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The impact of poverty on the ecological footprint in BRICS countries

Kirsten[*] , Biyase[†] , Zwane[‡]

Abstract

This paper investigates the relationship between poverty and ecological footprint for BRICS nations. The data for BRICS is obtained from the World Bank's world development indicators, Global Footprint Network, Worldwide Governance Indicators (WGI) and PovcalNet for the period 1996 to 2017. Panel autoregressive distributed lag (PARDL) and their corresponding preliminary cross-sectional dependence and second generations specification tests were used for the analysis of the data. The estimates from the full sample support the literature, revealing a robust long-run relationship between poverty and ecological footprint. Specifically, results demonstrate that poverty gap help to reduce environmental degradation in terms of EFP in the full sample. However, the effect of poverty on ecological footprint becomes positive when we split the sample—exclude China from the full sample. Our results are robust to various measures of ecological footprint, poverty and to alternative empirical specifications. The implication of the current upward trend of environmental degradation for some BRICS countries and the high poverty in others suggest that policy makers have a long way to go and given growth trajectory of the BRICS nations, the future of the planet could very well be in the hands of these developing nations.

Keywords: *BRICS; poverty; ecological footprint; PARDL*
JEL Classification Codes: *F18, Q56*

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1. Introduction

The ecological footprint of countries has become a popular topic in recent years. Mainly due to the shift of climate change to the forefront of sustainable development goals. The evidence of climate change captured by increasing droughts, floods, extreme storms, melting glaciers, and rising sea levels (UNFCCC, 2017), has made climate change research more important than ever and a host of studies have stepped to the forefront to shed more light on this issue. Nevertheless vigorous debates still remain about the interconnection between environmental stability and other sustainable development goals (Kham, 2021; Khan et al, 2022). Developing countries, especially those suffering from high levels of poverty pursue economic growth by stimulating industrialization and production levels while the same economic growth tends to also lead to higher demand for energy and the increased emission of CO2 and environmental degradation. Furthermore the production process in these developing countries is heavily reliant on fossil fuel, bringing further harm to the environment (Papakonstantinidis, 2017), creatinghere a possible trade-off between poverty alleviation and environmental sustainability. Many developing countries, including BRICS countries, are facing difficulty in concurrently meeting these two sustainable development goals.

BRICS countries presents an interesting dilemma, in recent years there has been a rapid economic expansion in these countries. This has led to significant poverty alleviation, where BRICS countries have seen the number of working poor fell by more than 540 million between 2000 and 2019, four times more than other middle-income countries (IOL, 2020). However the poverty alleviation has not come without a cost. There has also been a significant shift from an ecological surplus to an ecological deficit in BRICS countries, mainly due to the rapid economic transformation (Nathaniel et al, 2021). The BRICS region also now consume more than 40% of the world energy making it a major contributor to CO2 omissions (Danish and Wang, 2019). More notably Nathaniel et al (2021) empirically shows that economic growth and natural resources increases the ecological footprint in these regions. While human capital is not yet at a level needed to counter environmental degradation.

There is a view by some scholars that production, and economic growth in the BRICS countries are still also centrally dependent on fossil fuel leading to environmental degradations, and that there should be a shift to a more renewable energy system (Caglar et al, 2022). BRICS countries are then especially caught in a difficult conundrum, while poverty alleviation still remains one of their most important sustainable development objectives, the dynamic shift to a renewable energy is complexioned by its impact of job creation and poverty. To ensure both poverty alleviation and environmental sustainability, more information is needed about the complex poverty-environment nexus in these countries.

While these issues are important, little is still known about the poverty-environmental nexus in BRICS countries. While a host of studies have included the BRICS members in their analysis (Finco, 2009; Kocak et al, 2019; Khan, 2021), these studies do not specifically pool BRICS countries, an assessment that should provide vital information on the relationship between the ecological footprint and poverty in a collective assessment of BRICS nations. The study is a first of its kind to assess the relationship between poverty and the ecological footprint in the BRICS region. Given the economic transformation, poverty alleviations and dynamic ecological surplus/deficit changes in BRICS nations the study should provide further insight into the poverty-environment nexus in an era where climate change is a forefront of social science studies.

The study aims to add to current literature on ecological footprints by making several contributions. First, we aim to assess the poverty-environment nexus for BRICS countries, something that is yet to be done for this particular group of countries. Furthermore the relationship between poverty and ecological footprints also depends on the other factors like institutional quality (Rizk and Slimane, 2018; Kocak et al, 2019), that vary by country complexing the relationship between ecological footprints and poverty. Secondly, we make use of second-generation unit root tests to account for cross section dependence. Thirdly, we make use of several robustness checks to confirm the validity of the results for our full BRICS model and individual country level estimates. The first being the use of different poverty and ecological footprint measures in our analysis. Secondly, we use alternative empirical specifications to assess the relationship between poverty and the ecological footprint in BRICS nations, and finally we remove China from the full sample to further assess the robustness of the results.

2. Literature review

In the past, a vast number of studies have focussed on the impact of poverty on the ecological footprint in developed and developing countries. These studies show is a casual relationship between poverty elevation and the ecological footprint. For example, Khan (2021), observing developing Asian countries, find that there is a negative relationship between poverty and the ecological footprint in these countries. While Koçak et al (2019) shows for Sub-Saharan African countries that there is a clear trade-off between poverty and CO_2 emissions. Arguing that economic conditions that lead to lower poverty levels would also lead to environmental degradation. Similarly, Islam and Ghani (2018), find a negative relationship between poverty and energy consumption for ASEAN countries between 1995 and 2014. These studies argue that fossil fuel intensive industrialization and industrial policies aimed at eradicating poverty are driving environment degradation, while a reduction of poverty also leads to higher energy consumption that further strains the environment.

In contrast others have shown that there is a positive relationship between poverty and environmental population. Baloch et al (2021) assessed the relationship between poverty and CO_2 omissions for 40 Sub-Saharan African countries and shows that the increase in poverty leads to higher levels of CO_2 omissions. While Khan (2019), found using ASEAN countries that there is positive relationship between poverty and environmental degradation. Similarly, Masron and Subramaniam (2019), assessed the environmental-poverty nexus for 50 developing countries between 2001 and 2014, finding a positive and significant relationship between poverty and environmental degradation. These studies mainly flag the survival needs of the poor on natural resources as one of the main sources for environmental degradation and focus on measures to reduce poverty that will enhance environmental protection and reduce the ecological footprint. In sum, there is still contradicting views on ecological footprint-poverty nexus and there still remains uncertainty to how government should approach these two worldwide issues. A detailed summary of past empirical studies assessing the poverty-environment nexus can be found in table 1.

Table 1 Relevant literature on poverty and ecological footprints

Authors	Country	Time	Model	Main result
Khan 2021	Asian developing countries	2010-2016	Driscoll-Kray regression	The key finding shows that there is a negative relationship between poverty and the ecological footprint
Khan et al. 2022	Asian developing countries	2006 -2017	Driscoll-Kray standard error model	Their findings show a significant positive impact of poverty on the ecological footprint
Khan 2019	Southeast Asian countries	2007-2017	Generalized method of moments	The results show that poverty has a significant and positive relationship with greater environmental degradation

Baloch et al. 2021	Sub-Saharan African countries	2010-2016	Driscoll-Kray standard error model	Their findings shows that an increase in poverty has a detrimental effect on environmental pollution.
Masron and Subramaniam 2019		2001-2016	Generalized method of moments	Empirical results demonstrate that poverty is one of the main drivers for environmental depletion.
Rizk and Slimane 2018	146 countries	1996-2014	Three-stage least squares (3SLS)	A non-linearity relationship between poverty and CO2 emission is found. However an increase in institutional quality reduces poverty and added protection to the environment.
Kocak et al. 2019	Sub-Saharan African countries	2010-2016	Panel quintile regression model	Their findings indicate that there is trade off between poverty and CO2 emissions. Showing that access to electricity reduces poverty but has a negative impact on the environment. However their results show that institutional improvement help reduce both poverty and CO2 emissions.
Islam and Ghani 2018	ASEAN countries	1995-2014	Linear regression model	There is a positive relationship between poverty and environmental pollution.
Swinton and Quiroz 2003	Peru	1999	Random-effects regression model	Their findings shows that the link between poverty and environmental degradation is strongly linked to deforestation.
Barbier 2000	Various African countries		Case study	Their findings show the impact economic policies could impact the economic incentives for rural households decisions to conserve or degrade owned land.
Finco 2009	Brazil		Non-linear probit model	Empirical results demonstrate that the relationship between rural poverty and environment degradation is weak.
Zaman et al. 2010	Pakistan	1980-2009	Granger causality	Their findings report that rural poverty has a significant long run impact on environmental degradation. While also finding uni-directional causality between poverty and the environment.

3. Methodology

As indicated earlier that the aim of this paper is to establish whether not poverty affects ecological footprint in the BRICS countries. To this end, we follow previous studies in this field (such as Khan 2021) and use GDP per capita, its square term, poverty, FDI, and rule of law to accurately explain ecological footprint. Owing to the fact that institutional variables (such as the rule of law) is obtainable for the period 1996 and 2017, our study is limited to these years (1996-2017). Most of the variables are converted into a logarithmic form. The association poverty and ecological print, can be expressed as follows:

$$
\begin{aligned}
lnEF = \quad \delta 0 \; &+ \; \delta 1 lnPOV + \delta 2 lnINLF + \delta 3 lnAE + \; \delta 4 lnGDP_{pc} \\
&+ \delta 5 lnGDP_{pc}SQ + \delta 6 lnRoL \; + \delta 7 lnFDI \\
&+ \; \mu \qquad (1)
\end{aligned}
$$

where $\delta 0$ denotes the constant term and $\delta 1$, $\delta 2$, $\delta 3$, $\delta 4$, $\delta 5$, $\delta 6$ and $\delta 7$ signify the coefficients of the explanatory variables and last but not least μ is disturbance term. EF is our dependent variable of interest and represent a comprehensive measure (comprising of 6 variables: built-up land, crop land, CO2 emission, fishing, forest, and grazing) to proxy ecological degradation, POV is the poverty rate, $INLF$ is the inflation consumer prices (annual %), GDP_{pc} denotes the real GDP per capita (constant 2015 US$), $GDP_{pc}SQ$ is the square of real GDP per capita (constant 2015 US$), FDI represent the foreign direct investment (BoP, current US$), AE represent access to electricity (% of population). The data for inflation, GDP per capita, FDI, AE are obtained from the World Development Indicators. Data for the rule of law comes from the Worldwide Governance Indicators (WGI), data for ecological footprint per capita comes from the Global Footprint Network (GFN) and data for poverty comes from PovcalNet.

3.1.Panel Autoregressive Distributed Lag

As a way of setting the scene and paving the way for empirical investigation certain specification test were performed to detect cross-sectional dependence and unit root in the series. Cross-sectional dependence cannot be ruled out in the sample of countries under study given interdependence of these countries (owing to the buying and selling of goods between them and spatial spillover effects). What we have learned from existing studies is that cross-sectional dependency can contaminate the estimated coefficients. In view of this appropriate statistical tools (cross-sectional dependence test) were applied to detect the problem in the series prior to the implementation of unit root test. After detecting the presence of cross-sectional dependence in the series the next appropriate step is to apply second-generational unit root test advanced by Pesaran et al. (2001) to check the stationarity of the variable in the presence of cross-sectional correlations. To estimate the short-run and long-run relationship between poverty and ecological footprint in the BRICS countries, we specify a PARDL model. The reason for choosing PARDL is threefold: (i) it is appropriate for addressing cointegration, (ii) it permits variables that follow I(0) and I(1) process; (iii) it is robust in the presence of endogeneity. The PARDL model is expressed as follows:

$$
\begin{aligned}
\Delta lnEF_{it} = \Phi_0 \quad & + \sum_{i=1}^{n} \Phi_{1it}\, \Delta lnEF_{it-i} + \sum_{i=1}^{n} \Phi_{2it} \Delta lnPOV_{it-i} \; + \sum_{i=1}^{n} \Phi_{3i} \Delta lnINLF_{it-i} \\
& + \sum_{i=1}^{n} \Phi_{4it} \Delta lnAE_{it-i} + \sum_{i=1}^{n} \Phi_{5i} \Delta lnGDP_{pc_{it-i}} \\
& + \; \sum_{i=1}^{n} \Phi_{6it} \Delta lnGDP_{pc}SQ_{it-i} + \sum_{i=1}^{n} \Phi_{7it} \Delta lnRoL_{it-i} + \sum_{i=1}^{n} \Phi_{8it} \Delta lnFDI_{it-i} \\
& + \Omega_1 lnEF_{it-1} + \Omega_2 lnPOV_{it-1} + \Omega_3 lnINLF_{it-1} + \Omega_4 lnAE_{it-1} \\
& + \Omega_5 lnGDP_{pc_{it-1}} + \Omega_6 lnGDP_{pc}SQ_{it-1} + \Omega_7 lnRoL_{it-1} + \Omega_7 lnFDI_{it-1} \\
& + v_{it} \qquad (2)
\end{aligned}
$$

Where Φ_{1it}, Φ_{2it}, Φ_{3it}, Φ_{4it}, Φ_{4it}, Φ_{5it} Φ_{6it}, Φ_{7it}, represent the short-run estimated coefficients while Ω_1, δ_2, Ω_3, Ω_4, $\Omega_{5,}$ Ω_6, Ω_7, Ω_8 signify the long-run estimated coefficients. The null hypothesis of no cointegration is H0: $\Omega_1 = \Omega_2 = \delta_3 = \Omega_4 = \Omega_5 = 0$. On the other hand the alternative hypothesis of cointergration is expressed as follows: $\Omega_{1\neq}\ \Omega_2 \neq \Omega_3 \neq \Omega_4 \neq \Omega_5 \neq 0$. Similar to the standard ARDL the null hypothesis of no cointegration can be rejected if the critical values are exceeded by the F-statistics. On the other hand, if the F-statistics is less than critical values, then we fail to reject the null hypothesis of no cointegration, implying that the alternative hypothesis of cointegration can be accepted (Pesaran et al., 2001). The short-run dynamic parameters using panel error correction model (PECM) model with the long-run estimates specified as:

$$
\begin{aligned}
\Delta lnEF_{it} = \Phi_0 \quad & + \sum_{i=1}^{n} \Phi_{1it}\, \Delta lnEF_{it-i} + \sum_{i=1}^{n} \Phi_{2it} \Delta lnPOV_{it-i} \; + \sum_{i=1}^{n} \Phi_{3i} \Delta lnINLF_{it-i} \\
& + \sum_{i=1}^{n} \Phi_{4it} \Delta lnAE_{it-i} + \sum_{i=1}^{n} \Phi_{5i} \Delta lnGDP_{pc_{it-i}} \\
& + \; \sum_{i=1}^{n} \Phi_{6it} \Delta lnGDP_{pc}SQ_{it-i} + \sum_{i=1}^{n} \Phi_{7it} \Delta lnRoL_{it-i} + \sum_{i=1}^{n} \Phi_{8it} \Delta lnFDI_{it-i} \\
& + \; \delta_{it} ECM_{it-i} + v_{it} \qquad (3)
\end{aligned}
$$

Where ECM is the error correction model or term. All other variables are as previously defined. As noted in equation 2, Φ_{1it}, Φ_{2it}, Φ_{3it}, Φ_{4it}, Φ_{4it}, Φ_{5it} Φ_{6it}, Φ_{7it} represent the short-run estimated coefficients, while δ_{it} denote the the speed of adjustment coefficient to equilibrium. If there is adjustment to equilibrium, the coefficient of the error correction model is expected to be negative and statistically significant.

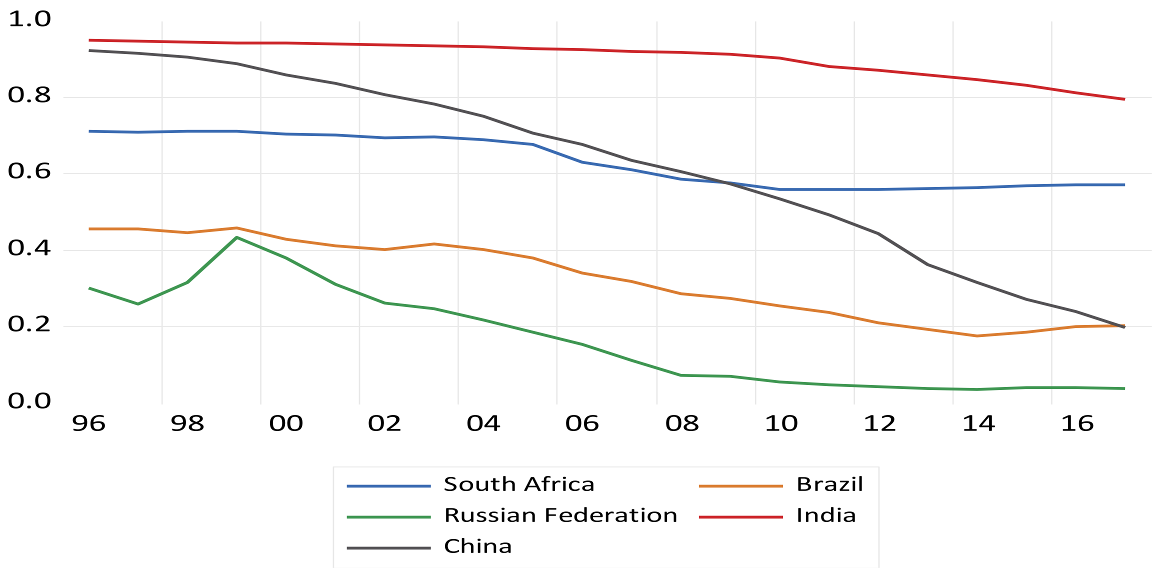
4. Empirical results and analysis

Before embarking into a discussion of the empirical regression results, it is helpful to take a closer look at graphical representation of the series, to get a sense of the direction of the variables (Rana and Sharma, 2018). Therefore, commence the analysis by describing the trends of ecological footprint for each member country within the BRICS community.

In figure 1, what stands out is that ecological footprint for China and India are upward trending. Likewise, Brazil records an objectively similar sort of trend during the same period although with assorted episodes. However, South Africa and Russian Federation records a fair degree of fluctuation during the course of the period under investigation. Figure 2 sheds some light on the trends in poverty headcount for BRICS nations put together. What emerges from this figure is steady declining trends in poverty headcount in almost all BRICS countries. What is also noticeable from figure 2 is a sharp decline in poverty head count for China

Fig. 1: Trends in Ecological footprint for BRICS nations

Fig. 2: Trends in poverty headcount for BRICS nations



As noted earlier this study attempts to investigate the relationship between ecological footprint and poverty for Brics nations. To this end, appropriate statistical tools are employed to obtain meaningful and consistent estimates. We performed various test such as Breusch-Pagan LM (1980), Pesaran (2004) scaled LM and CD, and the Baltagi, Feng, and Kao (2012) bias-corrected scaled LM tests. Table 2 present the results from these test and there is an unquestionable evidence of cross-sectional dependency in our panel dataset of Brics nations. After discovering CD between series, we proceed to test for unit root. However, we could not use first generation unit root test as these tests assume that cross-section units are cross-sectionally independent and therefore more likely to generate inconsistent outcomes amidst CD. As such, the second-generation unit root tests CIPS, proposed by Pesaran (2007) were performed and the results are shown in table 3. According to the results displayed Table 3, FDI, Inflation, and cropland are stationary at level, while the rest of the other variables (EF, POV, $lnGDP_{pc}$ and $lnGDP_{pc}SQ$ are stationary at first difference.

Table A in the appendix shows the descriptive statistics of the variables used in this study. EF fluctuated from 1.763062 to -0.215218, POV ranged from -0.556813–-4.935157, GDP_{pc} ranged from 11731.38 to 652.5661, GDPpcSQ ranged from 18.74005to 12.96182, FDI ranged from 26.39634 to 20.12604, INLF varied from 47.75201 to -0.731971, AE from 4.605170 to 3.970358, and RULE OF LAW from 0.353991 to -1.097559,

Table 2: Test for cross-sectional dependence

Variables	BP LM	PSLM	BCSLM	PCD
lnEF	65.80623***	12.47865***	12.35961***	5.140933***
lnPOV	60.23591***	23.36646***	23.29503***	7.759172***
$lnGDP_{pc}$	61.45472***	23.86404***	23.79261***	7.837237***
$lnGDP_{pc}SQ$	61.50989***	23.88656***	23.81513***	7.840788***
lnFDI	19.59396***	6.774455***	6.703027***	4.399705***
$lnINLF$	1.163546	-0.749729	-0.82116	1.046555

*** and ** denote significance at the 1% and 5% significance

Table 3: Second-generation panel CIPS unit root tests result

Variables	Level	First difference
lnEF	-1.56	-4.40***
lnPOV	-0.46	-2.28**
$lnGDP_{pc}$	-1.79	-3.04***
$lnGDP_{pc}SQ$	-1.79	-3.04***
lnFDI	-2.44**	-4.99***
$lnINLF$	-3.30***	-4.31***

*** and ** denote significance at the 1% and 5% significance levels.

4.1. Long and short-run estimates of PARDL approach

To affirm the impact of poverty on ecological footprint in the panel of BRICS nations, the study has applied PARDL estimation approach. Besides, all the variables used in the PARDL model are transformed into logarithmic form, so that the calculated coefficients of variables can be interpreted as elasticities, consistent with the work of Khan et al. (2022). Table 4 below present the empirical results of both the long run and the short run estimates. However, the ARDL estimates presented in table 4 will have to go through diagnostic statistics in order to determine robustness of the results (see table 5 to table 6 below).

As evident from the results presented in table 4 below, poverty head count reduces ecological footprint in the long-run ARDL estimates. The results suggest that ecological footprint diminishes by −0.326 percent in response to one percent increase in poverty head count in the long-run, while in the short-run, as poverty head count increases by one percentage point, ecological footprint escalates by 0.189 percent but the coefficient is insignificant. The long run results confirm the existence of a trade-off relationship between poverty and ecological footprints. In other words, a decrease in poverty would lead to an increase in environmental degradation in BRICS countries. Several reasons could explain the inverse relationship between poverty and ecological degradation. Centrally, the industrialization process needed to alleviate poverty requires significant C02 emissions, emissions that harm the environment and further leads to environmental degradation (Jin et al, 2018). Implicitly, our results are in consonance with the results of Khan (2021) for developing Asian countries, Dhrifi et al. (2020) for developing countries, and Islam and Ghani (2018) for ASEAN economies. Supporting the argument that a reduction of poverty, due to economic growth expansions lead to higher ecological footprint degradation. However, there contradicts the previous finding revealed by Abdul and Khan (2019a), Masron and Subramaniam (2019), Baloch et al (2020), and Khan et al. (2022). In their most recent study, Khan et al. (2022) applied the Driscoll–Kraay (D–K) regression approach for 18 developing Asian countries and came to a determination that a one-percentage increase in poverty headcount bring about 0.006 percentage increase in ecological footprint.

The results in table 4 reveals that the relationship between GDP per capita (proxy for economic growth) and ecological footprint is negative and statistically significant in the long-run ARDL estimates but the coefficients are positive but insignificant in the short run estimates. The long run estimated coefficient value of −0.00025 implies that one percent increase in the GDP per capita would reduces ecological footprint by 0.00025, whereas in the short-run estimates value of 0.00043 shows that one percent increase in GDP per capita would increase ecological footprint by 0.00043. Our results refute those of Islam et al (2021) who found that GDP per capita adds to the ecological footprint by 0.829 percent in the long run. However, these empirical results find support to those obtained by Mikayilov et al. (2018) for Azerbaijan, Nathaniel et al. (2019) for South Africa, Khan et al. (2019) for Pakistan, Zhang and Da (2015) for China, Alshehry and Belloumi (2017) and for Saudi Arabia.

Perhaps unsurprisingly, the GDP per capita square ─ square of economic growth has a positive and statistically significant effect on ecological footprint in the long run, while the coefficient is negative in the short run. Putting it more elaborately, the results indicate that a percentage increase in GDP per capita squared increase ecological footprint by 0.8162 percent in the long run, while a percentage change in GDP per capita squared in the short run reduces the ecological footprint by -0.7298 percent. Popular within the discussion between ecological footprints and economic growth is the Environmental Kuznets Curve (EKC) hypothesis, showing that there is a positive relationship between economic growth and the ecological footprint in the initial stages of development. However, over time the relationship becomes negative and more economic growth leads to more environmentally friendly practices and conduct environmental awareness programs and trainings that reduces the harmful impact of people on the environment. The EKC is not without is controversy and while many studies confirm the validity of the EKC hypothesis (Dogan and Seker, 2016; Inglesi-Lotz and Dogan, 2018; Danish et al. 2020; Khan et al. 2021) other argued against the validity of the EKC hypothesis (Gill et al. 2018; Pato and Aydin, 2020). Our results support the invalidity of the EKC hypothesis and is in line with the likes of Begum et al. (2015) for Malaysia between 1980-2009, Shafiei and Salim (2014) for 25 OECD countries between 1980-2011, Zoundi, (2017) for 25 African countries between 1980-2012, Lui et al (2017) for ASIA-4 countries between the 1970-2013 period, Destek et al. (2018) for 15 EU countries between 1980-2013. We confirm the relationship between economic growth and the ecological footprint starts off negative and then overtime becomes positive. Meaning the EKC path is rejected, and this might not surprising, since the continuous environmental degradation even after the initial stages of economic growth strongly relates to the failure of developing countries to reach a turning point in the economic growth-environment relationship. Furthermore, the extensive literature that either validates or rejects the EKC hypothesis relates to the heterogenous dynamics behind each stage of the Environmental Kuznets Curve for different countries and the different techniques used to determine threshold limits (Tato$\breve{g}$lu and Polat, 2021).

Similar to other developing countries, growth at its first stage might not be healthy for any environment and this is the intuition behind the Environmental Kuznets hypothesis (Khan et al., 2022). Access to education enters with negative but insignificant coefficient in the long run equation. However, the coefficient is positive and still insignificant in the short run.

Table 4: Panel ARDL estimation

Variable	*Coefficient*	*Std. Error*	*t-Statistic*
Long Run Equation			
lnPOV	-0.326666	0.095117	-3.434371
$lnGDP_{pc}$	-0.000253	4.83E-05	-5.248753
$lnGDP_{pc}SQ$	0.816250	0.108772	7.504218
lnAE	-0.204700	0.125858	-1.626440
lnFDI	-0.005226	0.006493	-0.804902
lnINFL	0.008102	0.000941	8.611859
Short Run Equation			
ECT	-0.596195	0.104216	-5.720758
Δln(POV)	0.189717	0.651540	0.291183
Δln (GDP_{pc})	0.000431	0.000239	1.804023
Δln ($GDP_{pc}SQ$)	-0.729862	0.501393	-1.455669
Δln (AE)	3.740541	3.160427	1.183555
Δln (FDI)	-0.015300	0.005364	-2.852362
Δln (INFL)	-0.003698	0.001515	-2.440074

C	-6.178430	0.974939	-6.337249
@TREND	-0.009089	0.007165	-1.268504

Foreign direct investment has a negative but statistically insignificant effect on ecological footprint in the long-run estimates, whereas in the short run estimates, the coefficient is negative and statistically significant at 5% level of significance. These results are to be expected since the inflow of foreign direct investment and the BRICS trade associations with other nations have been growing steadily over the years. However, Solarin et al. (2021) discovered the opposite for Nigeria. The authors revealed that foreign direct investment add 0.03 percent to environmental degradation in Nigeria by increasing ecological footprint. Unlike the results of foreign direct investment, inflation add 0.0081 percent to environmental degradation in BRICS nations by increasing ecological footprint, while in the short run, inflation has a reducing impact of −0.0036 percent. Lastly it is interesting to note that the ECT ─ which specifies the speed of adjustment from short-run towards long-run equilibrium has the anticipated sign. Thus, the ECM coefficient enters with a negative sign of -0.596195 in the short run equation.

4.2.Robustness check

The robustness check was performed in the results presented in table 5 above. To determine the robustness of the results, we first used an alternative measure of poverty ─ poverty gap instead of poverty head count. By and large, there are some noticeable similarities between the estimates obtained when using poverty head count and those found when applying poverty gap. The similarities are in terms of the level of significance and direction of the impact of explanatory variables on ecological footprint. Consistent with the results presented in table 4 above, poverty gap enters with the predicted negative sign significant at 5% level of significance in the long run. In line with the results of the short run equation presented earlier, poverty gap enters with positive but insignificant coefficient, reinforcing the estimates of model when using poverty head count. Other variables included in this estimation technique still mimic the same pattern in terms of the direction of the impact and the level of significance as those reported earlier. These variables include among others GDP per capita (proxy for economic growth), GDP per capita square (square of economic growth). Although foreign direct investment has changed the direction of the impact in the long run estimates presented in table 5, but the coefficient is still insignificant. In the short run, foreign direct investment has maintained its negative and statistically significant impact on ecological footprint in the BRICS nations. The ECM coefficient, which indicates how variables are readjusted back to equilibrium, still enters with the expected negative sign. The coefficient of access to education follows the same trend and direction of the impact as revealed in table 4 above. We can conclude that our results are not sensitive to the model used.

Table 5: Panel ARDL estimation

Variable	Coefficient	Std. Error	t-Statistic
Long Run Equation			
lnPOV	-0.244391	0.067604	-3.615046
$lnGDP_{pc}$	-0.000218	4.68E-05	-4.648639
$lnGDP_{pc}SQ$	0.693047	0.103656	6.686004
lnAE	-0.131732	0.129671	-1.015891
lnFDI	0.010398	0.007129	1.458568
lnINFL	0.008041	0.001007	7.981179
Short Run Equation			
ECT	-0.607713	0.116873	-5.199753
Δln(POV)	0.001949	0.229968	0.008476
Δln (GDP_{pc})	0.000312	0.000289	1.077790
Δln ($GDP_{pc}SQ$)	-0.692291	0.695569	-0.995288
Δln (AE)	4.960447	4.350726	1.140142
Δln (FDI)	-0.025054	0.008461	-2.961188
Δln (INFL)	-0.004279	0.001802	-2.374499
C	-5.691659	1.012670	-5.620445
@TREND	-0.008210	0.006372	-1.288474

It is interesting to observe that controlling for institution does not qualitatively change the results. Even if we use the rule of law (proxy for institutions), results are by and large similar as evident from table 6 below. Some of the results of the variables still mimic the pattern and structure of those presented previously, although the impact of some of the control variables differ in terms of the magnitude and level of significance. For instance, variables such as poverty gap, GDP per capita (proxy for economic growth), GDP per capita square (square of economic growth), access to education and inflation still present non-significant results in the long run equation. The conclusions advanced earlier also apply to the results presented in this part. Some of the results of the short run equation are still in line with previous estimates. As evident from table 6 below, the ECM coefficient enters with the anticipated negative sign of -0.269737 for the short run equation Our results are in agreement with those obtained by Uzar (2021) who found that institutions reduces the ecological footprint in China, India, Indonesia, and Russia. The rule of law proxy for institution enters with positive and statistically significant coefficient in the long run equation. On the contrary, the rule of law enters with negative and statistically significant coefficient, suggesting that institutional quality decreases the ecological footprint for the entire BRICS countries.

Table 6: Panel ARDL estimation

Variable	Coefficient	Std. Error	t-Statistic
Long Run Equation			
lnPOV	-0.556783	0.002531	-220.0280
$lnGDP_{pc}$	-7.26E-07	4.17E-07	-1.740539
$lnGDP_{pc}SQ$	0.054450	0.000361	150.6393
lnAE	-0.359348	0.008230	-43.66339
lnFDI	-0.011669	0.000490	-23.81170
lnINFL	0.023037	0.000214	107.6398
RULE OF LAW	0.746991	0.010458	71.43098
Short Run Equation			
ECT	-0.269737	0.136887	-1.970504
Δln(POV)	-0.270851	0.160382	-1.688785
Δln (GDP_{pc})	4.79E-05	0.000936	0.051129
Δln ($GDP_{pc}SQ$)	1.257057	2.258039	0.556703
Δln (AE)	4.203595	5.000276	0.840673
Δln (FDI)	-0.010345	0.018598	-0.556248
Δln (INFL)	-0.005210	0.002655	-1.962658
Δ (RULE_OF_LAW)	-0.160540	0.072489	-2.214684
C	0.141289	0.115735	1.220791

The results in table 7 which uses another measure only a component of ecological footprint (grazing land) indicate that the majority of variables included in this estimation technique still mimic the same pattern in terms of the direction of the impact and the level of significance as those reported earlier. More precisely, the results indicate that the coefficient of our variable of interest (poverty gap) has maintained its negative sign both in the long run and short run models. Thus, a percentage change in poverty gap leads to about -0.119022 reduction in ecological footprint and statistically significant at 1% level. These results are similar to those presented earlier. The coefficient of ECM is still negative as expected and statistically significant in the short run model. The direction of the impact of various variables still resembles those presented earlier.

Table 7: Panel ARDL estimation

Variable	Coefficient	Std. Error	t-Statistic
Long Run Equation			

lnPOV	-0.119022	0.019640	-6.060070
$lnGDP_{pc}$	-9.23E-05	1.73E-05	-5.348250
$lnGDP_{pc}SQ$	0.097894	0.059570	1.643346
lnAE	0.193827	0.077075	2.514802
lnFDI	-0.017959	0.003907	-4.596967
lnINFL	0.003324	0.000615	5.405378
Short Run Equation			
ECT	-0.565634	0.312268	-1.811374
Δln(POV)	-0.047674	0.026166	-1.821991
Δln (GDP_{pc})	0.000267	0.000145	1.838370
Δln ($GDP_{pc}SQ$)	-0.812742	0.396166	-2.051520
Δln (AE)	0.489455	0.393877	1.242659
Δln (FDI)	0.004488	0.004536	0.989412
Δln (INFL)	0.000117	0.000538	0.217912
C	-0.830506	0.482958	-1.719624
@TREND	-0.002956	0.002491	-1.186752

However, if we remove China from the equation, there are noticeable differences in the estimated coefficients as shown in table 8. The differences are in terms of the direction of the impact and the level of significance. For example, poverty gap enters the model with positive and statistical significant coefficient. Consistent with the results of Khan et al. (2022), our results shows that a one-percentage increase in poverty gap bring about 0.214083 percentage increase in ecological footprint. Other variables that have changed their signs include access to education and foreign direct investment. It is fascinating note that even if we remove China from the equation, there is still greater deal of consistent with regards to other estimates such as inflation, GDP per capita and GDP per capita square. The results of most variables shows that the signs of long-run coefficients remained the same as we reported in the full sample of the ARDL model. The short run results reveals that ECM is still negative and statistically significant.

Table 8: Panel ARDL estimation

Variable	Coefficient	Std. Error	t-Statistic
Long Run Equation			
lnPOV	0.214083	0.087756	2.439523
$lnGDP_{pc}$	-0.000272	8.22E-05	-3.314287
$lnGDP_{pc}SQ$	1.650579	0.318041	5.189824
lnFDI	0.012194	0.007841	1.555211
lnINFL	0.004069	0.001863	2.184307
lnAE	-0.188057	0.241352	-0.779180
Short Run Equation			
ECT	-0.673595	0.302499	-2.226770
Δln(POV)	0.097949	0.199119	0.491913

$\Delta\ln\ (GDP_{pc})$	4.66E-05	0.000444	0.104901
$\Delta\ln\ (GDP_{pc}SQ)$	-0.339837	1.211718	-0.280459
Δln (AE)	-0.026546	0.009489	-2.797535
Δln (FDI)	-0.004185	0.002746	-1.523991
	1.129162	0.912213	1.237828
C	-16.31008	7.611649	-2.142779
@TREND	-0.014699	0.010712	-1.372265

5. Conclusion

This paper investigates the relationship between ecological footprint and poverty with consideration of GDP per capita, its square term, FDI, access to education and rule of law within the BRICS countries (Brazil, Russia, India, China and South Africa). The study used panel data covering period 1990–2017 for BRICS nations. The data for this study was extracted from different sources of data, such as the Worldwide Governance Indicators (WGI), the Global Footprint Network (GFN) and the PovcalNet. To estimate the short-run and long-run relationship between poverty and ecological footprint within the BRICS countries, we specify a PARDL model. The reason for choosing PARDL was threefold: (i) it is appropriate for addressing cointegration, (ii) it permits variables that follow I(0) and I(1) process; (iii) it is robust in the presence of endogeneity.

The results of PARDL model showed an inverse relationship between ecological footprint and poverty head count in the long-run. Thus, the results suggested that ecological footprint diminishes −0.326 percent in response to one percent increase in poverty head count in the long-run, while in the short-run, as poverty head count increases by one percentage point, ecological footprint escalates by 0.189 percent but the coefficient was insignificant. Confirming the existing trade-off between poverty alleviation and environmental protection, two vital sustainable development goals. On the other hand, the study established, the relationship between GDP per capita (proxy for economic growth) and ecological footprint was negative and statistically significant in the long-run model but the coefficients were positive but insignificant in the short run estimates. For access to education variable, results surprisingly showed a negative relationship with ecological footprint in the long run equation, while the coefficient was positive and but insignificant in the short run. Foreign direct investment had a negative but insignificant effect on ecological footprint in the long-run estimates, whereas in the short run equation, the coefficient was negative and statistically significant at 5% level of significance. We also found an inverse relationship between ECT and ecological footprint within the BRICS nations. To check the robustness of our results, surprisingly, there were some noticeable similarities between the estimates obtained when using poverty head count and those found when applying poverty gap. The similarities were in terms of the level of significance and direction of the impact of many explanatory variables on ecological footprint.

The results also decompose the full sample and excluded China from the regression, fining that the sign of the environment-poverty nexus changes from negative to positive. These results are also robust when various other measures of ecological footprint, poverty and alternative empirical specifications are used. Moreover, the environmental-poverty nexus leads to a possible conflict of policies aimed at expanding economic activity, targeting poverty alleviation, and protecting the environment. Provided the BRICS nations still suffer from high poverty, our findings show the complex policy design needed to simultaneously reduce both poverty and reduce the ecological footprint. Most notably governments should aim to implement development policies that focused on renewable energy plans, creating a platform where poverty can be reduced, while at the same environmental degradation kept at a minimum. However, the current upward trend of environmental degradation for some BRICS countries and the high poverty in others leaves the environment-poverty nexus still the balance and given growth trajectory of the BRICS nations, the future of the planet could very well be in the hands of these developing nations.

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Appendix

Table A: Descriptive stats

	EF	POV-GAP	GDPpc	GDpcSQ	FDI	INFL	AE	Rule of law
Mean	0.987455	-1.858255	5877.340	16.87008	23.69986	7.176749	4.481869	-0.261325
Median	1.107304	-1.365319	5714.626	17.30157	24.07518	6.136020	4.575675	-0.193651
Maximum	1.763062	-0.556813	11731.38	18.74005	26.39634	47.75201	4.605170	0.353991
Minimum	-0.215218	-4.935157	652.5661	12.96182	20.12604	-0.731971	3.970358	-1.097559
Std. Dev.	0.573950	1.214843	3241.355	1.626325	1.617871	6.239859	0.163286	0.383371
Skewness	-0.856368	-1.184400	-0.034482	-1.023364	-0.391684	3.490691	-1.334404	-0.402534
Kurtosis	2.641853	3.536295	2.051340	2.805564	2.300852	21.55170	3.844543	1.956343
Jarque-Bera	11.86422	22.85796	3.505758	16.37923	4.272088	1522.508	30.36367	6.732248
Obs	93	93	93	93	93	93	93	93