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RESEARCH ARTICLE

Do foreign direct investment inflows affect environmental degradation in BRICS nations?

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Abstract

The acceleration in environmental degradation in the past few decades due to a spur in the emissions of greenhouse gases, massive deforestation and a loss of biodiversity has become a major concern of environmentalists, policy makers and researchers. Against this backdrop, the current paper empirically explores the impact of foreign direct investment inflows on environmental degradation. To do so, we have drawn a sample of BRICS nations because of its immense contribution to global environmental challenge. We collected the data since 1992 through 2014 and employed the panel cointegration techniques, and FMOLS and DOLS models. Our results confirm the significant role of foreign direct investment and gross domestic product in reducing the CO_2 emissions in these nations. Our results do not support the theory of environmental Kuznets curve and the pollution haven hypothesis valid for these nations. Our findings recommend the use of cleaner technology, and promotion of FDI that ensures environmental awareness. Furthermore, appropriate policies on climate change and effective delegation of environmental protocols will be able to reduce the environmental degradation in BRICS nations.

Keywords Foreign direct investment · Economic growth · Environmental degradation · Climate change · BRICS

JEL classification Q53 · Q54 · Q56 · Q58

Introduction

Economic growth is imperative for the development of the economies and has always been the key concern for developing nations. With a view of keeping the pace of growth with that of the world economy, most of the economies followed liberalization and globalization policies by dismantling restrictions on foreign trade and capital flows. As a result of collaborative dealings among the nations, investments and capital flow from the developed countries to the developing ones in the form of foreign direct investments (FDI) and foreign institutional investments (FII) (Pradhan and Hiremath 2020). Moreover, the availability of cheap resources and manpower allure the attention of the developed countries towards the developing economies. Also the weak environmental norms in developing nations become a good opportunity for the industrialists to boost up their productions in these economies. Therefore, the host countries receive investments in the form of FDIs as an important source of capital.

Past empirical studies on FDI have shown that FDI brings innovative management skills, knowledge spillovers and advanced technologies that help in generating new job opportunities and thereby enhancing the standard of living of millions of people in the region (De Mello 1999; To et al. 2019). However, FDI flows into these economies increase economic activities; and such activities heavily rely upon energy use and fuel combustion. At the same time, these economic activities necessitate setting up of more industries to meet the rise in aggregate demand of the growing population thereby taking away the spaces of forests and farm lands which is the

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foremost symptom of an imbalanced ecology. Therefore, these industries are a significant contributor of CO_2 emissions paving the way of environment degradation.

Various analysts and researchers have started focusing on this linkage between FDI and the environment, particularly since the mid-1990s. Recently, many countries have also started making serious efforts to reduce environmental pollution though the CO_2 level has gone up to an irreversible level. As per the reports, the world's CO_2 emissions have grown from 17.78 billion tons in the year 1980 to 33.1 billion tons in the year 2018 (IEA 2019). The persistent growth of CO_2 emissions to an alarming level has also been a major concern for a trade bloc such as BRICS. BRICS nations are some of the fastest-growing economies in the world, where industrial activities are fastening from the last few decades. Moreover, these nations are committed to taking sustainable measures towards environmental management, global climate and biodiversity issues.

Departing from the previous studies, the present study aims to explain the linkage between environmental degradation, FDI and economic growth. The present study contributes to the growing literature on environmental economics and macroeconomics in manifold directions. Firstly, to the best of our knowledge, the association between FDI, environmental degradation and economic growth has not been explored by the past research and is gaining importance only recently.

Secondly, we investigate the linkage between FDI, environmental degradation and economic growth in the context of BRICS nations. The rationale for a study on BRICS nations is motivated by O'neill (2001). The author posits that economies such as Brazil, Russia, India and China (South Africa was added to the trade bloc later in the year 2010) have more potential and they are set to grow more rapidly than the G7 nations. According to a report published by UHY[1], BRICS are able to attract a considerable amount of foreign funding in terms of FDI (the average FDI is approximately US $93.9 billion in the year 2015) and is 35% greater than G7 nations. The inclusion of the fastest emerging economy, China, and second fastest emerging economy, India, in the dataset provide intriguing insights about the growth of these economies.

Furthermore, these nations are committed to implementing the best and sustainable environmental practices and policies. In the fifth BRICS meeting on environment issues, the environment ministers of these five nations issued a joint statement regarding their commitment towards the support for the post-2020 global biodiversity framework and insisted on the negotiations made by the United Nations Framework Convention on Climate Change (UNFCCC) commission towards adopting fair and effective environmental practices.

[1] See BRIC Economies Attract 35% More FDI Than G7 Nations | Financial Tribune

Thirdly, many studies until recently have analysed on the impact of the linear and non-linear form of the GDP per capita or income variable on the environmental degradation in those studies by showing the evidence of Environmental Kuznets Curve (henceforth EKC) (Kostakis et al. 2017; Singhania and Saini 2021). Departing from many past studies, we show the N-shaped impact of the variable GDP by including the cubic term of the GDP figures for BRICS along with all other explanatory variables discussed in the extant literature. Therefore, the major contribution of this study is not only to examine the prevalence of EKC and Pollution haven/halo hypothesis but also to show the N-shaped pattern of the business cycle. Similarly, previous studies have explained the relationship between FDI and environmental degradation. However, the role of the non-linear component of FDI is seldom explored. Our paper untangles to fill these void in the extant research by incorporating the non-linear components of both GDP per capita and FDI.

Finally, a fresh empirical evidence on such a sensitive issue will help to extend our understanding about the FDI-economic growth-environment nexus and the outcome of the macro level cross country analysis is expected to provide appropriate policy inputs on environmental issues, and frame environmental management policies pertaining to the BRICS nations. Especially, this study will be helpful for government and environmental practitioners to make revisions in environmental policies. The findings of this study will also assist the corporates to take growth enhancing investment decisions based on the level of environmental standards and will be a motivation for those companies which are committed towards the use of eco-friendly techniques of production and pollution abatement goal.

The remainder of the paper is categorized into the following sections. The "Synthesizing the literature" section provides a brief overview of the literature. The "Data and model specification" section gives a description of the data and methodology. In the "Interpretation of the results" section, we discuss the empirical results and briefly interpret the findings in the "Discussions" section. The final section concludes the study with some important policy suggestions.

Synthesizing the literature

In this section, we provide a detailed discussion on the review of the theoretical and empirical literature explaining the FDI, environment and economic growth nexus.

Environmental degradation and economic growth

The linkage between environmental degradation and economic growth is a much-researched issue because of its theoretical

relevance. Simon Kuznets was among the first to discuss the possible non-linear and long-run relationship between economic growth and environmental degradation. This phenomenon was popularly known as the environmental Kuznets curve. The EKC explains that the economic growth increases with environmental degradation but takes an inverted U-shaped turn after reaching the saturation level. In a nutshell, the EKC represents an inverted U-shaped relationship between environmental degradation and economic growth. However, the empirical literature pertaining to the EKC explains mixed and inconclusive findings.

Among the past studies, Grossman and Krueger (1995) found empirical evidence of an inverted U-shaped relationship between environmental degradation and real income. By considering panel data of eight countries such as China, Egypt, Mexico, Japan, Brazil, South Korea, Nigeria and South Africa, Onafowora and Owoye (2014) found an N-shaped long-run relationship between CO_2 emissions and economic growth. Nevertheless, the authors reported the validity of EKC in South Korea and Japan only. Recently, Churchill et al. (2018) drew the data of 20 OECD nations dating from the period 1870 through 2014 and showed evidence of EKC pattern prevalent for the whole panel. Other studies in this area confirm a non-linear U-shaped relationship between environmental degradation and economic growth (Lean and Smyth 2010; Al-Mulali and Ozturk 2016). Table 1 shows the list of recent studies which explores the linkage between environmental degradation and economic growth.

There are many other studies that did not find any support for the presence of EKC. In similar lines, Narayan and Narayan (2010) examined the EKC hypothesis for a group of 43 developing economies and found that long-run income elasticity is smaller as compared to the short-run implying a reduction in environmental degradation with the growth in these economies. Therefore, the extant literature finds mixed evidence exhibiting the relationship between environmental degradation and economic growth.

FDI and environmental quality

There has been a substantial change in economic policy in the past two decades followed by the implementation of globalization strategies adopted by most of the developing economies (Pradhan and Hiremath 2020). Eventually, globalization leads to the integration of the developing economies, promotion of foreign trade in these economies, capital flows to these countries in the form of FDI, FII and the establishment of trade blocs.

The beneficial impact of FDI in stimulating economic growth also acquires a more or less universal acceptance. Empirical evidence reveals that FDI inflow has played an important role in triggering growth in the host countries through innovative activities, technology transfers and spillover effects. Although there is a rich body of literature that explains the nexus between FDI and environment, however, these studies have yielded inconclusive and mixed findings because of the usage of different estimation techniques, macroeconomic conditions, heterogeneity in the economic structure of the nations and indicators explaining the dependent and independent variables.

Although the association between FDI and environmental degradation has not received enough empirical research attention, however, the theoretical nexus between the FDI-environment relationship is explained by two competing

Table. 1 Studies examining the nexus between environmental degradation and economic growth

Srl. no.	Author (year)	Sample data	Sample countries	Econometric method
1	Phong (2019)	1971–2014	5 ASEAN nations	Fixed effects and Random effects regressions
2	Kahia et al. (2019)	1980–2012	12 MENA nations	ARDL
3	Hameed et al. (2019)	1957–2017	South and East Asian nations	GMM
4	Zhang et al. (2019)	1960–2014	121 countries	Box charts, distribution overlay, and scatter plot
5	Sharif et al. (2019)	1990–2015	74 nations	Panel cointegration, heterogeneous panel causality tests, and FMOLS model
6	Ganda (2019)	1980–2014	South Africa	ARDL
7	Churchill et al. (2020)	1990–2017	8 states of Australia and territories	Non-parametric global trend test, and Dynamic common correlated effects mean group estimate
8	Dogan and Inglesi-Lotz (2020)	1980–2014	7 European countries	Panel cointegration and FMOLS regressions
9	Boubellouta and Kusch-Brandt (2020)	2000–2016	30 European countries	GMM, 2SLS, and cross-sectional OLS
10	Sarkodie and Ozturk (2020)	1971 to 2013	Kenya	ARDL, *Statistically Inspired Modification Of Partial Least Squares* (SIMPLS) regression and Utest methods

hypotheses: (i) the pollution halo hypothesis; (ii) the pollution haven hypothesis. The proponents of the neo-technology school of thought state about the positive FDI-environment linkage thereby supporting the view of pollution halo hypothesis. The proponents of the pollution halo hypothesis claim that FDI will be beneficial for an economy because it brings in advanced technologies, knowledge spillovers and clean energy techniques of production (De Mello 1999) which consequently reduces the pace of environmental degradation in the host economies (Görg and Strobl 2005; Albornoz et al. 2009). Table 2 presents a list of those studies that confirm the evidence of pollution halo hypothesis.

The preponderance body of literature discovered about the evidence of pollution halo hypothesis for a group of countries. Destek and Okumus (2019) probed the impact of FDI on the ecological footprint of ten newly industrialized countries for the study period 1982 through 2013. Their study confirmed a U-shaped relationship between FDI and ecological footprint. In another recent study, Wang et al. (2019) studied the role of FDI to the Beijing-Tianjin-Hebei region in China and show that FDI to this region is able to reduce the emissions of industrial pollution. Several other studies also arrive at a conducive result confirming the evidence of the pollution halo hypothesis (Mert and Bölük 2016; Mert and Caglar 2020).

Albeit the positive impacts of FDI towards the environmental standards as documented by the pollution halo literature, there are studies which has validated the presence of pollution haven hypothesis—which states that FDI poses serious threats to environment sustainability. In a nutshell, the proponents of pollution haven hypothesis observe that investment in the form of FDI can be detrimental from the perspective of environmental sustainability. Copeland and Taylor (1994) were the first to propose the concept of the pollution haven hypothesis and explains that FDI from the developed economies will move to develop economies because of the availability of cheaper labour and resources.

Because there are stringent abiding environmental laws in most of the advanced economies, the investment flows from these economies and caters to developing economies with lax environmental regulations. Since stringent environmental laws increase the overall production cost, most of the capital-scarce economies, by design or default, prefer to lax their existing environmental regulations in an attempt to promote and attract foreign capital and investment (Aminu, 2005). Therefore, the prevalence of such lenient environmental regulations attracts dirty investments and will be a motivating factor for pollution-intensive productions (Levinson 1996; Zarsky 1999; Cole and Elliott 2005; Hassaballa 2014). Past studies empirically provide strong evidence of foreign capital inflow to host countries due to the lax of environmental regulations and avoiding paying high pollution fines (Xing and Kolstad 2002; Fredriksson and Svensson 2003). Table 3 exhibits the list of those studies which confirm the evidence of pollution haven hypothesis.

Chin et al. (2018) employ the ARDL and decomposition type threshold approaches from the period 1997–2014 to examine the factors causing CO_2 emissions in Malaysia. Their study shows that vertical Intra industry trade and bilateral FDI between Malaysia and China significantly contribute the environmental degradation in Malaysia. By using the data of 65 countries ranging from the period 1984 through 2005, Chang (2015) examines the nonlinear relationship between environmental pollution and FDI. The results of the threshold approach represent that FDI will tend to worsen

Table. 2 Studies that confirm the evidence of pollution halo hypothesis

Srl. no.	Author (year)	Sample data	Sample countries	Econometric methods
1	Tang and Tan (2015)	1976–2009	Vietnam	Johansen cointegration model, and Granger causality test
2	Zhang and Zhou (2016)	1995–2010	29 Chinese provinces	Driscoll–Kraay estimation
3	Mert and Bölük (2016)	2002–2010	21 Kyoto countries	Panel ARDL
4	Öztürk and Öz (2016)	1974–2011	Turkey	Cointegration models, DOLS regression and Granger causality
5	Zhu et al. (2016)	1980–2010	5 ASEAN nations	Panel quantile regression
6	Balsalobre-Lorente et al. (2019)	1990–2013	MINT countries	Cointegration tests, DOLS and FMOLS models, and Dumitrescu-Hurlin causality test
7	Mert and Caglar (2020)	1974–2018	Turkey	Hidden cointegration model, vector error correction model and crouching error correction model
8	Ahmad et al. (2021)	1998–2016	28 Chinese provinces	Dynamic common correlated effects mean group method
9	Singhania and Saini (2021)	1990–2016	21 developing and developed countries	System GMM
10	Xu et al. (2021)	2002 to 2016	30 Chinese provinces	Semi-parametric regression model, two-way fixed effects model

Table. 3 Studies that confirm the evidence of pollution haven hypothesis

Srl. no.	Author (year)	Sample data	Sample countries	Econometric methods
1	Millimet and Roy (2016)	1977–1984	States of USA	Fixed effect regressions
2	Zhang et al. (2017)	1995–2009	40 nations	Structural decomposition analysis, and multi-regional input-output analysis
3	Zheng and Shi (2017)	2004–2013	30 provincial locations of China	Probit and bivariate probit
4	Yang et al. (2018)	2006–2010	Jiangsu province of China	McFadden conditional logit model
5	Ur Rahman et al. (2019)	1975–2016	Pakistan	NARDL
6	Shen et al. (2019)	2001 to 2014	Guangdong Province of China	Pooled mean group (PMG)/ARDL
7	Sarkodie and Strezov (2019)	1982–2016	Indonesia, India, China, Iran and South Africa	Panel quantile regression
8	Guzel and Okumus (2020)	1981–2014	Indonesia, Malaysia, Philippines, Singapore and Thailand	Common correlated effect mean group (CCEMG) and augmented mean group (AMG)
9	Solarin et al. (2017)	1980–2012	Ghana	ARDL
10	Bulus and Koc (2021)	1970–2018	Korea	ARDL

the CO_2 emissions in these economies when the corruption level reaches the threshold limit. Rana and Sharma (2019) investigate the causal relationship between, FDI, economic growth, CO_2 emissions and trade in the context of India by employing the dynamic multivariate Toda-Yamamoto approach. The results confirm that FDI leads to economic growth in India but via CO_2 emissions. Similarly, many other country-specific studies confirm that FDI has exacerbated the environmental conditions in these nations (Jiang 2015; Tang and Tan 2015).

The overall summary of the empirical literature emphasizing the nexus between environmental degradation, economic growth, and FDI has been mixed and is indecisive. The lack of clear evidence supporting or rejecting the presence of EKC and pollution haven/halo hypothesis motivated us to have a fresh look at the issue in the context of BRICS nations which is still unexplored. Because of the existing slackness in the environmental policies, it is sceptical that the economic players and industrialists of BRICS nations tend to shift their focus away from environmental consequences on human well-being and will concentrate on growth-oriented and cost-cutting investments. Businesses involved in such practices will worsen the environmental performance of these nations if appropriate fiscal actions are not carried out.

Data and model specification

This study uses secondary data of five countries namely Brazil, Russia, India, China and South Africa from the period 1992 through 2014 subject to the data availability. The data for the present study is sourced from the World Bank database. The variables chosen for the empirical analysis is based on theoretical relevance and extensive literature review. The proposed empirical model is given in the following:

$$\begin{aligned} \mathrm{COEMI}_{it} = {} & \alpha_i + \beta_1 \mathrm{LNEN}_{it} + \beta_2 \mathrm{LNGDP}_{it} \\ & + \beta_3 \mathrm{LNGDPSQ}_{it} + \beta_4 \mathrm{LNGDPCB}_{it} \\ & + \beta_5 \mathrm{LNFDI}_{it} + \beta_6 \mathrm{LNFDISQ}_{it} + \mu_t + \nu_i \\ & + \varphi_{it} \end{aligned} \quad (1)$$

where COEMI_{it} denotes the CO_2 emissions metric tons per capita. LNEN_{it} shows the energy use measured in kilograms of oil consumed per capita, LNGDP_{it} implies gross domestic product per capita measured in current US $, $\mathrm{LNGDPSQ}_{it}$ represents the squared value of the gross domestic product per capita figures, $\mathrm{LNGDPCB}_{it}$ exhibits the cube value of the gross domestic per capita figures, LNFDI_{it} is the foreign direct investment net inflows of the balance of payment measured in current US $ and $\mathrm{LNFDISQ}_{it}$ refers to the squared value of the foreign direct investment measured in current US $ figures. The term μ_t denotes the unobserved time-specific effect whereas ν_i shows the unobserved firm-specific effect and φ_{it} is a zero mean random disturbance term with variance σ_v^2. All variables are expressed in its natural logarithmic form except COEMI.

BRICS nations are a set of developing countries which are expected to become dominant suppliers of raw materials, manufactured goods and services by the year 2050 (O'neill 2001). To propel the engine of economic growth, these economies have been relying on the non-renewable energy sources because the development of renewable energy is at its nascent stage in emerging economies including BRICS (Sharda 2016). Therefore, environmental degradation will be more pronounced with an increase in energy consumption. As a result, the expected sign of the coefficient β1 of the variable

LNEN on CO_2 emissions is positive. The prior expectation of the sign of the coefficient β2 is inconclusive. On one hand, the supporters of the EKC theory hold that there is a positive relationship between environmental degradation and economic growth. On the other hand, few pieces of research have suggested that GDP growth and an increase in economies' income can enhance the awareness of the government and its residents' which help them adopt stringent environmental laws and regulations (Hashmi and Alam 2019; Zhang et al. 2019) and will eventually improve the environmental conditions (Doytch and Uctum 2016). If the sign of the coefficients β2, β3 and β4 of the variable LNGDP, LNGDPSQ and LNGDPCB is positive, negative and positive, respectively, then there will be an N-shaped pattern explaining the relationship between economic growth and environmental degradation. An inverted N-shaped pattern is also possible if the coefficients β2, β3 and β4 of the variable LNGDP, LNGDPSQ and LNGDPCB are negative, positive and negative respectively.

The theoretical literature explains that the relationship between FDI and environmental degradation can be negative (i.e. showing the evidence of pollution halo hypothesis), whereas the anticipated sign of the coefficient β5 can also be positive confirming the validation of the pollution haven hypothesis. Additionally, we also use the non-linear component of the variable LNFDI. The expected sign of the coefficient of the variable LNFDISQ which examines the amplification effects of foreign investment inflow will be negative if the sign of the variable LNFDI is positive. In such a case, the association between the variable FDI inflow and environmental degradation represents an inverted U-shaped pattern. On the other hand, the pattern will be U-shaped when the sign of the coefficient of the variable LNFDI is negative and the sign of the variable LNFDISQ is positive.

Interpretation of the results

In this section, we describe and interpret the results of the empirical analysis. The summary statistics of the variable included in our analysis will provide intriguing insights into the data. The mean value of all the variables is positive. The low values of the standard deviation of all the variables except LNGDPSQ, LNGDPCB and LNFDISQ indicate that there is not much deviation of the values of these variables as compared to the mean values. The negative skewness values of all the variables (except COEMI and LNGDPCB) imply that the distribution of these variables is skewed to the left as compared to the normal distribution. The kurtosis of the variables namely LNFDI and LNFDISQ denotes leptokurtic distribution (because the kurtosis values of these variables are more than 3). We employed the D'Agostino et al. (1990) normality test with an empirical adjustment made by Royston (1991). This normality test overcomes the shortcomings of corrections for sample size as compared to the Jarque and Bera (1987) test for normality. The significant values of the normality test confirm that all variables follow the non-normal distribution (see Table 4).

In Table 5, we present the values of the correlation coefficients of the variables included in our empirical model. The high values of the correlation coefficient of the variables namely LNEN, LNGDP, LNGDPSQ, LNGDPCB, LNFDI and LNFDISQ show that there is a perfect linear relationship among these independent variables validating the possibility of multicollinearity in the model.

Pesaran (2004) holds that there can be a possibility of a presence of some unobserved common shock factors across the cross-sectional unit while dealing with the panel data. Such correlations across the cross-sectional units may display cross-sectional dependence in error terms, which may eventually lead to biases in the estimated standard errors and inconsistencies in the results. Therefore, checking the presence of cross-sectional dependence is a standard procedure while dealing with the panel data. We conducted the Pesaran (2007) cross-sectional dependence test to ascertain the presence of cross-sectional dependence across the panels. The insignificant *p* values of the Pesaran CD test fail to reject the null hypothesis of cross-sectional independence both at 1% and 5% level of significance (see Table 6).

In the Table 7, we incorporate the panel unit root test results. We employ the Breitung (2000) unit root test to examine the stationarity of the variables. The results of the Breitung test confirm that all the variables are non-stationary in their level form. The non-stationarity of the variables is also confirmed when we performed the Im et al. (2003) panel unit root test. After confirming the existence of unit root in its level form of all the variables, we performed the stationarity of all the variables in its first difference. We find that all the variables are stationary in its first difference form and none of the variables are *I* (2).

The results from the unit root test showed that all variables are integrated of the same order, i.e. non-stationary in their level form. Since all variables are non-stationary, we can use the cointegration test to examine the possible stable and long-run relationship among the variables. The cointegration technique is applied to eliminate the possibility of spurious causal results. The purpose of using the panel cointegration test is to transform the linear combination of a set of variables in a system stationary, which is individually *I* (1). We employed three cointegration methods in our analysis, i.e. Kao (1999) test, Pedroni (2004) test and Westerlund (2007) test (see Table 8). The results of Kao and Pedroni test confirm rejection of null hypothesis of no cointegration. However, Westerlund (2007) test did not confirm the cointegration relationship among the variables of interest. Both Kao and Pedroni tests of cointegration exhibit cointegration among

Table. 4 Descriptive statistics

Variables	Mean	Std. dev.	Skewness	Kurtosis	Minimum value	Maximum value	Normality test
COEMI	5.522	4.137	0.344	1.521	0.769	13.994	0.000(0.000)
LNEN	7.315	0.812	−0.129	1.883	5.895	8.586	22.07(0.000)
LNGDP	7.859	1.058	−0.373	2.205	5.708	9.679	8.56(0.014)
LNGDPSQ	62.889	16.264	−0.151	2.137	32.577	93.678	8.65(0.013)
LNGDPCB	511.319	190.833	0.071	2.167	185.939	906.690	7.47(0.024)
LNFDI	23.081	1.962	−0.948	4.993***	15.027	26.396	18.45(0.000)
LNFDISQ	536.567	87.202	−0.569	3.645***	225.807	696.767	7.64(0.022)

COEMI represents CO_2 emissions. LNEN symbolizes energy used. LNGDP denotes GDP per capita income. LNGDPSQ implies squared values of GDP per capita income. LNGDPCB refers to cubic values of GDP per capita income. LNFDI shows foreign direct investment flows. LNFDISQ is the squared values of the foreign direct investment flows. Values in the paranthesis refers to the *p* values of D'Agostino et al. (1990) normality test. *** indicates 1% level of significance

Source: Author's computations

the variables included in the system and confirm that all the variables move together in the long run. In a nutshell, the cointegration results show that the factors included in the model can empirically explain the reasons for environmental degradation in BRICS nations.

After confirming that there can be one or more cointegrating relationship among the variables included in the empirical model, we applied the dynamic ordinary least square (DOLS) and fully modified ordinary least square (FMOLS) models which are presented in Table 9. FMOLS model is able to mitigate the econometrics issues of endogeneity and serial correlation. On the other hand, the DOLS model incorporates the contemporaneous values, leads, and lags of the explanatory variables in its first difference form to overcome the problem of endogeneity and the serial correlation (Kumar et al. 2020). However, the results of DOLS are an underperformed one as compared to the FMOLS results because the former model uses leads and lags values of the first difference of the explanatory variables causing a reduction in the degrees of freedom. We employ both models since DOLS regression output will be robustness to FMOLS.

The results obtained from DOLS and FMOLS are reported in Table 9. The results exhibit the long-run relationship between CO_2 emissions and its regressors from the period 1992 to 2014 for BRICS nations. We find a positive and statistically significant relationship between energy use (LNEN) and CO_2 emissions. This implies that an increase in energy use measured in kilograms of oil consumed per capita will increase the environmental degradation in BRICS nations. This finding is in alignment with the previous environmental economics literature (Niu et al. 2011). BRICS nations are emerging competitors and suppliers of manufacturing goods, services and raw materials to the rest of the world. The increase in energy consumptions among these nations is possible because of the increase in the global demand and competition among its members' nations which consequently increases the CO_2 emissions. We include the variables LNGDP, LNGDPSQ and LNGDPCB to validate the

Table. 5 Correlation matrix

Variables	COEMI	LNEN	LNGDP	LNGDPSQ	LNGDPCB	LNFDI	LNFDISQ
COEMI	1						
LNEN	0.945	1					
LNGDP	0.539	0.719	1				
LNGDPSQ	0.528	0.704	0.998	1			
LNGDPCB	0.515	0.685	0.990	0.998	1		
LNFDI	−0.177	−0.053	0.234	0.244	0.256	1	
LNFDISQ	−0.173	−0.045	0.249	0.259	0.271	0.997	1

Variables are as defined in Table 4

Source: Author's computations

Table. 6 Cross-sectional dependence results

Tests	Pesaran CD test	*p* value
RE model	1.723	0.085
FE model	−1.740	0.082

RE and FE indicate random effects and fixed effects models respectively

Source: Author's computations

Table. 8 Cointegration results

Tests	Statistic	*p* value
Panel A: Kao cointegration test		
Modified Dickey-Fuller *t*	−3.751	0.000
Dickey-Fuller *t*	−3.163	0.001
Augmented Dickey-Fuller *t*	−1.459	0.072
Unadjusted Modified Dickey-Fuller *t*	−3.788	0.000
Unadjusted Dickey-Fuller *t*	−3.172	0.001
Panel B: Pedroni cointegration test		
Modified Phillips-Perron *t*	1.960	0.025
Phillips-Perron *t*	−1.504	0.066
Augmented Dickey-Fuller *t*	−1.234	0.109
Panel C: Westerlund cointegration test		
Variance ratio	−0.050	0.480

Source: Author's computations

EKC and N-shaped pattern among them. The negative and statistically significant values of the variable LNGDP and LNGDPCB and a positive and statistically significant value of the variable LNGDPSQ show an inverted N-shaped pattern contradicting the EKC. Our results are in congruence to previous studies (To et al. 2019) and not similar to other studies (Tamazian et al. 2009; and Pao and Tsai 2011; Sarkodie and Strezov 2019).

We use the central explanatory variable FDI to test its impact on CO_2 emissions. We find a negative and statistically significant association between the variable LNFDI and CO_2 emissions. The negative sign of the variable LNFDI confirms the evidence of the Pollution halo hypothesis thereby contradicting the validation of the pollution haven hypothesis. This implies that FDI inflow into the developing economies brings technological and knowledge spillovers from the developed economies. The transfer in the upgraded technology, eco-friendly techniques of production, and clean energy technologies will eventually reduce the environmental degradation in the developing economies (Görg and Strobl 2005; Albornoz et al. 2009). The non-linear component of the LNFDI variable is found to be positive and statistically significant. A negative coefficient of the variable LNFDI and a positive coefficient of the variable LNFDISQ imply the prevalence of a U-shaped pattern. Our findings are in contrast to the past studies (To et al. 2019; Kostakis et al. 2017). The results of LNFDI are also in alignment with the findings of other studies (Banerjee and Rahman 2012; Demena and Afesorgbor 2020; Zubair et al. 2020). The results from DOLS are reported to be consistent with that of FMOLS without any deviations in the sign in any of the variables.

Discussions

The overall empirical findings obtained from the DOLS and FMOLS models explain the factors that cause CO_2 emissions

Table. 7 Panel unit root tests

Variables	Levels		First difference		Levels		First difference	
	Breitung test				Im-Pesaran-Shin unit-root test			
	With trend	without trend	With trend	Without trend	With trend	Without trend	With trend	Without trend
COEMI	1.853	4.242	−3.903***	−4.631***	−0.085	3.535	−4.904***	−4.466***
LNEN	1.074	4.925	−2.815***	−4.058***	−0.866	3.656	−4.099***	−3.930***
LNGDP	−0.123	4.523	−3.082***	−3.809***	−0.391	3.882	−3.566***	−3.676***
LNGDPSQ	0.527	4.679	−2.978***	−3.690***	−0.199	4.686	−3.502***	−3.602***
LNGDPCB	1.202	4.782	−2.926***	−3.584***	−0.011	5.326	−3.483***	−3.488***
LNFDI	−0.079	1.933	−3.514***	−3.073***	−2.408***	−1.526	−5.691***	−5.569***
LNFDISQ	−0.255	1.916	−3.527***	−3.359***	−2.316**	−1.222	−5.699***	−5.606***

Variables are as defined in Table 4. Values of lambda statistic is reported for Breitung test. Values of Z-t-tilde-bar is reported for the Im-Pesaran-Shin unit-root test. *** and ** indicate significance at 1% and 5% level respectively

Source: Author's computations

Table. 9 DOLS and FMOLS regression results

Models	DOLS		FMOLS	
Variables	Coefficients	*p* values	Coefficients	*p* values
LNEN	6.097	(0.000)	5.951	(0.000)
LNGDP	−10.051	(0.000)	−10.104	(0.000)
LNGDPSQ	1.242	(0.001)	1.259	(0.000)
LNGDPCB	−0.051	(0.003)	−0.052	(0.000)
LNFDI	−1.292	(0.032)	−1.218	(0.001)
LNFDISQ	0.027	(0.035)	0.026	(0.001)
Diagnostic results				
Adjusted R^2	0.200		0.225	
S.E. of regression	3.699		3.602	

Variables as defined in Table 4. The values in the parenthesis represent *p* values

Source: Author's computations

in BRICS nations. The results show that except for energy use, the rest of the factors do not contribute to carbon emissions in these economies. A high coefficient of the variable LNEN shows that efforts required to reduce energy consumption can have a substantial impact on the improvement in environmental quality in these nations. The variable LNGDP is a proxy of domestic income and also implies income elasticity. We find that the variable LNGDP is negative but greater than unity (−10.051 and −10.101) indicating that CO_2 emissions in our sample countries are much sensitive to domestic income. We did not find any evidence of the EKC relationship between economic growth and environmental degradation. Our results also show a U-shaped pattern and an inverted N-shaped pattern when both the variable LNGDPSQ and LNGDPCB were included in the empirical model. The rudimentary analysis also explains the prevalence of a U-shaped pattern between LNFDI and the squared value of the LNFDI variable validating the pollution halo hypothesis. Finally, a positive and statistically significant value of the variable LNFDISQ explains that policymakers need to be more vigilant while formulating the regulations concomitant to FDI. Therefore, the local government must take a discretionary approach by looking into the past financial track records and investment origin of the parent company and accordingly filter out the dirty foreign capital flowing into these economies.

Research pertaining to environmental concerns especially in the context of BRICS nations are growing only recently. Similarly, many scholars have also ascertained that BRICS holds the potential to be one among the future emerging and developing hubs. The present study untangles the reasons of the environmental degradation by only identifying the role of foreign direct investment and domestic income in these economies. However, the future researches can look into the role of capital flight (resident capital outflows) and exodus illicit capital flows from these economies on environmental degradation by employing advanced panel data modelling to gain additional policy inputs and insights.

Conclusion

The current study examines the nexus between FDI, economic growth and environmental degradation on a sample of BRICS nations. To explore the relationship between these three strategic variables, we employ the panel cointegration models, and DOLS and FMOLS regressions. While investigating the relationship between environmental degradation and economic growth, the findings of the study neither support the EKC hypothesis nor the presence of an N-shaped pattern applicable for the selected countries. Additionally, we find a U-shaped pattern relationship between the FDI and its non-linear component on environmental degradation. The results of FDI-environmental degradation confirm the validation of the pollution halo hypothesis. This implies that FDI plays a pivotal role in reducing the CO_2 emissions in these economies. The results are applicable for the overall sample. The results also indicate that energy use in these economies is a major contributor to CO_2 emissions.

From the policy perspective, it is imperative for these economies to take a joint effort in reducing the reliance on non-renewable energy resources by promoting the use of eco-friendly and clean energy technologies of production. Over the competition, the pro-growth-oriented strategy might be harmful to these economies to retain the environmental standards to a permissible level. Therefore, the overall findings of the paper recommend the promotion of R&D related to clean energy technology and increasing efficiency of renewable energy use as an alternative source of energy. Therefore, the implementation of fair, sustainable and holistic environmental practices are important for BRICS nations. We also suggest that the investment inflows must ensure the promotion of environmental awareness and encourage industries to apply environmentally friendly techniques of production. The current study necessitates appropriate climate policy prescripts and delegation of environmental protocols in order to reduce the alarming environmental degradation in this region.

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Declarations

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