insignificant impact on carbon emissions in the long run. The Government needs to review and strengthen existing regulations and ensure better implementation of green policies..

Keywords: Carbon Emissions, BRICS, FMOLS.

1 Introduction

The biggest challenge in the 21st century is the increase in global temperature as a trigger for climate change (1). Climate change occurs due to the greenhouse gas effect (2). The greenhouse gas effect comes from carbon emissions (CO2), nitrous oxide (N2O), methane (CH4), and three other gases containing fluorine. The gases accumulated in the atmosphere have changed the radiation balance, causing the Earth to become warmer (3). According to the EPA or Environmental Protection Agency (2023), the world's greenhouse gas composition is dominated by carbon dioxide (CO2), the leading cause of global warming, at 79.4%. The second largest contributors are methane

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(CH_4) at 11.5%, nitrous oxide (N_2O) at 6.2%, and high potential gas global warming at 3% (4). CO_2 has a percentage reaching ¾ of the world's total greenhouse gas emissions. Carbon dioxide is an essential greenhouse gas, the leading cause of global warming, accumulating in the atmosphere due to human activities (5). Total global carbon emissions in 2010-2020 tended to increase. The peak in 2018 reached 35,560,555.79 kt. The impact of carbon emissions does not occur instantly but develops over time, so observations should be made in the long term.

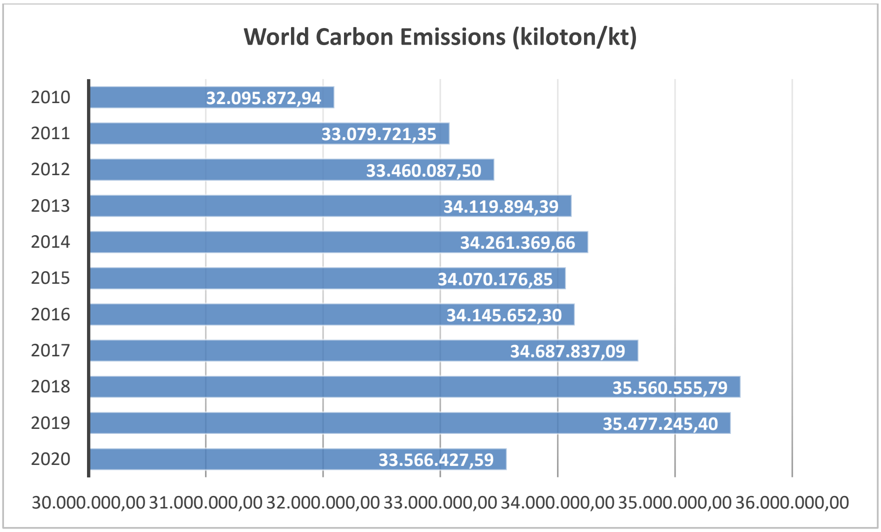

Figure 1. Carbon Emissions 2010-2020 (kt) (6)

BRICS is an abbreviation for five major countries: Brazil, Russia, China, and South Africa. Group This was formed in 2006 to combine the potency of these five countries' economic, political, and social aspects to play a more vital role in global politics. As BRICS economies have improved, they also face heavy challenges from climate change and carbon dioxide emissions. BRICS countries are responsible for consuming 40% of the world's energy and contributing to main CO_2 emissions (7). In addition, dependence on sources of energy materials burning fossil fuels caused these countries to become contributors to the most significant change in the climate. OECD countries still dominate the world economy. However, world market share has decreased, which indicates a shift in dynamics in the global economy, and some countries have economies that are the most essential thing in the world, aren't they? OECD member. The most important among these countries is BRIICS (Brazil, Russia, India, Indonesia, China, and South Africa) (8). Not only have a significant impact on the growth of the global economy, large population, and reserves, but BRIICS countries also have large foreign exchange reserves, which are essential in mitigating global carbon (9).

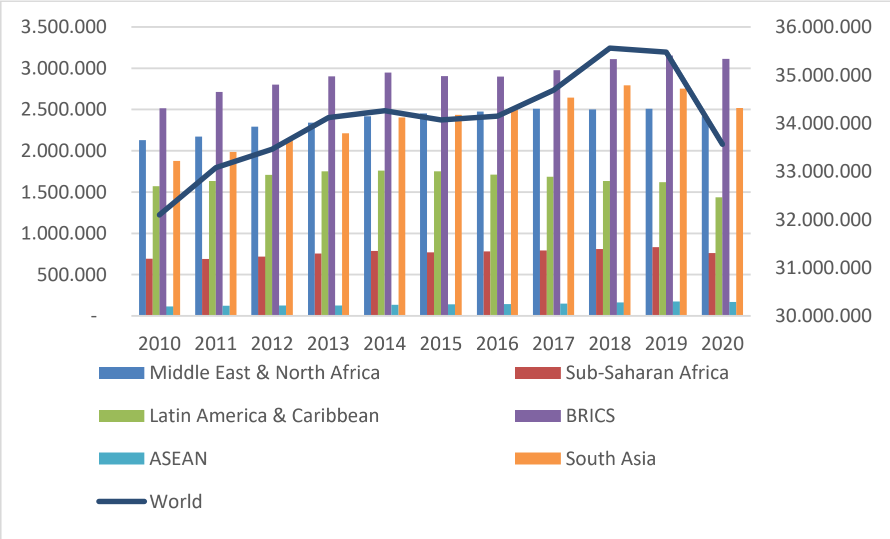

Figure 2. World Carbon Emissions and Several Country Groups 2010-2020 (kt) (6)

The contribution of the BRICS group to carbon emissions is significant in the face of global climate change. The figure above shows that BRICS countries contribute the highest carbon emissions compared to other groups. Carbon emissions in BRICS tend to increase. According to Wang & Huang (2023), BRICS countries collectively contribute about 38% of global carbon dioxide emissions and are also significant contributors to overall global carbon emission levels (10). Besides that, as developing countries, BRICS still rely heavily on natural resources in their production activities. So, the cause of high carbon emissions in BRICS countries is related to nature, such as the high proportion of coal, oil, and gas consumption due to high public demand (11).

The GDP per capita of BRICS countries tends to increase. The GDP of BRICS countries accounts for 24% of the world's GDP, and the population of BRICS countries accounts for approximately 41% of the world's population and more than 16% of the world's trade share (12). GDP per capita is an indicator used to measure a country's level of economic prosperity. The higher a country's GDP per capita, the higher its citizens' wealth or average income. Experts have widely discussed the impact of GDP and environmental quality. One uses the STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model. The model is commonly used to measure the impact of population, affluence, and technology factors on various social and environmental impacts, including carbon emissions. Affluence in the STIRPAT model can usually be seen from GDP per capita (13). The STIRPAT model assumes that higher levels of wealth tend to contribute to increased environmental impacts, including carbon emissions. Because higher energy consumption levels and production of goods and services usually occur in countries with high GDP per capita. The country's trade openness can impact high GDP per capita.

Trade openness refers to a country's access to international markets and can drive economic growth. Trade openness refers to removing tariff and non-tariff barriers to trade and measures the closeness of trade relationships between a country and other countries. The trade openness in BRICS will be low at around 39.33% in 2020, but it will have high carbon emissions. This situation does not align with modern international trade theory, specifically the Heckscher-Ohlin theory. The Heckscher-Ohlin theory assumes that a country that is abundant in a factor of production can export intensive commodities using relatively abundant factors of production due to abundant and cheap factors of production (14,15). The low level of trade openness should reduce the exchange of goods and factors of production between countries, which should also reduce carbon emissions. However, the carbon emissions of BRICS countries are high.

Environmental policy or regulation is considered one of the effective ways to reduce environmental pollution. The Environmental Policy Stringency Index (EPS) refers to the stringency of environmental policies implemented by the Government to protect natural resources and reduce negative environmental impacts. The stricter the country's environmental policy, the higher the index value (15). This indicates a greater level of environmental protection. The index provides a view of the extent to which BRICS countries are committed to reducing negative environmental impacts. The EPS in BRICS countries has been increasing from year to year. Until 2020, the environmental policy stringency index was at 1.79, a considerable increase compared to 1990, when it was only at 0.21. The hope is that the stringency of environmental policy variables will decrease carbon emissions. However, despite the increase in carbon emissions, the EPS Index of BRICS countries has also increased. The EPS is not in line with the Pollution Haven Hypothesis (PHH) theory, which states that firms will seek to avoid the costs of strict environmental regulations (high energy prices) and locate production in countries that have looser environmental regulations (16). This hypothesis also implies that countries with stricter environmental regulations tend to have lower carbon emissions as polluting firms tend to move their production to countries with looser environmental regulations to avoid the high costs associated with regulatory compliance. In other words, the stricter a country's Environmental Policy Stringency (EPS) will encourage firms to reduce their carbon emissions by moving their production.

The population is increasing every year. The population in BRICS countries is also increasing every year. Although carbon emissions have decreased, the population continues to increase. Based on STIRPAT theory, the larger the population, the greater the environmental pressure. The larger population relates to increased consumption of natural resources needed to support human life, generating more waste and accelerating deforestation or urbanization. Population can affect environmental consequences.

Renewable energy sources are a possible alternative for increasing access to electricity, reducing air pollution, and reducing carbon dioxide emissions. Renewable energy consumption is crucial in driving the growth and progress of a country's economy and vice versa. Renewable energy consumption in BRICS countries tends to fluctuate, while carbon emissions tend to increase from year to year. Research conducted by Hu et al. (2018) explores how renewable energy plays a role in developing countries and states that increasing renewable energy utilization can reduce carbon emissions [12]. The results of research by Liu et al. (2017) showed that using renewable energy can improve environmental quality in BRICS economies (17). Technological factors in STIRPAT theory refer to technological advances in production and consumption, including energy-related technologies. Examples of renewable energy include solar power, wind power, and hydroelectricity. As renewable energy consumption expands and is widely implemented, it can reduce carbon emissions.

Based on the description above, this study aims to analyze the impact of GDP per capita, trade openness, environmental policy stringency, population, and renewable energy consumption on BRICS countries' carbon emissions. Studying carbon emissions is essential to understanding and effectively addressing climate change.

2 Literature Review

2.1 STIRPAT Theory

The STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) theory was used in this research study. STIRPAT is often used in research because of its significance in addressing challenges related to ecological impacts (18). The IPAT theory was initially formulated by Ehrlich and Holdren in 1972 to investigate the main variables affecting environmental quality. IPAT theory is a broad approach to analyzing the impact of critical factors on the environment, but it fails to include other key impact factors (19). The model only allows one factor to change while others are kept constant, thus capturing impartial impacts on the dependent variable (20). The shortcomings of the IPAT model were overcome by a model developed by Dietz & Rosa (1994), namely the STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model [20]. The STIRPAT model is unlike the IPAT model, which can empirically test hypothesis models and include other non-proportional variables in the environment [21]. The STIRPAT model in a general form can be modeled as follows:

$I = \alpha.\ P^{b}_{i}.A^{c}_{i}.\ T^{d}_{i}.e$……………………………………(1)

Where α is a constant, b, c, d are each interpreted as a parameter, and e is the error. Similar to IPAT theory, the equation in STIRPAT theory still maintains the multiplication logic of I = PAT. An additive regression model where all variables are in logarithmic from facilitates estimation and hyphothesis testing. This modification results in the following model:

$\log I = \alpha + b(\log P) + c(\log A) + d(\log T) + e$……………………………(2)

In this model, a and e are the log of a end log of e from Equation (1), respectively. We drop the subscript i to reduce clutter in the equation. Technology in STIRPAT theory refers not only to aspects of technology as generally understood but also to factors such as social organization, institutions, culture, and other factors that affect human impact on the environment, apart from population and prosperity (21). According to York et al. (2003), technology in this theory balances environmental, population, and prosperity impacts (22).

2.2 Heckers Ohlin's theory

The Heckscher-Ohlin theory was introduced in the 1920s by two Swedish economists, Eli Heckscher and Bertil Ohlin. This theory hypothesizes that a country has a comparative advantage over a good, so it should export more of that good, which is produced intensively with relatively more affluent factors of production (the abundant factor). The Heckscher-Ohlin theory recommends that if trade openness occurs, developing countries would be better off specializing in labor-intensive products and exporting goods in large quantities or at low prices, such as abundant labor and natural resources. On the other hand, developed countries should specialize in capital-intensive products. According to Shafik Bandyopadhyay (1992), economies that are more open to trade will have higher pollution levels (23). Because in an open economy, they will face high competition and have to invest in advanced and effective technologies to reduce environmental pollution. Trade openness is good for the environment of high-income countries. Meanwhile, in developing countries, trade openness can pollute the environment because of the higher energy use intensity in the industrial sector. When a country opens up to international trade, the industrial sector's demand for goods and services will increase. Increased use of energy and fossil fuels can increase carbon emissions (24).

2.3 Pollution Haven Hypothesis (PHH) Theory

Copeland and Taylor introduced the Pollution Haven Hypothesis theory in 1994 in the context of north-south trade in the NAFTA case study. It was also the first study to find the relationship between a country's stringency of environmental regulations, trade patterns, and pollution levels (25). Due to trade liberalization, companies or industries that produce polluting output will move from developed countries with strict environmental regulations and policies to developing countries that tend to be poorer and have weak environmental regulations.

Environmental policy stringency (EPS) is a country-specific measure and can be compared internationally regarding the stringency of environmental policies. Stringency is the degree to which environmental policies place an explicit or implicit price on pollution or behavior that harms the environment. The OECD issued this measure in 2014, focusing on climate change and air pollution mitigation policies. According to research by Sadik-Zada and Ferrari (2020), environmental policy stringency (EPS) is one indicator that impacts imported carbon emissions. Weak environmental policy stringency (EPS) can cause carbon leaks (26).

3 Method

This research approach is quantitative research. Quantitative data analysis in this study uses the Eviews 12 test tool to test the research hypothesis. The data used in this research is panel data. The panel data in this study are carbon emissions, GDP per capita, trade openness, environmental policy stringency index, population, and renewable energy consumption. The data is obtained from official websites such as the Global Carbon Atlas, the World Bank, and the OECD. The data used comes from 6 BRICS countries, namely Brazil, Russia, India, China, and South Africa, with the period used from 1990 to 2020.

This research uses Fully Modified Ordinary Least Square (FMOLS) panel data analysis. FMOLS is an analytical tool that can see the long-term impact between the dependent and independent variables. FMOLS was first introduced by Philips and Hansen in 1990 to provide optimal analysis results for the model through cointegration in regression. This method modifies the OLS method by considering the impact of serial correlation/autocorrelation and endogeneity, which cannot be separated from the cointegration relationship. Analysis using the FMOLS panel can control endogeneity, serial correlation, and heterogeneity among individuals and produce consistent analysis (27). FMOLS has three estimators: pooled, pooled (weight), and group. In this study, FMOLS is pooled, which is the estimation for heterogeneity by using cross-section-specific estimates of the long-run covariance before the FMOLS estimates are pooled. This method is used based on research Nosheen (2020) (28) and Sultana (2023) (29), which, in general, form the regression equation as follows:

$Y = \alpha it + \beta X1it + \beta X2it + \beta X3it + \beta X4it + \beta X5it + \varepsilon it$ …………………...(3.1)

This study uses a semi-logarithmic equation, and the semi-logarithmic model is intended to handle data with abnormal distribution or heteroscedasticity and facilitate the interpretation of regression coefficients as percentage changes. The main advantage of using the model is that the estimation results are more stable. Next, the formulation is transformed into a logarithmic form with the following equation:

$LogCO2it = \alpha it + \beta 1LogGDPit + \beta 2TOit + \beta 3EPSit + \beta 4LogPOPit + \beta 5RECit + \varepsilon it$ ………(3.2)

Where LogCO2 is the logarithm of carbon emissions in BRICS countries at time t; LogGDP is the logarithm of GDP per capita in BRICS countries at time t; TO is the level of trade openness in BRICS countries at time t; EPS is the environmental policy stringency index in BRICS countries at time t; LogPOP is the logarithm of population in BRICS countries at time t; REC is the level of renewable energy consumption in BRICS countries at time t. FMOLS testing has several procedures, starting from the stationarity test using the Hadri test. Next is the cointegration test using the Kao Cointegration and classical assumption tests. After passing the Test, estimation was used using FMOLS, followed by the Wald test.

4 Results and Analysis

4.1 Stationarity Test

The tests carried out consist of the unit root test to determine the stationarity of data on variables dependent and independent, followed by the cointegration test for the model, which is said to be Fully Modified OLS (FMOLS) for a long balance period. This research uses the stationarity test, namely the Hadri Test. Where the variables are stationary, show a probability below 0.05.

Table 1. Stationery Test Result

Variable	Prob. (Levels)	Information
LogCO2	0.0000	Stationary
LogGDP	0.0000	Stationary
TO	0.0000	Stationary
EPS	0.0000	Stationary
LogPOP	0.0000	Stationary
REC	0.0000	Stationary

Source: Data processed Eviews 12, 2024

Based on the stationarity test in Table 1 using the Hadri Test, it shows that each variable has a probability < 0.05 or 5%. The probability result means the variables are stationary at a level, so all the variables are passed, and the FMOLS model can be used next.

4.2 Cointegration Test

The cointegration test is intended to determine whether there is a long connection period between dependent and independent variables. In research, the Kao test is used to determine whether there is cointegration between dependent and independent variables.

Table 2. Cointegration Test Results (Kao Test)

	t-Statistics	Prob.
ADF	-1889328	0.0294
Residual variance	0.000206	
HAC variance	0.000261	

Source: Data processed Eviews 12, 2024

Cointegration test results using the Kao test above shows that mark probability is under level 5% significance, meaning variables in the study, namely GDP per capita, trade openness, environmental policy stringency, population, and renewable energy consumption each other cointegrated and owned connection in long period. Therefore, those variables can fulfill terms and conditions and continue testing using the FMOLS method.

4.3 Classic Assumptions Test

Normality Test

This research uses the Jarque-bera test to see the normality of the data. The basis for deciding Jarque-Bear's probability test is If the probability value > alpha value, namely 5% or 0.05, then the data is usually distributed. On the other hand, if the probability <

0.05, then the data is not normally distributed. Normality test results in the study This can seen in Figure 3 below.

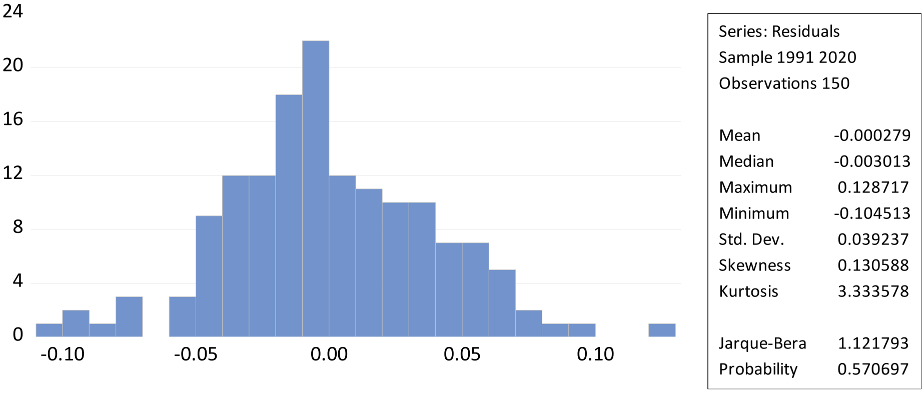

Figure 3. Normality Test Result

Source: Data processed Eviews 12, 2024

In Figure 3, the Jarque-Bera probability is equal to 0.570697 > 0.05, meaning that it is said to be an internal data study. The result indicates that the data is usually normally distributed.

Multicollinearity Test

On research, This uses Variance Inflation Factors (VIF) testing. The basis for deciding on VIF testing is no multicollinearity if the VIF value < 10. The research results on multicollinearity tests can be seen in Table 3 below.

Table 3. Multicollinearity Test Result

Variables	Coefficient of Variance	Uncentered VIF
LogGDP	0.007428	7.280464
TO	584E-07	1.987449
EPS	0.000382	5.201007
LogPOP	0.049981	2.543249
REC	6.54E-06	5.701530

Source: Data processed Eviews 12, 2024

Based on Table 3, it can be seen that Variance Inflation Factor (VIF) values throughout variable own < values are compared with 10. The result can be interpreted as the data not finding problems with multicollinearity or the data passing the multicollinearity test.

Heteroscedasticity Test

Testing heteroscedasticity aim in the regression model, inequality of variance happens from residual one observation to observation other. The good regression model is the one that does not happen heteroscedasticity. In research, this is a heteroscedasticity test using Harvey's Test.

Table 4. Heteroscedasticity Test Result

Variables	Coefficient	Std. Error	t-Statistics	Prob.
LogGDP	5.491220	4.036455	1.360406	0.1759
TO	-0.052179	0.035798	-1.457599	0.1472
EPS	-1.296672	0.914900	-1.417283	0.1586
LogPOP	18.55163	10.47051	1.771798	0.0786
REC	0.128289	0.119760	1.071218	0.2859

Source: Data processed Eviews 12, 2024

Based on Table 4, the probability of each variable having a value > 0.05 can conclude that variables are spared from symptom heteroscedasticity.

4.4 FMOLS Estimation Results

After escaping from testing stationarity and cointegration, the next step is to do FMOLS estimates. Testing this uses the pooled panel method. The study's FMOLS estimation results can be seen in Table 5.

Table 5. FMOLS Estimation Results

Variables	Coefficient	Std. Error	t-Statistics	Prob.
LogGDP	0.477685	0.086186	5.542493	0.0000
TO	-0.000234	0.000764	-0.306423	0.7597
EPS	-0.029306	0.019535	-1.500199	0.1358
LogPOP	1.289545	0.223565	5.768100	0.0000
REC	-0.006173	0.002557	-2.413947	0.0171

Source: Data processed Eviews 12, 2024

Based on Table 5, equality FMOLS estimates in the study can be obtained as follows.

$LogCO2 = 0.477685LogGDP – 0.000234TO – 0.029306EPS + 1.289545LogPOP – 0.006173REC + \varepsilon it$

Based on Table 5, the coefficient on the GDP per capita variable amounts to 0.477685 with a probability of 0.0000. The result shows that over a long period, GDP per capita positively impacts carbon emissions in the BRICS countries at a level of 5%. Therefore, If GDP per capita increases by 1 percent, carbon emissions will increase to

0.477 percent with a ceteris paribus assumption. The coefficient on a variable trade openness is -0.000234 with a probability of 0.7597. The impact of trade openness on carbon emissions is negative and insignificant levels authentic 5%. The condition shows that trade openness does not impact the carbon emissions in the BRICS countries.

Meanwhile, in the coefficient, the Environmental Policy Stringency variable is -0.029306 with a probability of 0.1358. The impact of the environmental policy stringency variable is negative and has an insignificant level of authenticity of 5%. The result shows that the environmental policy stringency variable does not impact carbon emissions in the BRICS countries. The population coefficient on variables amounts to 1.289545 with a probability of 0.0000. The result shows that population has a positive and significant impact on carbon emissions in the BRICS countries, which is at a level of 5%. Therefore, if the population increases by 1 percent, the carbon emissions will increase by 1,289 percent in a long period with the ceteris paribus assumption. The renewable energy consumption variable has a coefficient of -0.006173 with a probability of 0.0171. This shows that in the long-term, the renewable energy consumption variable has a negative impact and significant on carbon emissions in the BRICS countries at the level of 5%; therefore, if renewable energy consumption increases by 1 percent, carbon emissions will decrease by -0.006 percent in a long period with ceteris paribus assumption.

4.5 Statistic test

Coefficient Determination Test (R2)

Testing coefficient determination is done to know how much the far ability variable is independent of the explained variable. If the R-squared value of the results estimation approach is 1, the variable independent in the study is better at explaining the variable dependent. On the other hand, if the R-squared value of the results estimation approach is 0, the variable independent in the study's ability is limited in explaining the variable dependent. Following is the coefficient test results determination.

Table 6. Coefficient Test Results Determination (R2)

R-Squared	0.992784
Adjusted R-Squared	0.992320

Source: Data processed Eviews 12, 2024

Table 6 coefficient test results determination (R2) shows that the R-squared value is close to number 1, meaning that independent variables, namely GDP per capita, trade openness, environmental policy stringency, population, and renewable energy consumption, can explain variables dependent, that is, carbon emissions. As for 1 percent, others are explained by other variables outside the model.

Partial Test (t-statistical Test)

Testing t-statistics can done by comparing mark statistics on results calculation or average called t-statistics with t-table value or regularly called t-table at level authentic 5% or 0.05. The results of the t-statistical test comparison are as follows following.

Table 7. Results of the t-statistical test

Variable	t-stat	t-table	Conclusion
GDP per capita	5.542493	1.65514	Influential
Trade Openness	-0.306423	1.65514	No Impact
Environmental Policy Stringency	-1.500199	1.65514	No Impact
Population	5.768100	1.65514	Influential
Renewable Energy Consumption	-2.413947	1.65514	Influential

Source: Data processed Eviews 12, 2024

The table value amounts to 1.65514 based on the calculation of the results obtained. Table 7 shows that the variables of trade openness and environmental policy stringency have had no long-term impact on carbon emissions in the BRICS countries. In contrast, variables such as GDP per capita, population, and renewable energy consumption have had a long-term impact on carbon emissions in the BRICS countries.

4.6 Wald test

Wald test determines the extent of impact independent of and simultaneous to variables dependent on a study. In research, this level is accurate, 5% or 0.05. The following are Wald's test results for the study.

Table 8. Wald Test Result

Null Hypothesis: C(1) = 0, C(2) = 0, C(3) = 0, C(4) = 0, C(5) = 0

Statistical Tests	Value	Prob.
F-Statistics	117.2095	0.0000
Chi-Square	586.0476	0.0000

Source: Data processed Eviews 12, 2024

The Wald test results above show that the F-Statistic and Chi-Square probability is 0.0000 < 0.05, meaning variable independence is used in the study. This impacts the variable dependent. F-Statistic and Chi-Square values can be obtained by comparing the F and Chi-Square tables. If F table < F-statistic and Chi-Square> Chi-Square table, then the independent variable in the study together impacts the dependent variable. On research, this is F table of 2.43 < 117.2095 and Chi-Square of 586.0476 > 183.573. The result means that variables such as GDP per capita, trade openness, environmental policy stringency, population, and renewable energy consumption have an impact on carbon emissions in the BRICS countries.

4.7 The Impact Of GDP Per Capita On Carbon Emissions In The BRICS Countries

This study's findings align with the research hypothesis that GDP per capita can positively affect carbon emissions in the long run. The results align with the STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) theory, which states that GDP per capita as affluence affects environmental quality. An increase in GDP per capita indicates a higher level of energy consumption because more affluent people have greater access to goods and services that require energy use. This need for energy generates carbon emissions, so an increase in GDP per capita can increase carbon emissions.

This study's results align with the research of Sarkodie and Strezov (2019), who found that GDP per capita affects carbon emissions (30). Starting from the early stages of economic development, low industrialization, and economic growth levels result in relatively low intensity of natural resource use. As a result, environmental damage tends to be more limited because the impact of the economy on the environment is still limited. However, as economic development increases, there is an increase in the intensity of natural resource use and more significant industrial activity, which can lead to increased environmental damage. The result is also supported by research by Q. Wang & Li (2021), who found that GDP per capita has a more significant effect on carbon emissions in developing countries than the effect of GDP per capita on carbon emissions in developed countries (31). The research result also shows that the negative impact of economic development on the environment in developing countries is more significant. As is the case in BRICS countries, which are developing countries, BRICS countries are still undergoing industrialization. The secondary sector, especially the industrial sector, is still one of the drivers of economic development in BRICS countries. According to the World Bank, industrial value added (including construction) accounts for 31.29% of total GDP in BRICS countries. The value-added industries of China and Russia account for >49% of the total compared to other BRICS countries. In the process, from developing to developed countries, economic growth will exacerbate carbon emissions.

4.8 The Impact of Trade Openness to Carbon Emissions in The BRICS Countries

The findings result in a study that is not the same as the hypothesis in a study that says that variable trade openness has a positive impact on carbon emission over a long period. Findings Neither do in line with the results of research conducted by Wang & Zhang (2021), stated that trade openness impacts carbon emissions (32). However, the research results by Sun et al. (2019) explain that trade openness in connection with equilibrium period length and relationship causality has no influential significance in carbon emission (33). Research result This is also supported by research by Mahmood et al. (2019), which states that trade openness has no impact on carbon emissions (34). This matter can happen because carbon emission has no impact in a way that directly contributes to enhancing carbon emission. Some studies show that trade openness can push technology transfer and improve efficiency in production. In the long term, enhanced efficiency products can reduce carbon emissions per unit of output. Not only that is it, it is trade openness that gives countries more access to green technology that can help reduce carbon emissions.

The research results do not confirm the theory that previously stated that trade openness could impact and improve carbon emissions. This matter can happen because of the impact of trade openness. A country gets technology transfer and a new, more friendly environment from trade openness carried out by a country (35). Trade Openness makes access to the global market possible, increasing Power competitiveness and accelerating technology transfer green from developed countries. By adopting green and sustainable technology, the BRICS countries can increase efficient production, reduce carbon emissions, and manage sources of natural power more wisely. This matter helps fulfill the international commitment to change the climate and creates innovation and sustainable development opportunities. Thus, a combination of open trade and adopting a technology-friendly environment is a strategic step for increasing awareness about activity sustainability and ensuring production growth, an inclusive economy, and sustainability for the BRICS countries.

4.9 The Impact of Environmental Policy Stringency on Carbon Emissions in The BRICS Countries

The findings of this study are not based on the hypothesis that the environmental policy stringency variable impacts carbon emissions in the long run. The research result finding also differs from S. Li et al. (2023), which state that stringency in environmental policy impacts carbon emissions (36). However, this study is based on the research of Chen et al. (2022), which states that environmental policy stringency does not affect carbon emissions in both the short and long term (37). Wolde-Rufael and Weldemeskel (2020) also support this research, which states that stringent environmental policy reduces carbon emissions (38). Research by Ahmed (2020) and Sezgin et al. (2021) also discuss similar things regarding environmental policy stringency variables that can result in reduced carbon emissions (39,40). Stringent environment-related policies and regulations focus on clean energy, environmental taxes, and environmental management policies. The environmental policy stringency mechanism is based on regulations and rules that raise the costs of polluting agents. Thus, businesses and companies can implement preventive measures to control carbon emissions. Correspondingly, the consumption of polluting products also decreases. The existence of stringent environmental policy can also encourage environmentally friendly technologies that are useful for improving environmental and economic performance.

4.10 The Impact of Population on Carbon Emissions in The BRICS Countries

The discovery of results shows the same thing as the hypothesis of the main study. The population has a positive impact on carbon emissions in the long run in the BRICS countries. Research results of the STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) theory explain that the population has an impact on environmental quality. Classical theory shows that with a more significant population, increasing pressure is placed on the source power of nature and ecosystems.

The research result is also in line with research by Amer et al. (2024), who show that population and CO2 emissions have a positive and significant impact (41). Findings align with the theory that population enhancement and energy use for final production contribute to improving CO2 emissions. In their research, Xing et al. (2023) find that population impact positively affects carbon emissions (42). This matter hinted at the effect of the utilization of source Power. It also increases the number of residents, making it more necessary for many transportation and flight services. Research by Hargrove et al. (2019) also stated that the coefficient representing the total population relates to enhancement emission of carbon. The result shows that the need for enhancement and source power can contribute to carbon emissions (43).

4.11 The Impact of Renewable Energy Consumption on Carbon Emissions in The BRICS Countries

The research produces appropriate findings with the hypothesis that renewable energy consumption can impact negative emission carbon for a long period. The research result is based on the STIRPAT theory (Stochastic Impacts by Regression on Population, Affluence, and Technology), which states that variable renewable energy consumption as technology impacts environmental quality.

Research results are in line with research by Sheng Li et al. (2023), Awan et al. (2022), and Zeyun Li et al. (2022), which state that renewable energy consumption variables have an impact negative on the emission of carbon (36,44,45). These results were also supported by research by Ashraf et al. (2023), which states that the coefficient from renewable energy consumption variable negatively affects the effect of CO2 emissions in BRI countries (46). The life energy consumption cycle is renewable and produces few CO2 emissions. BRI countries push renewable energy development by enforcing the Constitution and several supporting legislation. Findings show that energy consumption is a worthy alternative to material-burning fossil and reduces CO2 emissions in BRI countries. The results show that the Government must use renewable energy to reduce carbon emissions. When the economy switches from source pollution to an energy-friendly environment, CO2 emissions will also be reduced. Wolde-Rufael and Weldemeskel's (2020) research shows results about the connection between variable energy renewables and CO2 emissions in prolonged energy consumption; renewables are influential and significant in carbon emissions [37]. Consumption of energy is beneficial for a quality environment. Enhancement consumption of energy can become an effective policy for increasing the quality of the environment.

5 Conclusions

This study aims to analyze the impact of GDP per capita, trade openness, environmental policy stringency, population, and renewable energy consumption in BRICS countries in the long run using panel data from 1990-2020. This research uses the FMOLS analysis tool to see the impact in the long run. The results show that GDP per capita and population variables positively and significantly impact carbon emissions in BRICS countries in the long run. Any increase in GDP per capita and population will increase carbon emissions in the BRICS countries. Renewable energy consumption variables negatively and significantly impact carbon emissions in the BRICS countries in the long run. This means that any increase in renewable energy consumption decreases carbon emissions in BRICS countries in the long run. Based on the STIRPAT theory, which states that GDP per capita is affluence, population, and renewable energy consumption as technology impacts environmental quality. At the same time, the variables of trade openness and environmental policy stringency do not impact carbon emissions in the BRICS countries.

The governments of the BRICS countries must integrate policy development sustainability into the economic agenda. In addition, a trade openness policy must cover a strict environment to prevent damage to the ecosystem. The Government needs to review and strengthen the return of existing regulations and ensure that the implementation policy is green and more suitable. Provisioning green infrastructure, transportation, and an efficient public are also prioritized. Government needs to give incentives and support for the development of energy. Education and campaigns awareness public about the benefits of energy must expanded. Society must push for a daily switch to a more energy-friendly environment.

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