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Testing the Environmental Kuznets Curve Hypothesis Test: A Case Study of BRICS Countries

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Abstract

The world's environmental crisis is a growing concern. Carbon dioxide is the most dominant greenhouse gas causing major climate change and global warming through human activities, including economic activities. This study aims to test the EKC theory in BRICS and the independent variables of exports, Foreign Direct Investment (FDI), and renewable energy consumption. Research method using the Pooled Mean Group method ARDL (1990-2022). The results show that the EKC hypothesis is proven in BRICS and forms an inverted U curve in the long run. Export has a positive effect in the long run. FDI has a positive effect in the long run. Energy consumption has a negative in the long run.

Keywords: EKC, Export, FDI, Renewable Energy Consumption, Autoregressive Distributed Lag

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INTRODUCTION

The global environmental situation is becoming increasingly serious. Starting with the industrial revolution, fossil fuel combustion activities resulted in a major increase in greenhouse gas emissions. Every year, commodities production, energy generation, transportation, agriculture, and building heating and cooling emit an average of 51 billion tonnes of greenhouse gases into the environment (Leal & Marques, 2022)

According to the Intergovernmental Panel on Climate Change (IPCC), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O),

and fluorinated gases (F) are the primary gases responsible for the greenhouse effect. In 2019, greenhouse gas emissions increased by 12% compared to 2010 and 54% compared to 1990 levels (Ritchie *et al.*, 2020).

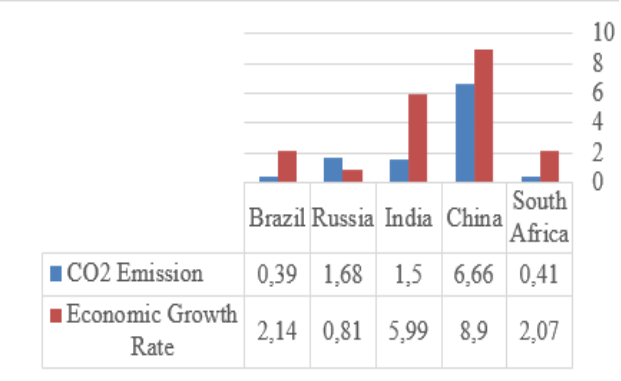
Carbon dioxide emissions differ between developed and developing countries. Prior to 2012, affluent countries often had higher per capita emissions than underdeveloped countries. The contrary is true: from 2012, emerging countries began to catch up and absorb more global CO_2 emissions. Developing countries now account for more global CO_2 emissions than industrialized countries, and this trend is accelerating. Several reasons can contribute to an increase in CO_2 emissions, including rapid economic expansion in developing countries, increased energy consumption due to high population, and continued reliance on fossil fuels (Meng *et al.*, 2023).

CO_2 emissions from a country can be classified according to its per capita income. Developed (high income) and upper-middle income (upper-middle income) countries create more emissions than the global population combined. According to reports, the poorest countries (lower-middle income) contribute less than 1% of global emissions, while lower middle class and low income countries emit less than 20%. (Ritchie, 2023).

According to Majewski *et al.* (2022) research, middle-income countries experienced the greatest growth in CO_2 emissions, increasing by over 130% between 1960 and 2016. Compared to high-income countries, member countries of the Organization for Economic Cooperation and Development (OECD) had increases of 40% and 25%, respectively.

Among middle-income countries participating in international organizations, one is BRICS (Brazil, Russia, India, China, and South Africa). According to the 2019 World Bank economic report, China's Gross Domestic Product (GDP) is USD 12.23 trillion, making it the world's second largest economy. India ($2.65 trillion), Brazil ($2.05 trillion), and South Africa ($351.4 billion).

China is the world's largest emitter of CO_2, accounting for 30% of worldwide emissions. India contributed 4.71%, Brazil 1.29%, and South Africa 1.09% to global CO_2 emissions. According to these numbers, these four countries account for around 37% of global carbon emissions and make major contributions to climate change, global warming, and environmental damage (Juan lin *et al.*, 2021).



	Brazil	Russia	India	China	South Africa
CO2 Emission	0,39	1,68	1,5	6,66	0,41
Economic Growth Rate	2,14	0,81	5,99	8,9	2,07

Figure 1. Average Annual CO_2 Emissions (Billion Tons) and Economic Growth Rate (Percent) in BRICS Countries 1990-2022
Source: World Bank, 2023

The Environmental Kuznet Curve (EKC) hypothesis can explain the occurrence of BRICS countries seeing high economic growth in proportion to high CO_2 emissions. According to the EKC hypothesis, the relationship between economic growth (measured by GDP) and CO_2 emissions varies with economic development.

Economic progress during the early stages of industrialization will be accompanied by

increased environmental damage. When an economy reaches a given stage of growth, the higher the GDP per capita, the lower the CO_2 emissions. When illustrated, the hypothesis creates an inverted U curve (Panayotou, 2003).

Exports contribute significantly to a country's economic prosperity. Increased export activity leads to stronger economic growth, which can subsequently drive improvements in the sectors of sustainability and environmental quality. Economic expansion can eventually have environmental implications because of enhancing the quality of exports through changes in the energy mix and transportation. (Trinh *et al.*, 2022).

According to World Bank data, BRICS exports were only 50.2% of GDP in 1990. This figure will rise to 191.8% of GDP by 2022. This shows how the BRICS countries have developed into major players in global trade. This increase in exports occurred for a variety of causes, including trade liberalization, industrialization, and economic prosperity.

Aside from exports, Foreign Direct Investment (FDI) can boost GDP per capita. The growing process of globalization has an impact on the expansion of multinational corporations and increased commerce in capital commodities. FDI has various effects on environmental quality. The Pollution Haven Hypothesis and Pollution Halo Hypothesis are two theories that link foreign direct investment and environmental quality.

According to the Pollution Haven Hypothesis, foreign direct investment (FDI) will reduce environmental quality. According to the Pollution Halo Hypothesis, FDI can improve environmental standards in host countries (Silvia et al., 2021). FDI has become a major driver of economic growth in many developing countries. FDI levels in several emerging countries have surpassed those of the larger OECD countries. Investment in emerging countries will increase by 4% in 2022. According to World Bank data, the FDI trend in BRICS countries from 1990 to 2022 is increasing, with the lowest amount occurring in 1990, at 10.8% of GDP, and the maximum amount occurring in 2022, at 60.2% of GDP. This growth shows that BRICS countries are appealing to overseas investors.

Renewable energy is one approach to reducing greenhouse gas emissions, particularly CO_2. Reducing CO_2 emissions attempts to create a greener, more sustainable planet. The United Nations proposes that the Sustainable Development Goals (SDGs) be fulfilled by 2030. This program emphasizes the urgent need for inexpensive and clean energy, comprehensive and sustainable economic growth, and technological innovation in the fight against climate change. (Samour et al., 2023).

According to the United Nations' official statistics page, developing has expanded renewable energy production capacity at a rapid pace, with a compound annual growth rate of 9.6% between 2016 and 2021. In BRICS, China, and Africa, the South uses less renewable energy. In contrast, Brazil has made great success in this endeavor.

Grossman & Krueger (1991) use the Environmental Kuznets Curve (EKC), based on Simon Kuznets' (1955) theory, to explain the inverted U-shaped link between environmental quality and economic progress. They used environmental indicator variables such as urban air pollution concentrations, measures of oxygen regime conditions in river watersheds, concentrations of fecal contaminants in river watersheds, and river flow concentrations in

their essay "Economic Growth and the Environment".

It demonstrates the presence of an inverted U-curve between per capita income. These data indicate that as per capita wealth rises, environmental impact will gradually diminish. This is the influence of raising public awareness of environmental improvement.

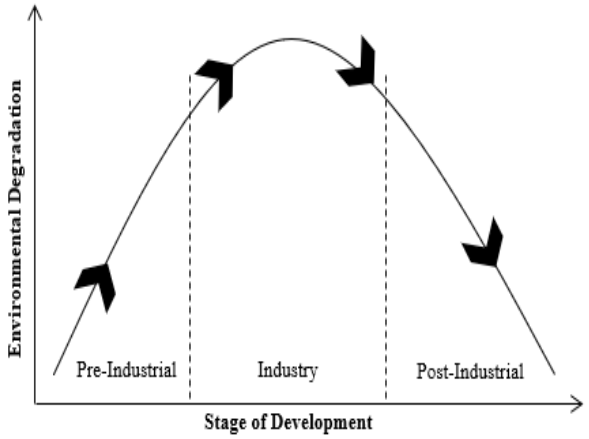


Figure 2. The Relationship between Economic Growth and the Environment
Source: Panayotou, 2003

Figure 2 depicts the relationship between economic growth and environmental quality, which begins in the pre-industrial age with low levels of development. Environmental deterioration reaches its climax as economic development progresses to the industrial stage. This phenomenon occurs in wealthy nations. Higher levels of economic growth lead environmental degradation to gradually reduce as a result of structural changes toward service- and information-based businesses, more efficient technology, and rising environmental standards (Panayotou, 2003).

Globalization has an impact on capital goods trade and multinational company expansion. Foreign direct investment (FDI) may have a negative environmental impact. According to the Pollution Haven Hypothesis, multinational corporations with significant levels of pollution will relocate to developing countries with laxer environmental rules in order to save pollution-related expenditures (Santiago *et al*., 2021).

According to recent studies, FDI flows can also help to reduce CO_2 emissions through technological advancements and more ecologically friendly production processes. This phenomenon is referred to as the Pollution Halo Hypothesis. According to the Pollution Halo Hypothesis, foreign direct investment can be leveraged to deliver new and clean technologies to host countries, resulting in a cleaner environment (Rahman *et al.*, 2019).

RESEARCH METHODS

This research uses a quantitative approach. The Pooled Mean Group ARDL method is used to analyze the influence of GDP per capita, FDI exports, and renewable energy consumption on CO_2 emissions in the short and long term over the period 1990 to 2022. The data used in this research comes from the official World Bank and Our World websites. in data, then processed using Eviews 12 software.

The stages in ARDL analysis includes first, stationarity test to determine whether there is a unit root in the time series data using the Augmented Dickey Fuller (ADF) method. Second, cointegration test to determine whether two or more time series have a cointegration relationship using the Kao Residual Cointegration Test technique.

Third, determining the optimum lag to determine the research model using the Akaike Information Criteria (AIC) method. Fourth, short and long term estimates to determine the

effect of each independent variable on the dependent variable through the t-statistical test. The short-term econometric model equation is as follows:

$$\Delta CO2_t = \alpha_0 + \Sigma_{e=1}^{n} a_{1e}\Delta CO2_{it-1} + \Sigma_{e=1}^{n} a_{2e}\Delta YCAP_{it-1} + \Sigma_{e=1}^{n} a_{3e}\Delta YCAP2_{it-1} + \Sigma_{e=1}^{n} a_{4e}\Delta EXP_{it-1} + \Sigma_{e=1}^{n} a_{5e}\Delta FDI_{it-1} + \Sigma_{e=1}^{n} a_{6e}\Delta REC_{it-1} + \varepsilon t$$

The following is the econometric model equation for the long term:

$$CO2_t = \beta_0 + \theta_2 YCAP_{it-1} + \theta_3 YCAP2_{it-1} + \theta_4 EXP_{it-1} + \theta_5 FDI_{it-1} + \theta_6 REC_{it-1} + \mu t$$

Where Δ is lag; CO_2 is Carbon Dioxide (CO_2) emission per capita; YCAP is GDP per capita; YCAP2 is GDP per capita2; EXP is export; FDI is Foreign Direct Investment; REC is Renewable Energy Consumption; εt and μt is Error term; Coefficient a_{1e}+ a_{6e} is Short term dynamic relationship model and Coefficient θ_1+θ_6 is Long term dynamic relationship model.

After that, a decision is made whether an inverted U curve has occurred in the EKC analysis. If the probability values of YCAP and YCAP2 are less than 0.05, then the YCAP coefficient value must be positive and the YCAP2 coefficient value must be negative.

RESULTS AND DISCUSSION

Based on the results of the level stationarity test in table 1, only two variables are stationary, namely CO_2 and exports. Therefore, a stationarity test was carried out at the first difference level and the results obtained were that all variables were stationary.

Figure 3 presents the results of the Kao Residual Cointegration Test with a probability of 0.0000 and less than the significance level α = 5%. Thus, it can be said that there is cointegration in this research. The existence of a cointegration relationship shows that the variables studied have a sustainable relationship.

Table 1. Stationarity Test Result

Variables	Level	Exp.	1st Diff.	Exp.
CO_2	0,0021	Stationary	0,0000	Stationary
YCAP	0,9873	Non - Stationary	0,0000	Stationary
YCAP2	0,9661	Non - Stationary	0,0000	Stationary
EXP	0,0252	Stationary	0,0000	Stationary
FDI	0,1827	Non - Stationary	0,0000	Stationary
REC	0,9922	Non - Stasioner	0,0000	Stationary

Source: Data Processed, 2023

Figure 4 shows that the ARDL model (2,2,2,2,2,2) is the optimum lag or best model for this research. This model produces the smallest AIC value so it can be chosen as a research model.

The EKC hypothesis predicts an inverted U-shaped relationship between economic growth and environmental degradation. Based on the short-term estimation results, the coefficients of GDP per capita and GDP per capita squared are positive with a probability value exceeding the significance value.

From these results it can be concluded that the EKC hypothesis does not apply to BRICS in the short term. Furthermore, the COINTEQ coefficient was negative with a probability value less than the significance value, so it can be concluded that there is a relationship between the short term and the long term in this research. Based on the long-term estimation

results, a positive coefficient of GDP per capita and a negative coefficient of GDP per capita squared were obtained with probability values for both being less than the significance value. From these results it can be concluded that the EKC hypothesis applies to BRICS in the long term.

	t-Statistic	Prob.
ADF	-5.329986	0.0000
Residual variance	0.121309	
HAC variance	0.248561	

Figure 3. Kao Residual Cointegration Test Result
Source: Data Processed, 2023

This finding is in line with the EKC hypothesis which describes an inverted U curve where until it reaches the turning point, an increase in GDP per capita will be followed by an increase in environmental degradation. After reaching this peak point, there will be a decrease in environmental degradation and an increase in GDP per capita.

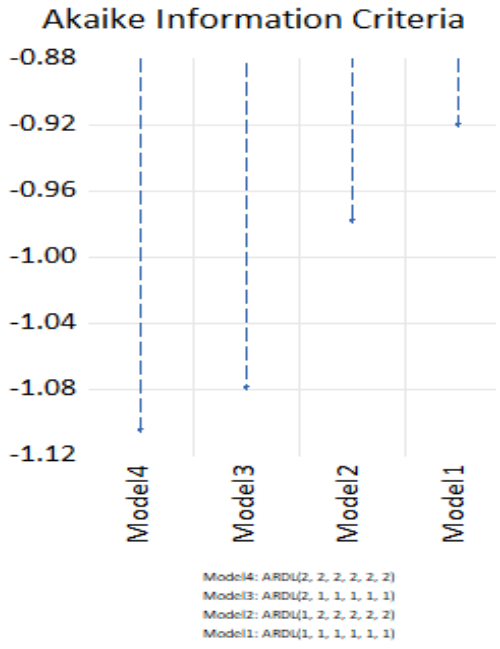


Figure 4. Lag Optimum Determination
Source: Data Processed, 2023

The findings of this study are consistent with those of Alkan & Bulut (2022) in Türkiye. The income elasticity coefficient in the short term is smaller than the elasticity coefficient in the long term, indicating that the EKC hypothesis holds true in the long term but not in the short term.

Table 2. ARDL Results in Short Term

Variables	Coefficient	t-Statistic	Prob.
COINTEQ01	-0,264209	-2,368584	0,0199
D(CO2(-1))	0,008567	0,053283	0,9576
D(YCAP)	0,160833	0,922509	0,3586
D(YCAP(-1))	0,192851	0,669258	0,5050
D(YCAP2)	0,034865	0,758974	0,4497
D(YCAP2(-1))	0,012069	0,285681	0,7757
D(EXP)	0,017778	1,054285	0,2944
D(EXP(-1))	0,016718	0,584754	0,5601
D(FDI)	0,033419	1,087251	0,2797
D(FDI(-1))	-0,005836	-0,174697	0,8617
D(REC)	-0,295599	-0,742832	0,4594
D(REC(-1))	-0,137294	-0,423196	0,6731
C	1,539492	1,337952	0,1841

Source: Data Processed, 2023

Dkhili (2023) research yielded comparable results, revealing that the EKC was implemented in Central Asia and North Africa (MENA) countries. CO_2 emissions are demonstrated to increase during the first phase of economic expansion before steadily falling after per capita income reaches a particular threshold.

The BRICS countries are developing countries that face the challenge of lowering carbon emissions and have a lot of potential for energy cooperation. The BRICS countries have launched a number of programs and collaborative efforts aimed at improving green energy development in the hunt for sustainable energy options. According to the official BRICS

website, one of the major projects is the establishment of the BRICS Energy Research Cooperation Platform.

The platform functions as a hub for collaborative research and development of renewable energy solutions. The BRICS also established the New Development Bank (NDB), which finances renewable energy installations and other sustainable infrastructure projects. The NDB uses green finance efforts to fund renewable energy projects such as solar parks, wind farms, and hydroelectric power plants.

Table 3. ARDL Results in Long Term

Variables	Coefficient	t-Statistic	Prob.
YCAP	0,427258	9,037650	0,0000
YCAP2	-0,016525	-5,876203	0,0000
EXP	0,044075	6,683215	0,0000
FDI	-0,181438	-4,136302	0,0001
REC	-0,382369	-2,932643	0,0042

Source: Data Processed, 2023

According to the estimates, exports have a positive long-term impact on CO_2 emissions. These findings are consistent with Rahman *et al.* (2021), who discovered that exports have a positive impact on CO_2 emissions in Newly Industrialized Countries (NICs). Wang *et al.* (2023) found similar results, with export results positively affecting China's CO_2 emissions. Increasing a country's exports boosts domestic output, which often leads to higher energy consumption, particularly fossil fuels, and carbon emissions. As a result, carbon emissions connected with making and shipping export goods and services grow, potentially increasing global CO_2 emissions.

Brazil, Russia, India, and China (BRICS) were designated as exporting countries in 2005. The BRICs' average carbon intensity was four times that of the US economy. BRIC output and emissions have increased as the United States and industrialized countries rely more on these developing countries for finished items like solar panels and clothes, as well as raw commodities like steel and gasoline. As a result, BRIC countries account for 90% of the rise in global emissions since 2005.

The BRIC countries' combined exports to the world amount to USD 4 trillion. In 2018, BRIC exports produced 3 billion metric tons of CO2 at a high carbon intensity. Meanwhile, South Africa is ranked 34th in the globe, with a total export value of USD 143 billion in 2021. South Africa's exports and imports of goods and services account for 31.19% and 25.02% of GDP, respectively (Sykes, 2022)

BRICS has developed a number of strategies to limit CO_2 emissions caused by exports. BRICS has implemented a carbon pricing program to encourage enterprises to minimize carbon emissions in both the manufacturing of export commodities and the importing countries where these items are consumed.

According to the official website of the South African Revenue Service, South Africa began implementing a carbon tax in 2019. In the first stage, the carbon tax rate was R120 (USD 11.20) per ton of CO_2 equivalent emissions. The rate will rise annually in line with inflation. A carbon tax ensures that firms and consumers consider the negative effects (externalities) of climate change when making decisions about future production, consumption, and investment (SARS, 2023).

According to short-term estimation results, FDI has little impact on CO_2 emissions. This finding is consistent with studies by Liu & Lai (2021) who discovered that FDI had no

influence on carbon emissions in 134 nations. The outcomes of this study indicate that the Pollution Haven Hypothesis does not apply to the BRICS in the short run. In contrast, Santiago *et al*. (2021) apply the Pollution Haven Hypothesis to Latin American countries. An increase in FDI will result in an increase in CO_2 emissions through energy demand, so that CO_2 emissions in the energy sector rise in proportion to rising energy demand.

Long-term estimates yield different results, indicating that FDI has a negative and large impact on carbon emissions. This finding is consistent with Mert & Caglar (2020) research, which demonstrated that FDI can lower Turkey's CO_2 emissions over time.

The outcomes of this study demonstrate the long-term validity of the Pollution Halo Hypothesis in BRICS countries, where FDI can be used to promote environmental sustainability. This suggests that increased FDI will result in decreased CO_2 emissions. Increasing FDI has the ability to improve efficiency and technology, thereby lowering CO_2 emissions.

The conclusions of this study have important implications for sustainable development policy. FDI can help cut CO_2 emissions. This condition is explained by the increasing expansion of FDI, as multinational corporations shift to more environmentally friendly areas and provide more environmentally friendly technologies to BRICS countries.

This will ultimately result in increased FDI inflows, lower pollution levels, and the implementation of environmentally friendly technologies in industrial processes while lowering carbon emissions. The government's methods of attracting FDI include incentives and investment facilitation. (Venkatraja, 2022).

According to the estimated results, renewable energy usage has a negative long-term impact on CO_2 emissions. These findings are consistent with Majewski *et al.* (2022) research, which demonstrated a negative link between renewable energy use and CO_2 emissions in middle-income nations. Minh *et al.* (2023) discovered that renewable energy use has a negative impact on CO_2 emissions in Vietnam. Dkhili (2023) discovered a similar link between renewable energy use and CO_2 emissions in Central Asian and North African (MENA) countries.

In 2021, China's installed renewable energy capacity exceeded one billion kilowatts; China's energy consumption intensity per unit of GDP declined by 26.2% compared to 2012; and the country contributed to 25% of the global net growth in green land areas (BRICS, 2022). According to the International Trade Administration's official website, Brazil has one of the cleanest energy networks in the industrial world and uses the most electricity from renewable sources among the BRICS countries. Renewable energy sources account for 89% of total electricity generation in the country (ITA, 2023).

Russia remains committed to achieving the Convention's and the Paris Agreement's goals. Russia believes it will be carbon neutral by 2060. Russia is constructing the infrastructure required to generate hydrogen, which will be utilized as an energy source and raw material (BRICS, 2022). India has taken tremendous steps to meet and even surpass the Paris Agreement's baseline NDCs. India has made bolder climate pledges, promising to attain net zero emissions by 2070, cut the carbon intensity of the economy by 45% by 2030, and use 50% of its installed power capacity from non-fossil fuel sources,

reaching 500 GW in the same year (BRICS, 2022).

In South Africa, coal-fired power stations generate around 42,000MW or 85% of total electricity production. The utilization of renewable energy sources is predicted to grow significantly. Therefore, the government is lowering the restrictions for domestic producers of solar modules (ITA, 2024).

CONCLUSION

The Environmental Kuznet Curve (EKC) hypothesis in BRICS is not proven in the short term, but there is the formation of an inverted U curve. in the long term. This is thought to be because BRICS members have begun to focus on overcoming the environmental crisis, including reducing CO_2 emission levels.

BRICS country governments need to optimize the policies or programs that have been created, such as diversification of energy sources and sustainable economic growth. BRICS can also work together with other countries to overcome the problem of environmental degradation, including reducing carbon dioxide emission levels.

Exports have no immediate impact on CO_2 levels, but they have a large long-term benefit. This long-term influence is assumed to be because during the export process, BRICS countries continue to rely on the use of fossil fuels. Members of the BRICS group of countries should boost low-carbon production and exports. Aside from that, governments in BRICS nations can also enforce carbon tax policies on exports.

FDI has no influence on CO_2 emissions in the short term. However, FDI has a major detrimental long-term effect. This is suggested because increased FDI produces a decrease in CO_2 emission levels in BRICS due to the optimization of FDI funding for environmentally friendly programs. 3. BRICS countries governments can use funds from foreign direct investment to reduce carbon dioxide emissions, such as providing subsidies to business actors who use green technology during production, as well as to conduct research on clean technology development.

Renewable energy usage has no immediate effect on CO_2, but has a considerable negative impact in the long run. This long-term effect is assumed to be due to the fact that renewable energy usage produces less residual in the form of CO_2, and renewable energy use is increasing in the BRICS countries. BRICS can minimize its reliance on fossil energy during the export process from production to distribution and needs to increase the use of renewable energy such as solar, wind, nuclear, and others.

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