The Energy Consumption-Environmental Quality Nexus in BRICS Countries: The Role of Outward Foreign Direct Investment (OFDI)

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The energy consumption-environmental quality nexus in BRICS Countries: The Role of outward foreign direct investment (OFDI)

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Abstract

This paper examines the role of outward foreign direct investment (OFDI) on energy consumption and environmental quality in BRICS from 1990 to 2019. We use cross-sectional dependence (CSD) and the Pesaran-Yamagata slope homogeneity for the diagnostic test. After confirming the diagnosis test, we employ CIPS and CADF second generation panel unit root test, which confirms that all elements are stationary at first difference. The Pooled Mean Group (PMG), Westerlund cointegration, two-step GMM, panel FMOLS and DOLS model have been used to determine the short term and long-term association among the variables. The cointegration and PMG results confirm that the short-run and long-run association exists among the considered variables. The GMM and DOLS results reveal that developing countries produced environmental pollution at the early stage of development and checked in the long run. The empirical results hold up the EKC hypothesis, which implies that OFDI and energy consumption help expand greener technology to host countries' environmental improvement in the long run and confirm that an inverted U-shaped linkage exists. Hence, the study suggests that developing countries should pay more attention to sustainable development and technological development that encourages more eco-friendly and environment-friendly technology. To frame the profitable strategies, governments of emerging countries should inspire public-private partnerships to circulate the environmental consciousness, guideline for energy efficiency, and generate a pollution-free environment.

Keywords: Outward FDI; Energy consumption; Environmental quality; BRICS Countries; Generalised Method of Moments; Environmental Kuznets curve

Abbreviations

CSD- Cross-Sectional Dependence
CIPS- Cross-sectionally augmented IPS
CADF- Cross-sectionally augmented ADF
OFDI- Outward Foreign Direct Investment
BRICS-Brazil, Russia, India, China, South Africa
EKC- Environmental Kuznets Curve
FMOLS- Fully Modified Ordinary Least Square
DOLS- Dynamic Ordinary Least Square
GMM- Generalised Method of Moments
PMG- Pooled Mean Group
OLS -Ordinary least squares
GHG -Green House Gases
IMF -International Monetary Funds
WIR- World Investment Report
BTUs- British thermal units
GDP- Gross Domestic Product
IPAT- Impact = Population + Affluence+ Technology
STIRPAT- Stochastic Impacts By Regression On Population, Affluence And Technology
UNCTAD- United Nations Conference on Trade and Development
WDI- World Development Indicators
ECM- Error Correction Model
ECT- Error Correction Term
PHH- Pollution Haven Hypothesis
R & D- Research and Development
FDI- Foreign Direct Investment
ARDL-Auto Regressive Distributed Lags
VECM-Vector Error Correction Model
OECD- Organisation for Economic Co-operation and Development
CO2- carbon emissions

1. Introduction

Particularly by virtue of liberalisation, globalisation and privatisation policies, energy utilisation and environmental pollution have continuously increased and are predicted to increase more in the coming future (Pandey et al. 1999; Jun et al. 2021). According to the International Monetary Funds (IMF) report, World's total output increased by 3.7% in 2017 and 3.9% in 2018 (IMF 2018). Similarly, the U.S. Energy Information Administration report reveals that the energy consumption is expected to increase by 736 quadrillions in BTUs (British thermal units) in 2040 compared to 575 quadrillion in BTUs in 2015 (US EAI 2017). This scenario creates a more significant challenge for developing and developed countries. Another report revealed that the Green House Gases (GHG) emissions might rise approximately up to 50 per cent by 2050, and 70 per cent of carbon emissions would be generated due to heavy energy consumption (OECD 2012).

To address certain pollution problems nations, need to give much more attention to their annual economic development. In developing countries, foreign direct investment (FDI) creates a significant positive impact on economic growth and hampers both the home and host countries environment (Anyanmu 2012). Emerging economies strengthen their domestic and foreign investment for more economic development, which eventually create environmental problems. Outward FDI enhances industrialisation and advances technology (Buckely et al. 2020). According to WIR 2016, OFDI from developing economics increased 91 billion to 400-dollar billion from 2000 to 2015. Developing countries like China and India have created a better position in FDI, and they have produced high environmental pollution, especially water pollution and air pollution (Wang and Yang 2016; Li *et al*., 2016; Abdouli & Hammami 2017). Conclusively a sizeable emerging country generates high environmental pollution.

Most of the earlier studies considered the EKC hypothesis on developed countries (Salahuddin et al. 2018; Chandran & Tang 2013; Kivyiro & Arminen 2014). From the previous study, we do not find proper evidence to reduce pollution in emerging nations. Few studies suggest the policy measures to shifting the countries' position haven hypothesis to halo hypothesis, particularly considering developed counties as their study area (Li et al. 2015; Sinha et al. 2017). However, very few studies focused on the essential factor affecting the environment in developing countries, but their findings did not help reduce pollution in developing countries like India and China. According to International Energy Agency, 2018 reported China is the most polluting country and produce 10.06 gig tons of carbon emissions in 2017-2018. Surprisingly, India and Russia were in 3rd and 4th rank and produced approximately three gig tons of carbon emissions per year. Likewise, Brazil and South Africa were in 13th and 14th globally and produced almost two gig tons of CO2 emissions in 2017-18. An increase in carbon emissions is a severe concern for the BRICS union to achieve sustainable goals. Therefore, this paper attempts to solve the problem by adopting basic and advanced techniques to identify the association between OFDI, energy consumption and carbon emissions in developing countries like BRICS and provide proper policy and regulation to reduce environmental degradation.

The present study covers the five fastest emerging economies, viz. Brazil, Russia, India, China, and South Africa. A considerable increase in economic growth has created transition and industrialised economies like the BRICS union for the last decades. BRICS nations are fast-growing developing countries and generate more impact in the environment (Akpanetal 2014). Among the BRICS countries, India and China have a significant role in global production and, Brazil and Russia are experts in energy resources and raw materials (Kobayashi-Hillary, 2007). The past studies reported that FDI outflow from emerging countries like BRICS is quite impressive and has shown a significant growth in the last few years, which gives a positive picture towards economic development (Sachs, 2003; WIR, 2017). The BRICS union is considered with almost 40 per cent of the global population, contribute 21 per cent of the GDP, consume almost 40 per cent of the World's energy, and generate a considerable part of global carbon emissions (WIR 2018 & Wang 2019). The BRICS nations need the right policy to use alternative energy solutions for the future. BRICS countries prefer more biomass energy for sustainable development to control environmental pollution (Shahbaz *et al*. 2018). The BRICS union is at risk of environmental degradation, so it is necessary to pay more attention to this field.

Several studies have analysed the effects of different macroeconomic variables on environmental pollution. Most of the literatures have considered carbon dioxide emissions for their analysis as a proxy variable for environmental pollution (Arouri et al. 2012; He et at. 2017; & Wang et al. 2018; Ahmad et al., 2019). However, very few studies empirically examine the nexus among quality of environment, OFDI, population and energy utilisation. Therefore, the primary focus of the study is to associate the link among outward FDI, energy consumption, innovation, economic growth and pollution in emerging economics like BRICS. The novelty of this study includes innovation, human capital, and outward FDI as new explanatory variables in the EKC framework. This study is quite different from other studies because it examines the dynamic relationship and identifies the EKC hypothesis by employing advanced panel techniques to estimate the results. The study applies a cross-sectional dependency test and slopes homogeneity test to check cross section's heterogeneity. For the cointegration analysis, the study uses Westelund cointegration and Pooled Mean Group (PMG) to identify the short-run and long-run relationship. We also use two-step GMM, FMOLS, DOLS to check the long-run robustness and avoid endogeneity and serial correlations problems. The rest of the article is organised as follows. Section 2 presents the related literature review. Section 3 the theoretical framework Section 4 discusses the data and methodology. Section 5 discusses the empirical results and discussions. Section 5 presents the conclusion and policy implications.

2. Literature review

Numerous researches have investigated the impact of OFDI and energy consumption on environmental degradation. In addition, to the existing literature, the study added different macroeconomic variables, which also play an essential role in environmental degradations. This study investigates OFDI, energy consumption, economic growth, R & D activities and secondary industries on environmental pollution. The literature review section has been classified into different sections to clarify the association among the selected variables used in the study.

2.1 Environmental pollution and Outward FDI nexus

The globe is currently in a conundrum because of drastic changes in climate and environment, which eventually destroys our natural environment and ecological system (Bonan 2015; Goldstone, 2018; Wang et al. 2017). Salahuddin et al. (2018) explore the impact of growth, financial development, foreign direct investment (FDI), and electricity consumption on Kuwait's environment. They employ time-series data from 1980 through 2013 and use CO_2 emissions as a proxy for environmental quality. For the practical analysis, they apply the ARDL bound testing method and conclude that economic growth, FDI and electricity consumption stimulates carbon emissions (CO_2) in Kuwait; thus, these three factors deteriorate the environmental quality. Outward FDI promotes national economic growth and development. The nexus between OFDI and pollution is "inverted u-shaped", which implies that OFDI will increase environmental pollution in the short run. Still, in the long run, OFDI reduces pollution (Hao et al. 2018).

The research on the effect of environmental pollution on OFDI is still in its infancy. Many researchers found that OFDI harms the environment (Xin et al. 2020; Hao et al. 2020). Similarly, Han (2021) analysed that the enhancement of OFDI tends to generate highly polluting companies, eventually deteriorating environmental quality. Chen (2013) empirically examined the home country's environmental quality and its effects on Chinese Outward investment. This study concludes by using an advanced technique that OFDI has positive and negative impacts on the China environment.

2.2 Environmental pollution, energy consumption and economic growth nexus

The nexus between environmental pollution and energy consumption is one of the current debates in the energy-environment literature. By taking carbon emissions as a proxy variable for environmental pollution, many studies confirm a long-run unidirectional link between CO2 and energy use (Alshehry & Belloumi 2015; Ahmad et al. 2017; Isik et al. 2018). However, some literatures found a short-run and bidirectional association between CO2 and energy consumption (Heidari et al. 2015; Jebli & Belloumi 2017; Mirza & Kanwal 2017). Topcu and Payne (2018) considered trade and energy consumption nexus in OECD countries. They applied panel structure with approval for heterogeneity and cross-sectional dependence. Their study concluded that the influence of trade on energy use revealed an inverted U-shaped pattern which explained that the impact of carbon dioxide emissions on energy consumption is more than economic growth.

Past literature (He and Richard 2010; Galeotti and Lanza 2005) have thoroughly used the EKC hypothesis framework to explore the nexus between environmental pollution and growth. Many studies have attempted to evaluate the environmental Kuznets curve to identify the relation between GDP and the environment (Tiwari et al. 2013; Shahbaz et al. 2014; Apergis and Ozturk 2015). However, other studies considered real GDP per capita with carbon dioxide emissions, gross fixed capital formation, energy consumption, exports and imports to see its association (Akalpler & Hove 2019; Hao et al. 2020; Shahbaz et al. 2020; Sahoo & Sethi 2021). By employing the ARDL model, Jalil and Mahmud (2009) examined the EKC hypothesis between carbon emissions and per capita GDP in China. Similarly, (Wang et al., 2011; Jayanthakumaran et al. 2012; Yin et al., 2015; Kang et al. 2016; Dong et al. 2017) empirical studies support an inverse relationship between pollution and growth. Likewise, Dinda (2004) study was examined by considering OECD and Non-OECD nations. His result deviates from other works of literature, i.e., CO2 emissions do not hamper economic growth in Non-OECD regions. In contrast, carbon emissions badly hindered economic growth in OECD countries.

2.3 Environmental pollution and other macro-economic variables

Many previous literatures have attempted to use eco-innovation to reduce carbon emissions, encouraging governments to promote R&D activity (Gu and Wang 2018; Long et al. 2017). Chen et al. (2018) research revealed that energy intensity and GDP would increase carbon emissions in OECD countries. Likewise, Ito (2017) considered the impact of energy structure on CO2 emissions in 42 advanced countries. In the last decades, research and development (R&D) has increased significantly over the World. Many research pieces focus on the role of R&D performance on carbon emissions in developed countries (Wang and Wang 2019; Greaker and Pade, 2009). Su and Moaniba (2017) used the GMM method to examine the nexus between innovation and environmental pollution and conclude that technical innovations in liquid fuels like petroleum and natural gas significantly reduce carbon emissions. Álvarez-Herránz et al. (2017) investigated that energy-centric innovation significantly reduced greenhouse gas emissions in OECD countries. Santra (2017) revealed that innovation enhanced energy use and increased carbon emissions in the BRICS. Likewise, Yii and Geetha (2017) employed the VECM model to support that R&D and innovation reduce environmental pollution in the short run but not in the long run. To examine the macro-level analysis, the relationship between human capital and carbon emissions is not well identified in previous studies. According to the endogenous growth model, human capital is a crucial driver of technical progress and creates a better investment environment by promoting more research and development (R&D) activities (Romer 1990; Vandenbussche et al. 2006). Hence, technological improvement provides efficiency at the production level and help to reduce carbon dioxide emissions (Cagno and Trianni 2013; Churchill et al. 2019).

Carbon emissions are among the most widely used indicators of environmental pollution. A large amount of CO2 emissions is associated with energy consumption, energy source, manufacturing industries and the population (Li et al. 2015; Zhang et al. 2017; Sinha et al. 2017). Xu and Lin (2017) examined that the manufacturing industry heavily affects carbon emissions in China. At the same time, Li et al. (2015) find that 75 per cent of total emissions are generated from chemical production and ferrous metal. Environmental pollution problems are now a matter of concern, attracting governments and policymakers' attention, specifically in developing countries (Lu et al., 2018). Therefore, developing nations need to promote sustainable growth, encourage sustainable energy consumption, and encourage more environmental-friendly technology and eco-friendly innovation (Liu and Bae, 2018). Duerksen and Leonard (1980) investigate trade and domestic investment data to examine a pollution haven effect in the United States (U.S.) and found that FDI in pollution-intensive industries has not significantly increased in developing countries than developed countries. Moreover, Wagner and Timmins (2009) examine the impact of environmental regulations across many host nations on the OFDI of German industries from 1996 to 2003. This study concludes that FDI creates negative externalities in both home and hosts countries and suggest effective policy needs to frame in such a way that help to control the environmental damages.

From the above literature reviews we found that as folows: Firstly, past studies considered the impact of FDI on environmental pollution, and very few studies focus on outward FDI. Secondly, we identify that most studies explain the association between economic growth and environmental degradation; few studies examined the link at the macro level. Thirdly, most of the researches have used time series analysis and microeconomic approaches, and a few kinds of research also consider country-level analysis from China (Hao et al., 2020). Fourthly, most of the previous academic studies considered foreign direct investment mainly focuses on the environmental impact on the host country effect and ignored the home country effect. Therefore, the present study is different from the previous studies in several aspects. Firstly, the study considers BRICS countries as the sample for panel analysis. Secondly, the study focuses on how OFDI affects the environment of the home country. Thirdly, the study examines the dynamic impact of considered variables on environmental pollution using rigorous econometric models.

3. Theoretical Foundation

Numerous studies have been proved reverse technological transformation from OFDI (Hao et al. 2020; Xia et al. 2020). Chen (2018) concluded that OFDI encourages economic growth by focusing more on the reverse technical transformation. The first stage of OFDI improves knowledge and management skills and encourages more advanced technology from their host destination (Dunning 1991; Pradhan & Singh 2008; Mohanty & Sethi 2019). In the second stage of outward FDI, parent companies must adopt advanced and new technologies (Dunning 1991; Liu & Liu 2017; Mohanty & Sethi 2019). Generally, when developing countries enhance their overseas investment, they generate environmental degradation (Christoforidis & Katrakilidis 2021); however, developed nations are more concerned about pollution and emphasise green investment (Sulemana et al. 2016).

Ehrlich & Holdren (1971) developed the IPAT model to examine the effect of human activities on the environment. The model as follows:

$$I = P + A + T \tag{1}$$

Where I = Impact, P =Population, A= Wealth, T= Technology. Due to restrictions on some factors and determinants, Dietz and Rose (1997) developed a random version of the IPAT model to estimate the impact of GDP, FDI and Innovation on carbon dioxide emissions.

$$lnI_{it} = ln\alpha_i + \beta lnP_{it} + \Upsilon lnA_{it} + \theta lnT_{it} + e_{it} \tag{2}$$

Where I stand for carbon emissions, P stands for per capita GDP, A stands for FDI, and T stands for innovation and technology (Commoner et al. 1971; Raskin 1995). The limitation of the IPAT model is some values are missing and not determined in the model to avoid the non-proportional and non-monotonic effects. Therefore, Rose & Dietz (1998) suggest the STIRPAT model for stochastic impacts by applying the regression model on population, affluence and technology. Thus, the STIRPAT model has been significantly used to see the impact of GDP, Outward FDI, Research and Development on Carbon dioxide emissions (Carmer 1998; DeHart & Soule 2000; York et al., 2003; Cai et al. 2021).

Grossman & Krueger (1995) developed the theoretical framework of environmental economics, popularly known as the Environmental Kuznets Curve or EKC hypothesis. EKC hypothesis explains that the level of environmental pollution increased as nations develop; after a particular point of development, the level of pollution will decrease with a further increase in the per capita income. This hypothesis is imitated as an inverted 'U' shape curve that explains the link between pollution and GDP per capita income. According to the EKC theory, the scale effect can be measured by taking the country's economic growth (Hao et al. 2020). The scale effect is generally accepted when a country mainly depends on primary and secondary sectors. The scale effect will increase the income level, and a transformation occurs in the secondary industry, considered a composition effect. When manufacturing industries are in the take-off stage, it encourages eco-friendly technologies to control environmental destruction. This stage increases the demand for a pollution-free environment, further encouraging more research and developmental activity and enhancing economic growth. This process is known as the technique effect. Therefore, a country needs to encourage green development by promoting eco-friendly technologies that eventually improve the environment and increase economic growth for proper development.

4. Data and methodology

To investigate the effect of outward FDI and energy consumption on environmental pollution, we consider the strongly balanced panel data for BRICS from 1990 to 2019. The panel data estimation is examined to capture the behaviour of dependent and independent variables and provide a more efficient estimation for further research. The data are obtained from secondary data sources such as UNCTAD (2020) statistics and World Development Indicators (WDI) of World Bank (2020). The STIRPAT model mainly was used to analyse the impact of the explanatory variables on the environment (Bargaoui et al., 2014). From the previous study (Wang and Liu, 2008; Cantwell, 2009; Grossman and Krueger, 1991) the present study develops the functional equation to investigate the effect of OFDI and the other explanatory variables on carbon dioxide emissions in BRICS. The Eq. (1) is formulated as follows:

$$ENV = f(OFDI, GDP, EC, LAB, GCF, SI, R\&D, HC, X) \qquad (3)$$

Where, ENV is denoted as environmental pollution, which is a function of outward FDI (OFDI), per capita gross domestic product (GDP), energy consumption (EC), labour force (LAB), physical capital (GCF), secondary industry (SI), research and development (R&D) and human capital (HC). This study also considered the geographical distance as a dummy variable, i.e., denoted as X. Taking geographical distance as a variable is essential to measure the pollutions like air pollution, water pollution etc (Zhao & Sing 2015; Hao et al. 2020). The considered variables' summary is signed positive and described in table 2. By considering the above eq. (3) our model specified to analyse the effect of energy consumption and outward FDI on the environment in BRICS.

$$ENV_{it} = \alpha + \beta_1 OFDI_{it} + \beta_2 GDP_{it} + \beta_3 EC_{it} + \beta_4 LAB_{it} + \beta_5 GCF_{it} + \beta_6 SI_{it} + \beta_7 R\&D_{it} + \beta_8 HC_{it} + \beta_9 X_{it} + u_{it} \qquad (4)$$

All the variables are considered in natural logarithm form, where, t = 1, 2… T refers to the time period and I = 1, 2 … N refers to the cross-section data. The parameters β_1 , β_2 ,.., and β_9 are represent the long-run elasticity estimators of dependent and independent variables and u_{it} is the white noise error term.

By adopting dynamic and static panel models, Zhu et al. (2018) examined that OFDI has not significantly improved the Chinese environment. However, Eskeland and Harrison (1997) study analysed that Outward FDI helps improve the environmental quality of the host and home countries by encouraging more pollution avoidance effects and green investment. Yang and Liu (2013) research focused on OFDI and its effect on home country carbon emissions in Japan and revealed that OFDI could effectively reduce carbon emissions. Ouyang et al. (2020) used the panel data analyses by considering listed Chinese companies found that the OFDI effectively improves regional environmental pollution. Many studies reported unidirectional causality from energy consumption to carbon emissions (Apergis & Payne 2009; Ozturk 2010; Pao & Tsai 2011). Likewise, some studies confirmed bidirectional causality between energy consumption and carbon emissions in the long-run and no short-run relations (Dogan & Aslan 2017; Cai et al. 2018). From the above evidence, the present study identified that the associations between outward FDI, energy consumption, and pollution are providing a mixed result; subsequently, the study develops the null hypothesis that:

H_{1a}: There are no long-run, and short-run causal relations exist between outward FDI and carbon emissions in BRICS.

H_{1b}: There are no long-run and short-run associations exist between energy consumptions and carbon emissions in BRICS.

Extensive research on the environmental Kuznets curve (EKC) explains the relationship between GDP and carbon emissions (Grossman and Krueger 1995; Dinda 2004; Nahman and Antrobus 2005). Since then, many studies have confirmed the EKC hypothesis exists in developed countries (Mielnik et al. 2002; Ahmad et al. 2021). For our dataset of five developing countries with data from 1990 to 2019, we test the second null hypothesis of this study, which is the EKC hypothesis.

H_2: The EKC hypothesis does not exist in BRICS.

Table 1: Description of Variables and Data Sources

Variables	Symbol	Measurement	Source
Environmental Pollution	ENV	CO2 emissions (metric tons per capita)	WDI
Outward FDI	OFDI	Outward Foreign Direct Investment (Current per capita US$)	UNCTAD
Gross Domestic Product	GDP	Gross Domestic Product Per Capita (Constant US$ 2010)	WDI
Physical Capital	GCF	Gross Capital Formation (Constant US$ 2010)	WDI
Labour	LAB	Labour force participation rate, total (% of total population ages 15-64)	WDI
Research and Development	R&D	Research and development expenditure (% GDP)	WDI
Human Capital	HC	Human capital index, based on years of schooling and returns to education	WDI
Energy Consumption	EC	Energy use (kg of oil equivalent per capita)	WDI
Secondary Industry	SI	Manufacturing, value added (% of GDP)	WDI

Source: Authors' compilation

Notes: WDI-World Development Indicators (2020), UNCTAD- United Nations Conference on Trade and Development (2020).

4.1 Cross-Sectional Dependence (CSD) test

The first-generation unit root tests have some disadvantages: the cross-sections in the panel data are independent. However, the presence of the CSD assumption is not appropriate for empirical investigation. The panel analysis's cross-sectional dependence (CSD) test is considered the most critical test because CSD might create biased and inconsistent results (Phillips & Sul 2003). This study uses the CSD test developed by Chudik and Pesaran (2015) to identify cross-sectional dependence (CSD) exists within our model or not. Pesaran's CSD test uses the following equation is based on the correlations between the disturbances in different cross-section units.

$$\text{CSD}\sqrt{2T/N(N-1)}\sum_{i=0}^{N-1}\sum_{j=i+1}^{N}\partial_{ij} \tag{5}$$

where T represents the period, N indicates the cross-sections in the panel, ∂_{ij}j is correlation coefficients of I and j unit. The null hypothesis of the cross-section is weak the CSD, and the statistic is asymptotically distributed.

4.2 Second-Generation Panel Unit-Root Test

Since CSD among countries, we apply the second-generation unit root tests for stationarity of the considered variables. Therefore, this study employs the CADF panel second-generation unit root test for the preliminary test. CADF test is an extended version of the Augmented Dickey-Fuller (ADF) test; these tests take the following equation form:

$$\Delta x_{it} = \alpha_{it} + \beta_{it-1} + \delta_I T + \sum_{j=1}^{n}\gamma_{ij}\,\Delta x_{it-j} + \epsilon_{it} \tag{6}$$

Where x_{it} is considered as an analysed variable, ϵ_{it} is the white noise error term, Δ is the difference and T and α are time trends and individual intercepts. The appropriate and optimal lag lengths are based on the Akaike Information Criterion (AIC).

4.3 Westerlund (2007) panel cointegration test

The study employs Westerlund's (2007) dynamic panel cointegration method to examine the selected variables' heterogeneity and cross-sectional dependence test. The null hypothesis of this approach is no cointegration exists in the error-correction term (ECT). To check the cointegrating association between dependent and independent variables; hence we have employed the following error-correction model:

$$\Delta Y_{it} = \rho_i d_t + \alpha_i (Y_{it-1} - \beta_i X_{it-1}) + \sum_{j=1}^{P_i} \alpha_{ij} \Delta Y_{it-j} + \sum_{j=0}^{P_i} \gamma_{ij} \Delta X_{it-j} + \mu_{it} \tag{7}$$

Where d_t contains the deterministic element, and cointegration is expressed by $Y_{it-1} - \beta_i X_{it-1} = 0$. α_i measures the velocity of adjustment, and cointegration is assured by $\alpha_i < 0$, whereas $\alpha_i = 0$ falsifies the presence of cointegration.

4.4 Generalised Method of Moments test

The Generalised Method of Moments test can apply from both level and difference equations. GMM work better for panel with large sample size. The GMM estimator gives more robustness results as compared to the other econometrics model. By considering various weight matrixes, GMM approach is generally divided into one-step GMM estimators and two-step GMM estimators. The two-step GMM is comparable a better instrument than the conventional one-step GMM because it helps to remove simultaneity from the regressor set by including instrumental variables. Ullah et al. (2018) developed some generic STATA codes for using GMM estimator to control three sources of endogeneity problem better, i.e., i) unobserved heterogeneity, ii) simultaneity, and iii) dynamic heterogeneity. Arellano and Bond (1991) and Blundell and Bond (1998) included lagged dependent variable as a regressor in the model to reduce possible endogeneity; thus, they developed a GMM estimator for dynamic panel modelling. Windmeijer (2005) explained that biases could be rectified by giving more attention to small samples' variation. A null hypothesis of the Sargan test is the instruments are exogenous. Therefore, the higher the p-value of the Sargan test is the better. The Arellano-Bond two-step difference GMM test for autocorrelation has a null hypothesis of no autocorrelation. This test generally applied to differenced residuals. The AR (2) process in the first differences generally rejects the null hypothesis. Therefore, the AR (2) test is more critical to define autocorrelation in the regression models.

4.5 Panel FMOLS and Panel DOLS

This is essential to check the robustness of the long-run connection among the elements in our model. Hence, this is necessary to examine the elasticity of dependent variables with respect to considered independent elements. Pedroni (2001) employed the Fully Modified Ordinary Least Square (FMOLS) technique to solve the problem related to endogeneity between regressors. This test corrected the stochastic regressor and the correlation between the cointegrating equations in the long run. Likewise, the Dynamic Ordinary Least Square (DOLS) test was propounded by Kao and Chiang (2000) to identify and remove the endogeneity and autocorrelation problems using a parametric approach in the panel data set. DOLS estimators are applied for both homogeneous and heterogeneous panels. This test is better than FMOLS because it removes endogeneity and autocorrelation problems by adopting a parametric approach.

5. Empirical results and analysis

We employ panel data techniques to estimate the dynamic behaviour of the dependent variable on independent variables in BRICS countries. The primary motivation of summary statistics is to analyse all sample summaries and selected elements of the study. The Correlation matrixes provide a podium for regression to verify the association of dependent and independent variables. Hence, descriptive statistics and correlation analysis have been carried out before estimating advanced tests for panel analysis.

Table 2: Descriptive Statistics and Pair-wise Correlation Matrix

	ENV	OFDI	GDP	EC	R&D	SI	LAB	GCF	HC
Mean	5.42	2.15	12.08	3.19	-0.03	0.98	1.82	1.39	2.40
Median	5.92	2.45	12.14	3.20	0.01	1.16	1.83	1.36	2.28
Max.	7.01	3.68	13.06	3.77	0.33	1.51	1.92	1.66	3.43
Min.	0	-0.89	11.33	2.54	-0.24	0	1.71	1.16	1.48
SD	1.86	1.10	0.39	0.35	0.11	0.48	0.05	0.14	0.52
Obs.	150	150	150	150	150	150	150	150	150
ENV	1								
OFDI	0.30*	1							
GDP	0.02***	0.03*	1						
EC	0.09**	0.62*	-0.08	1					
R&D	0.01***	0.26*	0.56*	0.35*	1				
SI	-0.15*	0.32*	0.04	-0.10**	0.20*	1			
LAB	0.18*	-0.02	0.54*	0.27*	0.53*	-0.45*	1		
GCF	0.25*	-0.40*	0.58*	-0.32*	0.19*	-0.09**	0.31*	1	
HC	0.21*	0.59*	0.26*	0.83*	0.40*	-0.12**	0.39*	-0.15**	1

*Note: ***, **, * indicate 10%, 5% and 1% level significance respectively.*
Source: Authors' calculation

Table 2 presents the summary statistics results of dependent and independent variables. It observed that outward FDI and carbon emissions have the highest standard deviation than other independent variables with 2.15 and 5.4 mean. This result implies the flow of outward FDI and carbon emissions are relatively high in BRICS. The volatility of carbon emissions is less than the volatility of OFDI. Pearson pair-wise correlation matrix explains the strength and nature of the correlation among the considered variables. The variables outward FDI, GDP, EC, R&D, and HC positively correlate with environmental pollution (ENV). The results from the correlation matrix explain that the model is free from the multicollinearity problem as the element does not exceed more than 0.85, leading to VIF values of less than 5 (Gujarati and Porter 2009).

Table 3: Pesaran-Yamagata homogeneity test

Variables	OFDI	EC	GDP	R&D	SI	HC	GCF	LAB
Delta	1.85***	1.78*	1.37***	2.09*	4.82*	3.58*	1.40*	1.56**
Adj. delta	1.93***	1.83*	1.45***	2.21*	4.57*	3.78*	1.48**	1.66***

*Note: ***, **, * indicate 10%, 5% and 1% level significance respectively.*
Source: Authors' calculation

Table 3 represents the slope homogeneity test. As per the CSD and slope homogeneity results, the study has considered employing heterogeneous panel models that control the cross-sectional dependency among the variables. Before adopting the panel methodologies, it is necessary to examine the existence of cross-sectional dependency in the model. Thus, the study uses the Pesaran (2007) CD test, as it provides the confirmations result about the use of panel unit root test for further explanations. The null hypothesis of the CSD test is there is cross-sectional independence among cross countries, against the alternative hypothesis is cross dependency among the sample size.

Table 4: Cross sectional dependence test

Variables	Breusch-Pagan LM	Pesaran scaled LM	Pesaran CD
ENV	298.92*	63.34	17.27*
OFDI	173.78*	35.5*	12.7*
GDP	251.02*	52.77*	15.75*
EC	107.69*	20.72*	8.41*
R&D	49.94*	7.81*	0.70
SI	69.76*	12.24*	1.19*
LAB	73.85*	13.16*	1.66*
GCF	44.16*	6.52*	4.95*
HC	279.16*	59.06*	16.69*

*Note: ***, **, * indicate 10%, 5% and 1% level significance respectively.*
Source: Authors' calculation

The study assumes there is a high probability of the existence of cross-sectional dependence among considered variables as the BRICS countries are interlinked internationally and based on a different type of cultural and economic background. We employ Breusch, and Pagan (1980) L.M. test, Pesaran (2004) CD test, and Pesaran (2004) Scaled L.M. for testing the cross dependencies. The study rejects the null hypothesis of no cross-sectional dependencies at 1% significance level. The results reveal that the selected variables exhibit the presence of heterogeneity across the cross-sections significantly. Therefore, this confirms the presence of cross-sectional dependence among the variables.

Table 5: Second Generation Panel Unit Root Test

Variables	**CADF**				**CIPS**			
	Level		First Difference		Level		First Difference	
	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend
ENV	-0.87	-0.28	-5.49*	-5.34*	-2.13	-2.48	-4.14*	-4.53*
OFDI	-0.615	1.86	-6.91*	-6.99*	-2.02	-1.53	-4.75*	-5.15*
GDP	-0.89	0.76	-2.51*	-2.52*	-2.28	-1.91	-2.85*	-3.15*
EC	-0.47	1.05	-5.39*	-5.24*	-1.95**	-1.87	-4.12*	-4.48*
R&D	-1.19	-0.12	-8.63	-7.57*	-2.27**	-2.36*	-4.39*	-4.94*
SI	-6.21	-10.35*	-16.76*	15.59*	-2.74	-3.01*	-5.15*	-5.16**
LAB	2.56	2.32	-3.03*	-2.35*	-1.64	-2.01	-3.07*	-3.28*
GCF	-1.01	-0.212	-6.74	-5.92*	2.68	-3.62*	-3.82**	-4.68*
HC	0.24	3.96	0.81***	-1.68**	-1.85	-0.88	-1.40*	-3.09**

*Note: ***, **, * indicate 10%, 5% and 1% level significance respectively.*
Source: Authors' calculation

In the presence of CSD, the study employs second generation panel unit root tests CADF and CIPS to examine the stationary properties of the considered variables in table 5. We find that some variables like human capital labour force and manufacturing industries, and R&D are stationary at their levels. However, this result cannot be generalised to the stationarity at level; subsequently, we employ the first difference where all the elements are stationary at 95% and 99% significance level. The panel data further employs an advance econometric test for long-run analysis of the parameters.

Many panel cointegration approaches are available to identify the long-run cointegration among the variables developed by Pedroni (2001) and, Westerlund (2007). Westerlund (2007) cointegration approach generally employs for CDS and heterogeneity analyses for the dynamic cointegration relationship among variables. The Westerlund panel cointegration test reveals a more robust and consistent result for dependent and independent variables. The results are divided into panel statistics (Pt, Pa) and group statistics (Gt, Ga). The panel statistics method focuses on the error correction mechanism and includes the cross-sectional units, where the group statistics method does not consider the information from the error term (Latif *et al*., 2018).

Table 6: Westerlund-ECM panel cointegration tests

Statistic	Value	Z-value	P-value
Gt	0.337*	5.035	0.020
Ga	-0.618 **	2.912	0.053
Pt	-2.74*	0.685	0.082
Pa	5.604*	0.156	0.002

*Note: ***, **, * indicate 10%, 5% and 1% level significance respectively.*
Source: Authors' calculation

The null hypothesis of this error correction model is there is no cointegration. The panel cointegration results are reported in Table 6. The p-value indicates that the cointegrating association is significant at a 95 per cent level. Hence, it confirms a long-run association exist among the selected variables. This result implies that OFDI and energy consumption have a long-run relationship with the home countries' environmental pollution.

After confirming the existence of panel cointegrating relations among the selected macroeconomic variable, the study employs a long-run elasticity model. We have used Pooled Mean Group (PMG) to identifying the short-run and long-run associations between dependent and independent variables.

Table 7: Pooled Mean Group

Short Run Equation			**Long Run Equation**		
Variables	**Coefficient**	**Std. Error**	**Variables**	**Coefficient**	**Std. Error**
ECT	-0.38*	0.09	**-**	-	-
D(OFDI)	-1.47*	0.77	**OFDI**	-0.87***	0.52
D(EC)	24.50*	12.62	**EC**	-30.58***	18.23
D(GDP)	-8.00	24.59	**GDP**	8.74***	20.04
D(R&D)	4.73*	1.15	**R&D**	-20.64*	7.20
D(SI)	-2.74*	2.23	**SI**	6.02**	2.75
D(HC)	-23.64***	12.66	**HC**	-19.58*	5.71
D(GCF)	-6.94	4.96	**GCF**	24.99*	7.45
D(LAB)	39.86*	50.33	**LAB**	-71.64	49.65
D(X)	41.81*	9.73	**X**	-21.64	9.11
C	46.58	9.834	**-**	-	-

*Note: ***, **, * indicate 10%, 5% and 1% level significance respectively.*
Source: Authors' calculation

The table 7 reveals PMG results which confirm that a short-run nexus exists because the error correction term is negative and statistically significant (-0.38), implying a short-run link exists among the considered variables. The ECT value reveals that the short-run disturbances will be corrected at − 0.38 per cent to achieve the long-run equilibrium level (Christoforidis & Katrakilidis 2021; Sahoo & Sethi 2021). The findings also explain that some independent variables are positive nexus with carbon emissions, and some are not statistically significant. However, the variables like OFDI and HC are negative and statistically significant, indicating an indirect relationship with dependent variables. The long-run equations confirm that there is a long-run association present among the variables. That means outward FDI and energy utilisation will help to reduce BRICS' pollution in the long run.

The robustness of long-run results is discussed in Table 8 and Table 9. We estimate Generalised Methods of Moments (GMM) to ignore the endogeneity and serial correlation problem. For a more convenient result, this study also considers the panel fully modified ordinary least square (FMOLS) and the panel dynamic ordinary least square (DOLS), which considered by many researchers (Apergis & Payne 2010; Jebli et al. 2016; Sahoo & Sethi 2021) for robustness test of EKC hypothesis.

Table 8: Two-step GMM

	Two-step system GMM		**Two-step difference GMM**	
Variable	**Coefficient**	**SE**	**Coefficient**	**SE**
l. ENV	0.03	0.39	-0.64	0.69
GDP	-3.51	1.49*	74.19*	32.84
OFDI	4.04	1.63**	10.21*	4.64
EC	17.72	7.51	22.65***	3.87
RD	-	-	109.7*	49.39
SI	-	-	-	-
LAB	-	-	26.02*	7.84
GCF	-	-	-	-
HC	-4.23	1.78	19.09**	5.83
X	0.091	0.14	60.45*	27.10
AR (1)	0.67**		1.47*	
AR (2)	1.48		1.52	
Sargan test	147.5		137.4	

*Note: ***, **, * indicate 10%, 5% and 1% level significance respectively.*

Source: Authors' calculation

The study employs both system and difference two-step GMM. The result shows that energy consumption directly affects the environmental quality in BRICS in difference GMM, not in system GMM. This also shows that a decrease in CO2 emissions by -0.64 per cent is impacted by a 1 per cent rise in the outward FDI coefficient, thereby validating the higher levels of outward FDI in BRICS reduce carbon emissions, improving environmental quality (Braconier et al. 2001). In this study, Sargant test statistics' application fails to reject the null hypothesis, implying that our instrument set is robust. The AR (2) coefficient of each dynamic panel model elaborates that the study accepts the alternative hypothesis. This result reveals an upturn U-shaped link between outward foreign investment and CO2 emissions and confirms the existence of PHH in BRICS. This study finding verifies the existence EKC hypothesis exists in BRICS (Bakirtas and Cetin 2017).

Table 9: Panel DOLS & Panel FMOLS Results

Panel FMOLS cointegration			**Panel DOLS cointegration**		
Variable	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**	**Prob.**
OFDI	-2.60*	2.57	-0.73	2.05	0.02
GDP	11.3*	2.15	-1.94	2.82	0.04
EC	-31.19*	-2.81	4.39	1.28	0.10
R&D	6.95*	2.58	3.08	0.71	0.09

SI	-1.780	-0.57	0.76	0.66	0.50
GCF	-0.73	-0.21	13.02	2.52	0.01
LAB	-146.24*	-3.50	18.79	1.06	0.29
HC	-13.73*	-3.57	-2.87	-1.48	0.14
X	0.37*	2.31	-59.78	-0.69	0.48
$\mathbf{R^2}$	0.99828		0.96562		
Adj. $\mathbf{R^2}$	0.97667		0.88724		

*Note: ***, **, * indicate 10%, 5% and 1% level significance respectively.*

Source: Authors' calculation

The panel FMOLS and the DOLS methods are effective in eliminating the endogeneity problems and serial correlation problems. First, the study reports the estimators obtained by dynamic least squares (DOLS) for the countries individually with effects fixed time. The estimators can be computed as elasticities directly. The positive coefficient elements explain the ratio between pollution and each explanatory variable, and some variables' strength of the cointegration vector is overwhelming. Results from panel both estimators Table 10 indicate that some variables like R&D, EC are positive and statistically significant on carbon emissions.

Meanwhile, GDP per capita and outward FDI is negatively statistically significant at the 1 per cent and 5 per cent level on carbon dioxide emissions. Thus, the connection between environmental pollution, outward FDI, and economic growth confirms an inverted U-shaped curve exists. Therefore, the results of FMOLS and DOLS validate the EKC hypothesis that exists in BRICS countries. These results resemble previous studies by Heidari et al. (2015) and Apergis and Ozturk (2015) and Sahoo & Sethi (2021) that found that the EKC hypothesis is validated developing countries in long-run and contradictory with previous studies by Boluk and Mert (2014) and Liu et al. (2018) found that EKC hypothesis is invalid in developing nations. The indicator like human capital reveals a negative and insignificant value that explains human capital is insufficient in reducing the pollution in BRICS countries in the long run.

6. Conclusion and policy implications

This paper investigates the effects of outward FDI and energy utilisation on environmental pollution in BRICS from 1990-2019. The study first employed the second-generation unit root tests to satisfy the selected determinants' stationarity properties. The Westerlund (2007) cointegration approach is used to scrutinise the long-run cointegrating relationship among the variables. The study also employed robust two-step difference GMM, panel FMOLS and DOLS to avoid endogeneity problems and verify the connection among the macro-economic variables. The PMG results confirm a short-run nexus, and the ECT value revealed that the short-run disturbances would be corrected at − 0.38 per cent to achieve the equilibrium level in the long run. PMG results confirm that OFDI and HC are negative and significant, which means an inverse relationship exists with ENV and explains there is a long-run association present among the variables. The study used advanced models like GMM and DOLS for the robustness check, which reject the study's null hypothesis and confirms that both short-run and long-run associations exist between OFDI, energy consumption, and carbon dioxide emissions (Cole, 2006; Anyanwu, 2012).

Therefore, at the early stage of development, developing countries produce environmental pollution and will be checked in the long run. It can be concluded from empirical results domestic investment (OFDI) and more use of energy increase carbon emissions in BRICS in the short run and will be checked in the long run. Hence, the most popular EKC hypothesis exist in developing nations like BRICS (Braconier *et al.*2001; Pao & Tsai 2011) and also confirms that an inverted U-shaped connection exists between outward FDI and carbon emissions in BRICS (Hao *et al.* 2018). In GMM, the GDP per capita is positive and significant, indicating that an increase in the growth rate of countries will lead to an increase in the number of carbon emissions in the long run. This evidence is consistent with the studies of (Jayanthakumaran et al. 2012; Wu et al. 2015; Mahalik et al. 2018). From a policy point of view, the study suggests that generating a sustainable healthy environment from the future fear of climate change and global warming should reduce excessive energy consumption without hampering rising growth.

The study used the STIRPAT model to build an extended carbon dioxide emissions model by incorporating outward FDI, GDP per capita, and technology to achieve our objectives. The idea of the IPAT and STIRPAT model explains that a statistical and conceptual framework for assessing human impacts on the environment. The goal of STIRPAT theory is to provide an analytic strategy for testing. The underlying goal is to identify the primary drivers of environmental harm and to uncover lever points for ameliorating that harm. Hence, we hope that the STIRPAT model will contribute to the fundamental understanding of both human and natural systems and provide results that help policymakers and decision-makers.

According to the Energy Gap Report, 2020 reported that the Green House Gas (GHG) emissions continued to increase for the last couple of years in 2019, particularly in China and India. However, due to the COVID-19 pandemic from the end of 2019, the global CO2 emissions reduce by about 7 per cent. Global pandemic and environmental degradation is now a matter of concern that what will be the future situations? After the normalisation, the GHGs will be predicted to increase more than before to achieve the market demand-supply equilibrium positions. Therefore, the study suggests that developing countries should give more attention to sustainable development. Energy consumption in emerging economies is relatively high than in advanced countries because of the initial development stage; therefore, it is a concern. So, policymakers and governments should give more attention to alternate energy solutions.

Developing countries should encourage more sustainable energy technologies. Developing economies like BRICS enhance their domestic as well as foreign investment by adopting advanced technology. This transfer should be continued till the emerging economies can achieve proper economic progression. The technological development in emerging economies should encourage more eco-friendly and environment-friendly technology to achieve a sustainable natural environment. Another crucial implication is also the needed to design environmental policies focused on green innovation. Being a desirable market, the BRICS union should boost green innovation drive by using market-oriented policies. Developing countries need to open and strengthen their market by providing incentives for technology developers, spending more on R&D activities, and encouraging governments to venture capital. The government also needs to frame the profitable strategies, inspire PPP, i.e., public-private partnerships to circulate the environmental consciousness, guideline for energy efficiency, and generate a pollution-free environment.

The current research has certain limitations: Firstly, the study considered BRICS countries over 1990-2019 for panel analysis. Secondly, due to the lack of data, the analysis is focused on specific determinants and ignores many crucial factors that influence the quality of the environment. However, the current study provides a fruitful direction for further future research. The researcher can use both time series and extensive panel framework to identify the link between outward FDI and pollution concerning each of the variables. The research can be expanded by considering developing countries and a comparative analysis on developed and developing countries by employing advanced methods. By covering up these research gaps, the present study would be pretty effective from a policy aspect for other emerging and developing economies.

Declarations

Ethics approval and consent to participate: Not applicable

Consent for publication: Not applicable

Availability of data and materials: The datasets generated and/or analysed during the current study are available in the World Development Indicators (2019) and UNCTAD,

Links: https://databank.worldbank.org/source/world-development-indicators#

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