International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2025, 15(4), 525-536.

Navigating Environmental Challenges in BRICS+ Nations: The Impact of Economic Growth, Globalization, and Urbanization on Environmental Performance

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Received: 17 January 2025 **Accepted:** 16 May 2025 **DOI:** https://doi.org/10.32479/ijeep.19294

ABSTRACT

Globalization has sparked significant environmental and social challenges. While extensively debated, the exact nature of these environmental issues remains contentious. This paper seeks to enhance understanding of the economic factors influencing environmental quality, measured by the Environmental Performance Index (EPI), a comprehensive metric surpassing traditional pollutant emission indicators. The study examines how economic growth, globalization, and urbanization influence environmental performance in BRICS+ nations—comprising Brazil, Russia, India, China, South Africa, and additional emerging economies, including Argentina, Egypt, Ethiopia, Iran, Saudi Arabia, and the UAE. Using panel data from 1995 to 2022 and econometric modeling, the analysis explores the effects of these key drivers on environmental outcomes such as carbon emissions, resource utilization, and pollution levels. The findings reveal that economic growth and globalization often exacerbate environmental degradation, while urbanization exhibits mixed effects. In some contexts, urbanization improves environmental conditions through enhanced infrastructure and policy implementation, while in others, it intensifies pollution and resource stress. These results underscore the dual challenge faced by BRICS+ nations: advancing economic development while ensuring environmental sustainability. The study emphasizes the need for targeted policies that address the specific environmental consequences of growth, globalization, and urbanization, offering actionable insights for policymakers striving to align economic modernization with sustainable practices in emerging economies.

Keywords: Environmental Performance Index, Economic Growth, Economic Globalization, New Information and Communication Technologies, BRICS countries

JEL Classifications: Q56, O47, F63, O57

1. INTRODUCTION

For decades, conferences on the environment and development have followed one another. From Stockholm in 1972 to Rio in 1992, the Earth Summit called Rio+20, to the latest UN international conferences called the Conferences of the Parties (COP28 organized in the United Arab Emirates in 2023) and COP29, which has just been organized in Baku, Azerbaijan, from November 11 to 22, 2024.

However, the question of "sustainable development," precisely economic activities without harmful effects on the environment, has not yet been resolved. On the contrary, the situation seems more dramatic today, and the environment, which was the first wealth of human beings, has become its victim. Nature, being the primary source of supply, has become threatened.

At the same time, economic enrichment has experienced an exponential boom. Also, international trade has gained momentum through the establishment of a specific institutional framework (the WTO in the mid-1990s) to eliminate barriers and implement free trade agreements. This globalization is not without effects on the environment and the stability of the ecosystem.

Multiple globalization is accused of being one of the causes of ecological imbalances. The problems of pollutant emissions and the depletion of natural resources are exacerbated. Various types of effects can be highlighted. However, the economic studies carried out suffer from a serious shortcoming in using a simple indicator. This paper uses a composite indicator reflecting various facets of environmental quality, namely the environmental performance index.

Indeed, countries in the South are accused of having less environmentally friendly practices. In addition, the environmental good is a superior good demanded more by high-income households. This accusation could be unfair knowing that the South considers itself to have a comparative advantage in labor-intensive goods, the most abundant factor. It would then be the exporter of the cleanest goods. On the other hand, the North is relatively richly endowed with capital, the factor that generates pollution.

The BRICS countries that are the subject of this study constitute a group of countries richly endowed with natural resources (oil deposits, natural gas, phosphates, etc.) and which are often overexploited. The countries are thus exposed to the amplification of environmental risks.

In this context, we ask the following research question: What is the impact of economic growth, various globalizations, and urbanization of the BRICS countries on the quality of the environment? From this question, the objective of the article arises, which is specifically to analyze and evaluate the links between economic growth, economic and informational globalizations as well as urbanization and this group of countries on their environmental performance index (EPI). The environmental Kuznets curve hypothesis outlines these links.

After this introduction, which constitutes the first section, the rest of this article is structured as follows: The second section reviews the existing literature. The third section presents the methodological framework used. The fourth section presents the different results obtained and the discussions that follow, and the fifth section concludes this work.

2. THEORETICAL BACKGROUND

2.1. “Ecological” Comparative Advantages

The harmony between ecology and the economy goes back to the ancestral schools of economic thought. The classical theory considers wheat, cloth, wine, etc. They are products of nature, and on which the Ricardian analysis of foreign trade is based (Chapter VII). Cloth is the specialized good of England and wine for Portugal. Also, according to the expression of the physiocratic economists, “nature is the mother of all goods.” Nature is, thus, the exclusive source of all wealth. This is also the case with the mercantilists who exalt the foreign trade of spices, precious metals, etc. All are products of nature. With these three schools of economic thought, the structure of each country’s foreign trade and its specialization are determined by ecological factors in the broad sense: “...each country producing those commodities for which by its situation, its climate, and its other natural or artificial advantages, it is adapted, and by their exchanging them for the commodities of other countries,…” (Ricardo, 1821; p.136-137). A link between ecology and free trade is then highlighted in the sense that nature has long been the primary source of production and exchange of products.

It is obvious that the debate on the ecological environment and economic activity began with early economic thought. It is currently, in the era of globalization, increasingly lively. This question of the link between globalization in the broad sense and the environment, as well as the reciprocal repercussions, remains a controversial question. One obvious fact worth repeating is that the economy always needed nature; today it needs to be respected.

Indeed, the differences in economic and ecological characteristics between countries are undeniable (the type and level of emissions emitted, the biophysical characteristics of natural environments, the capacities for assimilating pollutants, etc.). They generate differences in the environmental standards applied, which are severe in some countries and more lenient in others (generally developing countries). On this basis, economists speak of an “ecological” comparative advantage. Which is created by rational decisions and consists of manipulating environmental policies by an open country in order to protect its economy and/or promote the competitive situation of domestic companies. On the one hand, the protection of the national economy from external competition can be ensured by the adoption of rigorous environmental regulations. They make it possible to create barriers to the entry of imported products unable to comply with national standards. This setting of environmental standards at a high level, even beyond national collective preferences, is described as an “ecological overbidding.” It corresponds to disguised protectionism, reducing international trade.

On the other hand, the absence of environmental regulations or their laxity in certain countries exempts national companies from part of the external cost, linked to the environment, generated by their activities. This favor creates unfair competition. It is a strategy applied by certain countries of the South, and it is qualified by “ecological dumping,” also called “eco-dumping.” This ecological dumping then comes from environmental legislation that does not fully internalize the social cost of domestic pollution and thus favors domestic producers on international markets. We even distinguish between strong ecological dumping and weak ecological dumping.

Ecological dumping, as well as ecological overbidding, are two strategies corresponding to disguised protectionist behavior. By which the country aims to achieve a comparative advantage to the detriment of its partners under environmental pretexts.

Currently, the trend towards strengthening environmental regulations in developed countries is a major source of concern.

The South sees these demands of the North as barriers to the entry of its products (Ayasamy, 1996). The representatives of developing countries at the WTO claim that environmental protection is a means used by industrialized countries to impose their sovereignty and penalize exports from the South. In turn, the North accuses the South of practicing ecological dumping. The repercussions on the environment are undeniable in the North as well as in the South. Song et al. (2024) assessed the effectiveness of strict environmental policies in addressing environmental problems. The study focused on BRICS-T economies over the period 1990–2020. The empirical results suggest a potential effectiveness of strict regulatory measures in mitigating negative environmental impacts.

2.2. Globalizations and the Environment: Rereading the Kuznets Environmental Curve

It is accepted that international trade allows large-scale production of goods and services and large-scale consumption. These activities are, in general, sources of negative externalities on the environment. This challenges us on the link between economic activity and the quality of the environment in general and on international trade and the environment in particular.

Indeed, free foreign trade affects the ecological environment, at least, on two levels. On the one hand, it accelerates economic activity, generating various effects, some of which are positive and others of which are harmful to the environment. According to Grossman and Krueger (1995), these are respectively the technical effect and the scale effect. On the other hand, there is a third effect known as the composition effect. Foreign trade generates a change in the economic structure of countries. This is the example of the change in the specialization of countries, the displacement of polluting industries, generally, from developed countries to developing countries with weak environmental regulations.

The evolution of theoretical studies on the relationship between the liberalization of foreign trade and the environment has allowed the multiplication of empirical literature on this subject. The study by Grossman and Krueger (1993) is a reference on this subject. The authors highlight the three effects: scale, technical, and composition. Their study seeks to evaluate the environmental impacts of NAFTA and addresses the relationship between the costs of reducing pollution and the structure of trade and investment between Mexico and the United States.

However, it is obvious that any change in economic activity also affects income. The scale effect will then be counteracted by the positive impact of income gains on environmental regulation. This positive income effect, known by the technical effect, must be taken into consideration. It is explained by the great capacity and goodwill to establish and strengthen environmental regulations, ensured by the real income generated (Abid, 2017; Song et al., 2024). This increase in income levels is guaranteed by international trade to all partner countries.

This technical effect can also be explained by the foreign direct investments acquired, particularly in the case of countries in the South. When the free movement of capital is ensured, foreign firms should transfer more modern technologies to host countries. These new technologies are generally cleaner and more economical in non-renewable energy.

Indeed, this form of evolution returns to the logic of the Kuznets environmental curve. The ascending phase of the curve is only the dominance of the scale effect over the technical effect, where environmental quality deteriorates as and when there is an increase in economic activity. This is the opposite case in the descending phase where the positive technical effect dominates. More economic wealth allows for fewer pollutant emissions.

Antweiler et al. (2001) seek to distinguish between the scale effect and the technical effect by putting forward theoretical conditions to determine which of the two effects is the largest. They conducted empirical work corresponding to a measurement of sulfur dioxide (SO_2) concentrations in more than 100 large cities around the world. By isolating the two effects generated by international trade, important estimation results were obtained. A trade liberalization that increases the scale of economic activity by 1% increases pollution concentrations by 0.25-0.5% via the scale effect, but the increase in per capita income, which will be followed, pushes these concentrations down by 1.25-1.5% via the technical effect.

The empirical verification of the environmental Kuznets curve has not been the subject of consensus among economists. Among the many studies conducted, the results varied and were even contradictory. This is due to many reasons, the most important of which are the samples studied and the indicator of environmental quality measurement taken into account. On the one hand, this hypothesis has been studied at the level of a single country using time series. Indeed, some of them prove the validity of the CEK hypothesis, such as the studies conducted by Jalil and Mahmud (2009) on China, Fosten et al. (2012) on the United Kingdom, Esteve and Tamarit (2012) on Spain, and Sahoo et al. (2021) on India. Other studies deny this hypothesis, such as Fodha and Zaghdoud (2010), Ben Jebli and Ben Youssef (2015), Amri (2018), and Amri et al. (2019) for the case of the Tunisian economy; Pao et al. (2011) for Brazil; and Al-Mulali et al. (2015) for the case of Vietnam. Recently, for the case of BRICS countries, Imran and al. (2023) claim that there is an inverted U-shaped relationship between economic growth and energy consumption. Neffati and Khemiri (2025) refer to the topic of economic green growth (EGG) and its key drivers, such as government effectiveness and renewable energy. Based on evidence for BRICS+ economies between 1996 and 2021, assess the contribution of globalization, renewable energy, and institutional quality in determining EGG. They conclude that globalization, good institutions, and economic development are likely to enhance green growth.

On the other hand, several studies using panel data for a group of countries show that the results obtained fluctuate. For example, Adu and Denkyirah (2018) through the study of West African countries, Antonakakis et al. (2017) in 106 countries classified by different income groups during the period 1971-2011, and Ben Jebli et al. (2016) rejected this hypothesis in the different samples of selected countries. As for the studies of Apergis and Payne (2010) on the Commonwealth of Independent States, Apergis and Ozturk (2015) on a set of Asian countries, N'Dri et al. (2021)

on a group of developing countries, the study of Haini (2021) on ASEAN countries, Khan et al. (2020) for a group of developed and developing countries, and Danish et al. (2019) at all income levels, for all these studies the hypothesis was confirmed.

Dhingra, V. S. (2023) shows that for the four countries of the BRICS group (exception China) economic growth and globalization negatively affect environmental quality in the short and long term. Financial development is the only variable that acts positively by contributing to the reduction of GHG emissions.

This difference in results is not only limited to the samples studied, but also it is due to the additional variables used in the model. In previous studies, we find those that used the variable of corruption (Apergis and Ozturk, 2015), population (Apergis and Ozturk, 2015), energy consumption (Amri, 2018), financial development (Chen and Lei, 2018), urbanization (Li et al., 2016), and trade openness (Ben Jebli et al., 2016; Adu and Denkyirah, 2018). There are also those that added the variable of information and communication technologies (ICT) in the approved model in order to estimate the relationship between it and carbon dioxide. Some have adopted the use of a group of indicators as a measure of ICT, such as mobile phone subscriptions, fixed-line subscriptions, and internet usage, or the limitation to the use of a single indicator. Nowadays, ICT is linked to the development of societies because it is part of the most important means of transition between developing societies and more advanced societies (Abbass et al., 2024).

This technology has been able to unite the world and make it continuously connected to each other. There is no doubt that this informational globalization has radically changed the reality of societies and the modes of production. This recent, widespread, and rapid development of ICT in the world has had a worrying environmental impact, including a decline in the consumption of non-renewable energy, the significant production of toxic waste, as well as the contribution to carbon dioxide emissions. Awosusi et al. (2022) confirms this technological effect in BRICS countries.

Roughly speaking, it appears that economic globalization relating to the free exchange of goods and services, capital, and factors, as well as informational globalization, has a significant impact on the environment. However, among the large literature, the majority of studies conducted are limited to a single elementary indicator of economic activity in order to determine the impact on environmental quality. The results will thus be divergent and even contradictory. In addition, for the measurement of environmental quality, there are few studies using a global measurement indicator, which is composite and reflects different ecological aspects. Neither the use of CO_2 emissions alone nor any other emissions indicator can be exhaustive and reflect the deterioration of environmental quality. However, among this abundant literature, there are few studies focused on the case of developing countries. For the small price-taking economy at the global level, and for a given level of income and knowing a certain allocation of the key parameters of the model, it is shown that the composition effect associated with trade liberalization in this country corresponds to an increase in pollution. This affirms the ascending phase of the Kuznets environmental curve hypothesis.

Copeland and Taylor (2003), in a reference model, examine the relationships between trade liberalization, economic growth, and the environment. They consider a Southern country establishing trade relations with the North, where the capital factor is relatively more abundant. The authors show that the effects of trade liberalization on environmental quality are weak. However, the explanations are different. Considering capital flows helps to clarify the results of econometric estimates. For the Southern country, capital accumulation, which is a source of growth, degrades its environment. However, this remains preferred to the case of autarky. Copeland and Taylor say, “As well, it suggests that trade liberalization plus capital accumulation is far less environmentally friendly than trade liberalization alone” (p. 69). Recently, Ben Zineb (2019) used a simultaneous equation model for a sample of different countries, namely 27 OECD countries over the period 1996-2015 and 58 developing countries during the period 2005-2015. The results found are varied. For the group of developed countries, the composition effect is the most dominant. The scale effect is also highlighted; on the other hand, the positive technical effect only manifests itself through the development of agricultural activities preserving the quality of the environment and not through the strengthening of environmental policy. In addition, for both samples, the author shows that through the accumulation of capital, international trade can lead to an increase in pollution, leading to environmental degradation. This overview of the literature on trade liberalization and the environment highlights two observations. On the one hand, there is an opposition to the theoretical arguments put forward. This opposition partly explains the antagonism between environmentalists and defenders of globalization. On the other hand, the diversity of the results of empirical work opens the way to several interpretations.

This paper considers different inadequacies by studying the impact on environmental quality measured by the environmental performance index. Which includes various components (Pinar, 2022). The explanatory variables are themselves exhaustive, ranging from economic growth to a composite index of economic globalization and an index of informational globalization to the socio-economic domain reflected by the urbanization of the population in the country.

3. VARIABLES, DATA AND MODEL SPECIFICATIONS

The mean variable that we seek their determinants, in this study, is Environmental Performance Index (EPI). It measures environmental sustainability and performance across countries, typically covering areas like air and water quality, biodiversity, climate policy, and resource management. The data for EPI is obtained from the 2024 Environmental Performance Index by Yale University’s Center for Environmental Law and Policy (Block et al., 2024). This index is widely recognized and frequently used in environmental research to assess and compare environmental health and ecosystem vitality across countries.

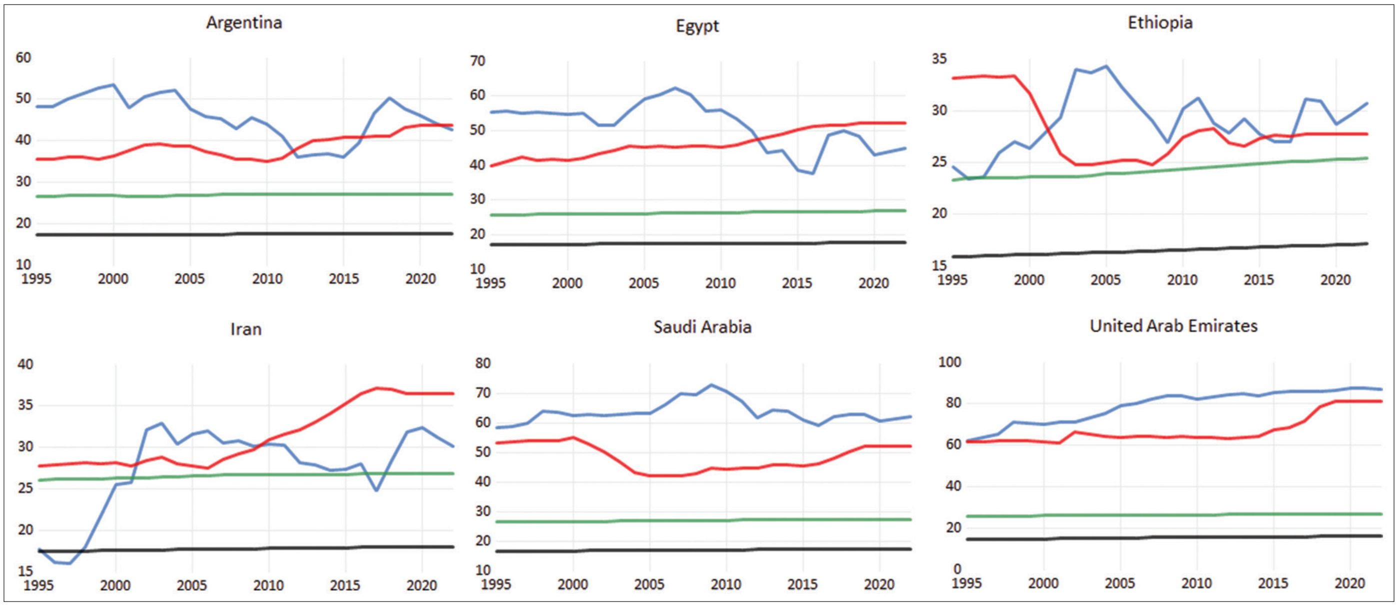
Table 1 provides foundational information about the variables used in study for understanding the empirical analysis. The

Table 1: Variables definition and sources of data

Variables codes	Definition	Sources of data
EPI	Environmental Performance Index	2024 Environmental Performance Index. New Haven, CT: Yale Center for Environmental Law & Policy. https://epi.yale.edu/
GDPC	Gross domestic product per capita (constant 2015 US$)	World Bank; World Development Indicators
ECGI	Economic globalization index	KOF Swiss Economic Institute
INGI	Informational globalization index	
URB	Total Urban population	World Bank; World Development Indicators

Source: Authors elaboration

Figure 1: Indicators evolution of BRICS+ Countries



Source: Authors elaboration from original data

definitions and data sources clarify the scope of each variable and establish credibility by using widely accepted and reliable sources, such as Yale University, the World Bank, and the KOF Swiss Economic Institute. These variables collectively capture economic, environmental, and globalization dimensions, allowing for a comprehensive analysis of factors influencing environmental performance (EPI). This table provides a concise summary of the variables used in the analysis, including their definitions, measurements, and data sources:

Figure 1 above illustrates the evolution of selected indicators for BRICS+ countries over the period 1995-2022. The figure highlights the varying paths of economic growth and tracks the Economic Globalization Index (EGI, blue), Environmental Performance Index (EPI, red), GDP (LNGDP, green), and Urban Population (LNUBP, orange). The core BRICS countries (Brazil, China, India, and Russia) show increasing globalization and environmental performance, with China and India experiencing sharp rises due to rapid integration into global markets and export-driven growth. GDP consistently grows for all, with China leading in acceleration, while urbanization rises gradually, reflecting steady demographic shifts. South Africa shows moderate growth across all indicators, with stable urbanization and GDP trends. Among the other countries, Argentina, Egypt, and Ethiopia exhibit mixed results: Argentina shows moderate growth, Egypt has steady GDP growth but fluctuating exports, and Ethiopia displays volatile export performance despite stable GDP and urbanization growth. In the Middle East, Iran's export performance grows steadily, but globalization remains limited, likely due to geopolitical constraints. Saudi Arabia demonstrates strong export growth tied to oil, while the UAE stands out with high globalization and export levels, reflecting its role as a global trade hub. Across all countries, urbanization correlates strongly with GDP growth, while export performance and globalization vary, with some countries showing consistent trends (e.g., China, UAE) and others experiencing volatility (e.g., Ethiopia). This analysis highlights the diverse economic trajectories of BRICS+ nations and their varying levels of integration with the global economy.

The right methodology consists on determining whether these used variables are stationary or non-stationary, and in what level they are stationary. The stationarity test help as to choose, relatively, the suitable method of estimation.

3.1. Specification Tests

3.1.1. Panel unit root test

The Table 2 provided a Panel Unit Root Test that examines the stationarity of several variables taken in natural logarithm, using three statistical tests (LLC, IPS, and ADF) at both the level and first-difference.

This table suggests that EPI and GDPC are non-stationary in levels but become stationary after differencing once, meaning they are integrated of order 1, or I(1). However, ECGI, INGI, and URB

Table 2: Panel unit root test

Methods	LLC	IPS	ADF	LLC	IPS	ADF	Stationarity
Variables		In level			In 1st difference		Order of integration
EPI	−1.6312 (0.0514)	−0.1726 (0.4315)	24.734 (0.3099)	−1.5978 (0.0551)	−3.8420 (0.0001)	50.3213 (0.0005)	I (I)
GDPC	−1.49605 (0.0673)	1.63302 (0.9488)	12.646 (0.9426)	−7.3013 (0.0000)	−7.5226 (0.0000)	100.13 (0.0000)	I (I)
ECGI	−6.7605 (0.0000)	−4.8658 (0.0000)	66.212 (0.0000)	--	--	--	I (0)
INGI	−9.6655 (0.0000)	−5.1792 (0.0000)	69.1823 (0.0000)	--	--	--	I (0)
URB	−4.0095 (0.0000)	−1.2803 (0.1002)	35.361 (0.0355)	--	--	--	I (0)

The methods assume (common/individual) unit root process are: LLC: Levin, Lin & Chu t*.IPS; Im, Pesaran and Shin W-stat, ADF: ADF - Fisher Chi-square. Source: Authors elaboration

Table 3: Dumitrescu Hurlin panel causality tests

Null hypothesis	W-stat.	Zbar-stat.	Prob.	Causality direction
GDPC does not cause EPI	3.9436	2.3396	0.0193	GDPC↔EPI
EPI does not cause GDPC	7.4306	7.0468	2.1E-12	
GDPC2 does not cause EPI	3.8837	2.2587	0.0239	GDPC2↔EPI
EPI does not cause GDPC2	7.5337	7.1864	7.1E-13	
URB does not cause EPI	5.2106	4.0494	5.0E-5	URB↔EPI
EPI does not cause URB	5.2454	4.0968	4.0E-5	
LINIGI does not cause EPI	2.5339	0.4365	0.6624	No causality
EPI does not cause INGI	2.4886	0.3753	0.7074	
ECGI does not cause EPI	2.9047	0.9365	0.3490	No causality
EPI does not cause ECGI	2.2156	0.0086	0.9946	
ECGI does not cause GDPC	7.2453	6.7969	1.1E-11	ECGI→GDPC
GDPC does not cause ECGI	2.2277	0.0232	0.9815	
INGI does not cause GDPC	5.2217	4.0642	5.0E-5	INGI↔GDPC
GDPC does not cause INGI	5.5589	4.5209	6.0E-6	
ECGI does not cause GDPC2	7.2283	6.7735	1.5E-11	ECGI→GDPC2
GDPC2 does not cause ECGI	2.2242	0.0427	0.9659	
INGI does not cause GDPC2	5.3057	4.1774	3.5E-5	INGI↔GDPC2
GDPC2 does not cause INGI	5.5349	4.4879	7.0E-6	
URB does not cause ECGI	3.4024	1.6098	0.1076	URB←ECGI
ECGI does not cause URB	3.7097	2.0247	0.0432	
URB does not cause INGI	2.6941	0.6528	0.5139	No causality

Source: Authors elaboration

are stationary in levels and are thus I(0).

3.1.2. Panel causality test

Table 3 presents the results of causality tests between different economic, social, and environmental variables from 1995 to 2022. Using the Dumitrescu Hurlin Panel Causality Test, it examines whether past values of one variable help predict another variable across panel data entities with two lags.

Findings from the causality test shed light on the complex interconnections among environmental, economic, and social indicators:

- There is bidirectional causality between GDP per capita (GDPC) and Environmental Performance Index (EPI). Similarly, GDPC2 (GDP per capita squared) has bidirectional causality with EPI. Both directions show statistically significant results (p-values < 0.05). This mutual influence between Economic Growth (GDPC, GDPC2) and Environmental Performance (EPI) suggests that policies targeting economic growth should incorporate environmental considerations, and environmental policies may also, impact economic growth.
- Urbanization influences and is influenced by environmental performance, which highlights the importance of sustainable urban planning to mitigate environmental impacts in densely populated areas.
- The unidirectional causality from ECGI to GDP implies that increased economic globalization contributes positively to economic growth but does not have a direct impact on environmental performance within this data.
- The Informational Globalization Index (INGI) shows significant bidirectional causality with both GDP per capita (GDPC) and the alternate GDP per capita measure (GDPC2), indicating a robust mutual influence. As informational globalization increases, it drives economic growth, and as economic growth occurs, it likely supports further development in information technology and globalization. But There is no observed causality between informational globalization (INGI) and environmental performance (EPI). This suggests that informational globalization, while potentially beneficial for awareness and knowledge sharing, does not have a direct measurable impact on a country's environmental performance indicators in this dataset.

3.2. Estimated Model

In the context of the variables defined in Table 1 and this study, we might refer to the general form of the Kuznets Model; known as the Kuznets Environmental Curve, by examining how different economic and globalization indicators relate to environmental performance (EPI).

$$LnEPI_{it} = \alpha_i + \beta LnGDPC_{it} + \gamma LnGDPC^2_{it} + \delta LnECGI_{it} + \lambda LnINGI_{it} + \theta LnURB_{it} + \varepsilon_{it}$$

Where: EPI, Environmental Performance Index. GDPC, Gross domestic product per capita. ECGI, economic globalization index. INGI, informational globalization index. URB, Urban population.

In applying the Kuznets Model, this study likely seeks to verify if the relationship between economic growth (GDPC) and environmental quality (EPI) follows the hypothesized inverted-U shape. By including both linear and squared terms for GDP per capita and assessing additional factors like globalization and urbanization, the analysis attempts to capture the complex interactions between economic progress and environmental impact across different stages of development.

4. ESTIMATION RESULTS AND ANALYSIS

4.1. Panel estimation with Cross-sections and Periods specification

Table 4 based on the Panel EGLS (Estimated Generalized Least Squares) present the estimation results for the dependent variable EPI (Environmental Performance Index), using data from 1995 to 2022 with cross-sectional and period weights. The table explores how different factors influence environmental performance, with 11 cross-sections and 28 periods in the sample.

Figure 2 above explain the estimation process, and implement the right method of estimation that corrects the fixed and random specification problem in order to perform the estimation results summarized in Table 4.

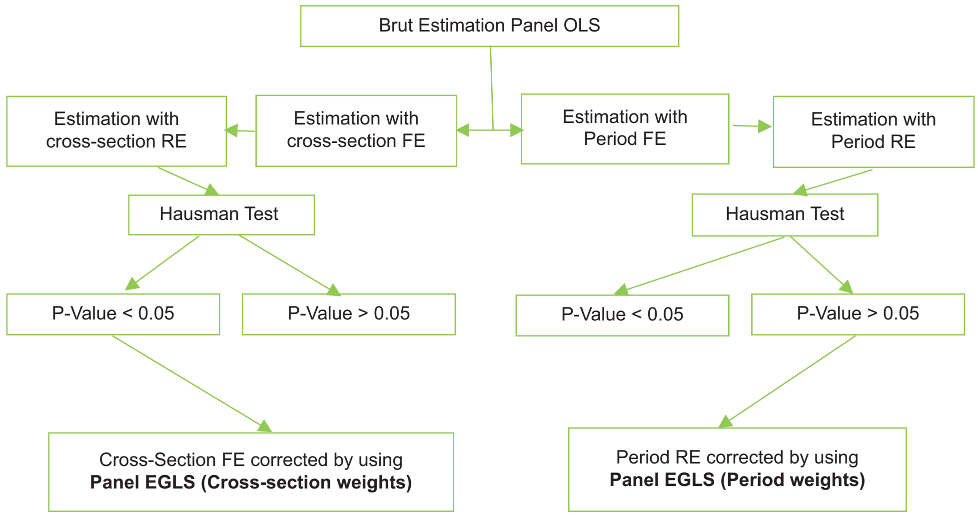
Based on these specifications, in Table 4, the Gross Domestic Product per Capita (GDPC) shows a significant negative relationship with the Environmental Performance Index (EPI) in both models (Cross-section weights: Coefficient = −0.2504, P = 0.0000; Period weights: Coefficient = −0.5270, P = 0.0000), indicating that as GDP per capita increases, environmental performance tends to decline. This suggests that economic growth, particularly in early stages or without stringent environmental controls, may lead to environmental degradation due to increased industrial activity and pollution. However, the positive and significant coefficients for the Square of GDP per Capita ($GDPC^2$) (Cross-section weights: Coefficient = 0.0157, P = 0.0000; Period weights: Coefficient = 0.0264, P = 0.0000) imply a non-linear relationship, consistent with the U-Curve hypothesis, where environmental performance initially worsens but improves at higher levels of economic development as cleaner technologies and stricter environmental regulations are adopted. The Economic Globalization Index (ECGI) has a positive and significant effect on EPI (Cross-section weights: Coefficient = 0.3367, P = 0.0000; Period weights: Coefficient = 0.2850, P = 0.0000), suggesting that globalization facilitates better environmental performance through access to green technologies, international standards, and global environmental norms. In contrast, the Informational Globalization Index (INGI) is not statistically significant (Cross-section weights: Coefficient = 0.0553, P = 0.0845; Period weights: Coefficient = 0.0708, P = 0.1144), implying that the spread of information and communication alone is insufficient to drive significant improvements in environmental performance. Urbanization (URB), however, has a positive and significant impact on EPI (Cross-section weights: Coefficient = 0.2098, P = 0.0000; Period weights: Coefficient = 0.4336, P = 0.0000), indicating that higher levels of urbanization correlate with better environmental performance, likely due to improved waste management, cleaner energy access, and stricter policies in urban areas. Finally, the Constant (C) is positive in both models (Cross-section weights: Coefficient = 4.0208, P = 0.0000; Period weights:

Table 4: Panel EGLS estimation with cross-sections (11) and periods (28) specifications

Sample: 1995 2022	Dependent variable: EPI			
Estimation methods	Panel EGLS (Cross-section weights)		Panel EGLS (Period weights (PCSE))	
Variable	Coef.	Prob.	Coef.	Prob.
GDPC	−0.2504***	0.0000	−0.5270***	0.0000
GDPC2	0.0157***	0.0000	0.0264***	0.0000
ECGI	0.3367***	0.0000	0.2850***	0.0000
INGI	0.0553*	0.0845	0.0708**	0.1144
URB	0.2098***	0.0000	0.4336***	0.0000
C	4.0208***	0.0000	6.7750***	0.0000
Observation	308	308	308	308
R-squared	0.80995		0.686929	
Durbin-Watson stat	0.12079		0.278	
F-statistic	257.4181	0.0000	132.528	0.0000
Hausman test (test cross-section random effects)	Chi-sq. Statistic 10.328	0.0665		
Panel cross-section Heteroskedasticity LR test	Value 156.54	0.0000		
Hausman test (test period random effects)			Chi-sq. Statistic 26.2933	0.0001
Panel period Heteroskedasticity LR test			Value 5.16036	0.9232

***Significant at 1%, **5, and *Significant at 10% level of significance. Source: Authors elaboration

Figure 2: Methodology of estimation process. FE: Fixed effects, RE: Random effects



Source: Authors elaboration

FE, Fixed effects and RE, Random Effects

- *Panel EGLS (Cross-section weights); this method uses Linear estimation after one-step weighting matrix, Cross-section weights (PCSE) standard errors & covariance (d.f. corrected).*
- *Panel EGLS (Period weights) this method uses Swamy and Arora estimator of component variances, Period weights (PCSE) standard errors & covariance (d.f. corrected).*

Coefficient = 6.7750, P = 0.0000), representing a baseline level of environmental performance that is independent of other variables in the analysis.

From the previous results, economic development, globalization, and urbanization all play crucial roles in shaping environmental performance index in BRICS countries. This is done through three significant conclusions, which can be taken as follows:

1. Economic Growth and Environmental Impact: While initial economic growth (GDPC) is negatively associated with environmental performance, the positive coefficient for GDPC2 suggests a non-linear relationship. The curve is U-shaped, not inverted U-shaped. This implies that, at higher income levels, countries may adopt more environmentally friendly practices. The positive technical effect dominates the scale effect, hence environmental performance increases.
2. Globalization and the Environment: Economic globalization (ECGI) significantly enhances environmental performance, likely due to the adoption of global standards and technology transfer. Informational globalization (INGI), however, shows no significant direct effect, which may imply that simply sharing information is not enough without accompanying policy or economic changes.
3. Urbanization and Environmental Improvement: Urbanization is associated with better environmental outcomes, possibly due to the concentration of resources, infrastructure, and policies that can mitigate environmental harm in urban settings.

4.2. Panel estimation with Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS)

Table 5 presents the results from Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) panel estimations for the dependent variable EPI (likely indicating the natural log of the Environmental Performance Index). The sample period is adjusted to 1996–2022, with 297 observations. Both methods estimate the long-term relationship between the dependent variable (EPI) and the explanatory variables.

Table 5: Fully Modified OLS (FMOLS) and dynamic OLS (DOLS) panel estimation (Sample (adjusted): 1996-2022)

Method	Dependent variable: EPI			
	Panel fully modified least squares (FMOLS)		Panel dynamic least squares (DOLS)	
Variable	Coefficient	Prob.	Coefficient	Prob.
GDPC	−1.1852**	0.0000	−0.8102**	0.0002
GDPC2	0.1794**	0.0000	0.038724	0.0006
ECGI	0.0648**	0.0022	−0.1215*	0.0443
INGI	−0.0467*	0.0138	0.1625*	0.0171
URB	0.2407**	0.0000	0.8266**	0.0001
Observation	297		297	
R-squared	0.9152		0.9436	
Long-run variance	0.0041		0.0221	

**Significant at 1% and *Significant at 5% level of significance. Source: Authors' own calculation

From Table 5, R-squared values of 0.9152 (FMOLS) and 0.9436 (DOLS) indicate that both models explain a high percentage of the variance in LNEPI, suggesting good model fit. Long-run variance values are 0.0041 (FMOLS) and 0.0221 (DOLS), which are small, indicating stability in the long-run relationships captured by these models.

- GDPC (Natural Log of GDP per Capita): The coefficient is −1.1852 with a P-value of 0.0000, indicating a significant negative relationship at the 1% level. This suggests that an increase in GDP per capita is associated with a decrease in environmental performance (EPI). The coefficient is −0.8102

with a P-value of 0.0002, also showing a significant negative relationship at the 1% level. Both models (FMOLS, DOLS) suggest that higher GDP per capita is negatively associated with environmental performance. This could indicate that economic growth is linked with environmental degradation in the sample.
- GDPC2 (Squared GDP per Capita): The coefficient is 0.1794 with a P-value of 0.0000, showing a significant positive relationship at the 1% level. In DOLS: The coefficient is 0.0387 with a P-value of 0.0006, also showing a significant positive relationship. This suggests a non-linear relationship between GDP per capita and environmental performance, aligning with the U-shaped curve hypothesis. This is the inverted environmental Kuznets curve. Initially, economic growth may degrade the environment (decrease in environmental performance index), but after a certain level of GDP per capita, the effect on environmental performance becomes positive.
- ECGI (Log of Economic Globalization Index); in FMOLS: The coefficient is 0.0648 with a P-value of 0.0022, indicating a significant positive relationship at the 1% level. In DOLS: The coefficient is −0.1215 with a P-value of 0.0443, showing a significant negative relationship at the 5% level. The results are mixed between the two models, with FMOLS suggesting that economic globalization improves environmental performance, while DOLS shows the opposite. This inconsistency may reflect varying impacts of globalization components on environmental outcomes.
- INGI (Log of Informational Globalization Index); FMOLS: The coefficient is −0.0467 with a P-value of 0.0138, indicating a significant negative relationship at the 5% level. DOLS: The coefficient is 0.1625 with a P-value of 0.0171, indicating a significant positive relationship at the 5% level. There is inconsistency between FMOLS and DOLS. The negative sign in FMOLS could suggest that informational globalization (e.g., communication and information exchange) may have environmental costs, while the positive sign in DOLS could imply benefits, such as the diffusion of environmental awareness.
- URB (Log of Urban Population); FMOLS: The coefficient is 0.2407 with a P-value of 0.0000, indicating a significant positive relationship at the 1% level. DOLS: The coefficient is 0.8266 with a P-value of 0.0001, also showing a significant positive relationship. Both methods show a strong positive association between urbanization and environmental performance. This might suggest that urban areas have better infrastructure or policies that support environmental improvements, or that urbanization is linked with higher levels of environmental awareness and resource efficiency.

Globally, Table 5 provides evidence for complex and varied relationships between economic, globalization, and urbanization factors on environmental performance. Key takeaways include:
- The downward phase of the U-shaped curve between EPI and GDPC suggests that environmental impact initially worsens with economic growth but may improve as economies mature
- Mixed results on globalization indices, highlighting that the impact of globalization on the environment may depend on different dimensions of globalization
- Positive associations between urbanization and environmental performance, implying that urban areas may contribute to improved environmental outcomes
- These results contribute to understanding how economic and demographic factors influence environmental sustainability over the long term.

4.3. Panel ARDL Estimation and Result Analysis

Table 6 presents the results from a Panel Autoregressive Distributed Lag (ARDL) model, which analyzes the relationship between the dependent variable D(EPI) (the first difference of the logarithm of the Environmental Performance Index EPI) and several exogenous variables, using both long-run and short-run equations.

In Long-Run Impacts (Table 6); GDP per capita, economic globalization, and urbanization have positive long-run effects on environmental performance, with economic globalization showing the strongest positive impact. However, informational globalization (INGI) shows a negative impact on EPI.

In Short-Run Dynamics: The error correction term (COINTEQ01) confirms that the model adjusts to deviations in the long-run equilibrium. The short-run effects reveal mixed responses, with lagged terms indicating short-term adjustments.

Table 6 suggests that economic and urbanization factors generally contribute positively to environmental performance over the long term, though informational globalization might have adverse effects. In the short term, adjustments toward equilibrium are apparent through the error correction term.

As far as the model equation is concerned, the coefficients are replaced by their values which are given by the estimation results (Table 6). The results obtained are as follows:

$$EPI = 0.3529\ GDPC - 0.0076\ GDPC^2 + 0.2739\ ECGI - 0.1704\ INGI + 0.1189\ URB$$

(1,996) (−0.768) (12,043) (−10,220) (8,952)

Only the variables with a statistically significant coefficient are kept, then it will be found as follows:

$$EPI = 0.3529\ GDPC + 0.2739\ ECGI - 0.1704\ INGI + 0.1189\ URB$$

The relationship between GDPC and EPI is then linear increasing. Any increase in per capita income of 10% generates an increase in the EPI index of 3.52%. The ascending relation between economic growth and the environmental performance index in this study, it means dominance of the technical effect over the scale effect. So environmental quality ameliorates as and when there is an increase in economic activity.

This monotonically increasing relationship invalidates the hypothesis of the Kuznets environmental curve, which claims the existence of an inverted U-shaped relationship between environmental quality and per capita income.

Indeed, the error of this hypothesis is notably in the consideration of a single pollutant emission indicator, case of CO_2, to assess environmental quality. A decrease in a single pollutant emission does not certainly mean an improvement in environmental quality, "one flower does not make spring."

Among the large literature focusing on the examination of the environmental Kuznets curve; it has become notorious that the environmental Kuznets curve is therefore not verified. This study encompassing economic growth, globalization of economies and urbanization is more robust, giving results that are more conclusive.

In short, the environmental Kuznets curve represents an ideological design much more than a scientific one. Saying that economic growth is a cause and remedy for environmental degradation is only a reference for the non-interventionist approach in economics.

Table 7 below presents the "Time required for equilibrium" for every county of BRICS+, and for all BRICS+. It is based on the ARDL-Cross-Section Short Run Coefficients.

According Table 7 there are differences between countries in the

Table 6: Panel ARDL estimation

Selected model: ARDL (3, 3, 3, 3, 3, 3)				
Exogenous variable	Dependent variable: D (EPI)			
	Coefficient	Std. error	t-statistic	Prob.*
Long run equation				
GDPC	0.352906	0.176640	1.997883	0.0486
GDPC2	−0.007596	0.009880	−0.768861	0.4439
ECGI	0.273960	0.022748	12.04313	0.0000
INGI	−0.170430	0.016675	−10.22050	0.0000
URB	0.118924	0.013284	8.952279	0.0000
Short run equation				
COINTEQ01	−0.408062	0.196290	−2.078878	0.0404
D(EPI(−1))	0.329529	0.193788	1.700459	0.0924
D(EPI(−2))	0.236843	0.139169	1.701841	0.0921
D(GDPC)	−5.358561	7.908029	−0.677610	0.4997
D(GDPC(−1))	−2.210109	5.705050	−0.387395	0.6993
D(GDPC(−2))	−0.951682	5.838640	−0.162997	0.8709
D(GDPC2)	0.257569	0.421912	0.610480	0.5430
D(GDPC2(−1))	0.153362	0.333518	0.459833	0.6467
D(GDPC2(−2))	−0.000483	0.294924	−0.001638	0.9987
D(ECGI)	−0.008129	0.075041	−0.108329	0.9140
D(ECGI(−1))	−0.020285	0.062993	−0.322023	0.7482
D(ECGI(−2))	0.026911	0.043887	0.613184	0.5412
D(INGI)	−0.013329	0.119468	−0.111567	0.9114
D(INGI(−1))	0.030737	0.124850	0.246189	0.8061
D(INGI(−2))	−0.086589	0.108739	−0.796298	0.4279
D(URB)	0.857680	2.040648	0.420298	0.6752
D(URB(−1))	2.666660	2.473212	1.078217	0.2837
D(URB(−2))	−3.822636	2.074660	−1.842536	0.0685
C	−0.472178	0.255516	−1.847939	0.0678
Root MSE	0.009342	Mean dependent var		0.005770
S.D. dependent var	0.027859	S.E. of regression		0.016910
Akaike info criterion	−4.937364	Sum squared resid		0.026879
Schwarz criterion	−2.345671	Log likelihood		974.3540
Hannan-Quinn criter.	−3.901086			

P values and any subsequent tests do not account for model section. Source: Authors' own calculation

Table 7: Time required for equilibrium (ARDL-cross-section short run coefficients)

Countries	ECM	Coefficient	Prob. *	Required time to equilibrium
ARGENTINA	COINTEQ01	−0.5329***	0.0001	1.87 (1 year, 10 months and 5 days)
BRAZIL	COINTEQ01	−0.5811***	0.0011	1.72 (1 year, 8 months and 19 days)
CHINA	COINTEQ01	−0.1902***	0.0000	5.26 (5 year, 3 months and 3 days)
EGYPT	COINTEQ01	−0.1884***	0.0001	5.30 (5 year, 3 months and 18 days)
ETHIOPIA	COINTEQ01	−0.662***	0.0000	1.50 (1 year and 6 months)
INDIA	COINTEQ01	0.3440	0.0026	Not significant (positive coef)
IRAN	COINTEQ01	−1.052***	0.0000	0.95 (11 months and 12 days)
RUSSIA	COINTEQ01	−1.774***	0.0000	0.56 (6 months and 21 days)
SAUDI ARABIA	COINTEQ01	−0.4070***	0.0000	2.45 (2 year, 5 months and 12 days)
SOUTH AFRICA	COINTEQ01	−0.2486***	0.0000	4.02 (4 year and 7 days)
UAE	COINTEQ01	0.1652	0.0002	Not significant (positive coef)
Overall BRICS+	COINTEQ01	−0.4080***	0.0404	2.45 (2 years, 5 months and12 days)

Source: Authors' own calculation

time required for the adjustment of exogenous variables to the endogenous variable (EPI).

On the one hand, the ECM (Error Correction Model) coefficient, shown under the "Coefficient" column, represents the speed of adjustment toward long-term equilibrium following a short-term shock. A significant negative coefficient indicates that a country will return to equilibrium after a deviation, with larger absolute values indicating faster adjustment. Positive or non-significant coefficients (e.g., India and UAE) suggest that the country may not revert to equilibrium effectively or does not have a stable equilibrium relationship.

On the other hand, the "Time required for equilibrium" column translates each coefficient into the approximate time (in years or months) needed for a country to adjust back to equilibrium; Argentina: With a coefficient of −0.5329, Argentina takes around 1.88 years (1 years, 10 months and 5 days) to reach equilibrium. South Africa: With a coefficient of −0.2486, requires approximately 4 years and 7 days to reach equilibrium. Overall BRICS+: With a coefficient of −0.4080, takes around 2.45 years (2 years, 5 months and 12 days) to reach equilibrium.

5. CONCLUSION, LIMITATIONS AND FUTURE PERSPECTIVES

Economic growth is accused of affecting environmental quality. This relationship continues to attract the attention of economists, politicians, and environmentalists. World summits follow one another, and research work is multiplying. However, studies lead to overlapping, even contradictory results. Economists say that many economic factors contribute to environmental degradation in the context of emerging economies (Balsalobre-Lorente, et al., 2023; Abbass et al., 2024).

This paper corresponds to a study of the effects of different variables on environmental quality for the BRICS+ countries panel in its new composition. The endogenous variable is the environmental performance index, a composite indicator of multiple ecological aspects. On the other hand, the explanatory variables are not limited to income per capita only towards the economic globalization index, the informational globalization index, and the urbanization of economies.

Except for the variable of the informational globalization index, the other variables positively affect the EPI. Any increase of 1% in income per capita, economic globalization, or urbanization generates an increase in the EPI, respectively, of 0.35%, 0.27%, or 0.11%. This monotonically increasing relationship between economic growth and the environmental performance indicator calls into question the Kuznets environmental curve hypothesis.

The apparent simplicity of the shape of this curve should be interpreted carefully, knowing that appearances are generally deceptive. The EKC hypothesis turns into a means to justify the relaxation of societal responsibilities and state non-interventionism.

5.1. Limitations and Future Direct of the Research

This study reveals a complex and nuanced relationship between economic growth and environmental quality, particularly within the context of BRICS+ countries. It challenges the Kuznets Environmental Curve (KEC) hypothesis by suggesting that economic growth does not always lead to improved environmental performance. To better understand this finding, further research is necessary, particularly through comparative case studies. Such studies could shed light on how specific national policies, economic structures, and cultural factors influence varying environmental outcomes, even among countries with similar economic growth rates.

6. FUNDING

This work was supported and funded by the Deanship of Scientific Research at Imam Mohammad Ibn Saud Islamic University (IMSIU), (grant number: IMSIU-DDRSP2504).

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