DOES FOREIGN DIRECT INVESTMENT REDUCE CARBON EMISSION? EVIDENCE FROM THE PANEL OF BRICS COUNTRIES

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DOES FOREIGN DIRECT INVESTMENT REDUCE CARBON EMISSION? EVIDENCE FROM THE PANEL OF BRICS COUNTRIES

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Abstract: The nature of the impact of Foreign Direct Investment (FDI) on environmental pollution is unclear from the available literature and the present paper examines the short-run and long-run association of FDI with carbon emissions (CO2) in BRICS countries (Brazile, Russia, India, China and South Africa). The study estimates the panel data for the BRICS region from 1992 to 2018 with yearly frequency through panel cointegration test, panel vector error correction model and panel variance decomposition. The results, though have not found any long-run relation between FDI and CO2, they indicate that carbon emissions reduce in BRICS countries with increasing FDI in the short run and support the pollution halo hypothesis. This implies that the Multi-national Companies (MNCs) shift relatively cleaner industries and transfer greener technologies to BRICS. The results also indicate reverse causation running from CO2 to FDI in the short run. Furthermore, the Gross Domestic Product (GDP) of the BRICS region appears to be directly influenced by both FDI and CO2. Findings suggested that BRICS countries should furthermore liberalise FDI policies and parallelly tighten the environmental regulations alongside creating awareness and enhancing the capabilities of the country to absorb efficient and eco-friendly technologies. Policies should provide impetus to industries to shift energy-efficient technologies and less emitting equipment.

Keywords: FDI; CO2; BRICS; GDP; pollution halo hypothesis; pollution heaven hypothesis

JEL codes: F21; F18; C01; F43; Q5

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Introduction

Several growth models have established a relationship between foreign direct investment and economic growth, particularly in developing and emerging economies. The classical growth models (Harrod, 1939 and Domar, 1947) postulate savings as a key driver of capital accumulation and growth and Rostow's (1959) growth theory also emphasises that savings are critical for development. Rising savings may seem to be difficult in the short term, especially in developing countries. Since the developed countries have largely accumulated savings, the International Monetary Fund (IMF) and the World Bank advised emerging and third world nations to borrow savings from abroad via loans, portfolio investments, and FDI to achieve a targeted growth rate (Jorge and Richard, 2018). The endogenous growth theory (Lucas, 1988; Barro, 1990; Romer, 1990) propounded that FDI ignites domestic productivity by transferring technology. Though the exogenous growth model (Solow, 1957) argued that long-run growth is due to technical progress, not because of infusion of capital or investment, FDI has an important role in economic growth (Omri et al., 2014). The host countries, particularly those less developed, can enlarge GDP by the shared knowledge (Shahbaz et al., 2015) and technologies (Mielnik and Goldemberg, 2002) derived through the FDI. In view of amassing the benefits of FDI, some countries have introduced policy measures to move in the direction of liberalisation and facilitation and promotion of FDI (United Nations Development Program, 2019). Though FDI accelerates the economic growth, it has a few spillover effects and the major amongst is the serious environmental damages it inflicts. FDI can harm the environment through the transfer of polluting industries (Baek, 2016). However, it is also argued that FDI facilitates the transfer and adoption of greener technology (Marques and Caetno, 2020) that boosts efficiency (Pao & Tsai, 2011), leading to improved environmental quality (Marques and Caetno, 2020). The available studies and literature have paid very little attention to the spillover effect of FDI on environmental quality. Against this backdrop, the present paper examines the short-run and long-run association of foreign direct investment with carbon emissions in BRICS countries.

Review of Literature

1. Theoretical Reviews

There are several theories advocating different perspectives to the impact of FDI on the environment. Two major hypotheses are worth denoting; firstly, Pollution Halo Hypothesis and secondly, Pollution Heaven Hypothesis. The Pollution Halo Hypothesis argues that foreign direct investment by multi-national companies will reduce pollution in the host country. If the host country has stronger environmental regulations, the MNC firms are encouraged to invest in innovations of green technologies (Porter, 1991) that are energy efficient and eco-friendly (Zhang and Zhou, 2016) and transfer them to the host country. The transfer of such innovative technologies can decrease energy consumption (Mielnik and Goldemberg, 2002), and the transfer of business know-how (Shahbaz et al., 2015) are the two major benefits host countries will enjoy from the MNCs if they are less pollution-intensive (Marques and Caetno, 2020). The innovation toward greener technology becomes essential to the firms when the host countries with high environmental awareness levy stronger regulations to protect against climate change.

The Pollution Heaven Hypothesis, on the other hand, states that when high pollution intensity industries are levied with high pollution tax or faced with strict environmental regulations in their home country, they relocate their production factories to less developed countries which have weaker pollution regulation laws or where they are required to comply with no or fewer emission standards. In such cases, the host country will have increased carbon emissions from inflowing foreign direct investment and thereby harm the environment (Baek, 2016). However, Pollution Heaven Hypothesis occurs only when the transfer of the industries is relatively easier and less expensive than the cost of technological innovation. The relocation of industries becomes easier when the industries are strongly mobile in nature (Dou and Han, 2019) and hence the FDI is more polluting in nature to the host country. Thus, the pollution heaven hypothesis implies that for industrialised economies, less developed economies become pollution heavens.

2. Empirical Reviews

The studies that evaluated the impact of FDI inflows provide different results. If some of them support the pollution halo hypothesis, some others have evidence to agree with the pollution heaven hypothesis. For instance, Zhang and Zhou (2016) examined the impact of FDI on China's CO2 emissions for provincial panel data from 1995 to 2010 and found that FDI contributes to reduced CO2 emissions in China. This supports the pollution halo hypothesis. The finding of Xie et al. (2020) also corroborates the pollution halo hypothesis. The result displays that in developing countries, with the rise in FDI inflows, the CO2 concentration decreases. In contrast, an empirical study on Asian economies for the period 2001-2019 by Farooq (2021) found support for pollution heaven hypothesis. It observed that FDI inflows result in industrial proliferation, and this enhances emitting of CO2.

Abid et al. (2021) studied the nexus of foreign direct investment and carbon emission along with other parameters for G8 countries for the data period ranging from 2001 to 2019. Estimation based on FMLOS denoted a negative association of CO2 with FDI and thereby provided supporting evidence to the pollution halo hypothesis. Further, the study reveals that foreign direct investment and carbon emissions have unidirectional causality. However, the finding of Balsalobre-Lorente et al. (2021) was dissimilar. They analysed the relationship between foreign direct investment, economic growth, urbanisation, energy use, and carbon emissions in BRICS countries for the period from 1990 to 2014. One of the key empirical results of this paper that examines the moderate effect was the dampening impact of foreign direct investment on energy use and thereby causing enhanced emitting of carbon dioxide.

Whereas, Marques and Caetano (2020) find different results in the different types of economies. The results from an evaluation of the impact of FDI on the level of carbon emissions in 21 developed and developing countries for the period between 2011 and 2017 suggest that more FDI decreases emissions in developed economies, and increases emissions in developing countries in the short run. This underlines that the developed economies, by virtue of adoption of innovative eco-friendly technologies due to stronger environmental regulations, have made FDI less pollution-intensive.

However, that is not the case in the less developed economies.

Since the results are contrasting and very limited studies focused on the evaluation of the impact of FDI on the environment, the present study attempts to fill the vacuum. This apart, in BRICS economies, the economic growth is primarily driven by FDIs. Very limited studies have focused on the FDI-emission nexus in the BRICS region and this is the other motivation for the present study.

Overview of BRICS Economies

Table 1 presents the trends in the FDI inflow, GDP and CO2 emissions in BRICS countries. It is denoted that Brazil has been facing an economic slowdown since the global economic recession of 2008 and it is indicated by the trends in its GDP growth rate. During 2013-18, the annual average growth of GDP in Brazil appears to be zero and it indicates the contraction in economic activities compared to the previous periods. It is during the same time, the growth rate of the inflow of FDI declined substantially and it became negative during 2013-18. The economic slowdown and reduced growth of FDI inflows along with rigid environmental policies would have also brought down the environmental pollution levels as denoted by the negative growth rate of CO2.

Russia had high fluctuations in the FDI growth rate during the study period. In the face of an economic crisis, if the FDI annual growth rate fell to 4 per cent during 2008-12, it recovered since then and rose to 32 percent during 2013-18. However, the annual growth rate of GDP had continued to decline despite the recovery in FDI inflow and so was carbon emission. The annual growth rate of carbon emission turned negative in the last half decadal period. At the outset, economic growth and carbon emission do not seem to correlate directly with the inflow of foreign investment.

Whereas, India’s case appears to be interesting as the trends in growth rate indicate that GDP growth rate and CO2 growth rate were on the decline alongside the falling growth rate of foreign direct investment. Compared to the rest of the countries in the region, India still has higher growth rates of the economy and carbon emissions.

China was the most emerging economy in the region. It is noteworthy that the growth rate of FDI inflows to China had a big hit and this appears to be reflected in the economic slowdown and reduced growth rate of carbon emissions.

South Africa is the most backward economy in the region and efforts are on to attract huge foreign capital, as indicated by the data. Most of the developed and emerging economies find South Africa as a new destination for their business expansion and industrial production. However, not much drastic growth of the economy was seen, rather was slowing down alongside a major part of the rest of the world. It is important to note that despite the rise in FDI, the annual average growth rate of CO2 continued to decline in the recent decade in the face of shrinking economic activities.

It is evident that the region appears to be less attractive to foreign companies in the recent years as the FDI growth rate slowed down across the region. This may be attributed to the increasing awareness of these countries on environmental pollution and tightening of the regulations by the national governments. This is also evident from the falling rate of growth in carbon emission.

Table 1. Half decadal annual average growth rate (in %) of study variables in BRICS countries

Period	**Brazil**	**Russia**	**India**	**China**	**South Africa**
FDI					
1992 to 1997	73.7	54.9	71.4	40.1	803.6
1998 to 2002	1.7	-2.9	13.2	3.5	124.6
2003 to 2007	36.1	82.8	50.7	24.9	327.7
2008 to 2012	30.4	4.0	6.0	14.6	-0.1
2013 to 2018	-1.2	32.2	10.6	2.0	30.6
GDP					
1992 to 1997	4.0	-5.5	6.1	11.4	2.9
1998 to 2002	1.9	4.2	5.5	8.3	2.7
2003 to 2007	4.0	7.5	7.9	11.7	4.7
2008 to 2012	3.7	2.0	6.0	9.4	2.0
2013 to 2018	0.0	0.9	7.2	7.1	1.4
CO2					
1992 to 1997	6.2	-6.5	5.5	5.4	3.9
1998 to 2002	2.4	0.9	3.8	4.1	3.0
2003 to 2007	2.1	1.3	6.3	12.9	3.7
2008 to 2012	5.3	1.0	7.4	6.5	1.6
2013 to 2018	-0.8	-0.6	4.2	1.3	0.3

Methodological Framework

1. Model Specification

Most of the past studies on the relation between FDI and carbon emissions used a bivariate framework (Narayan & Smyth, 2009) and some studies (for instance, Lutkepohl, 1982) concluded that the bivariate model by omitting other relevant variables might result in a spurious findings of causality and one can visualise misdirected policy recommendations. Further, omitted variables, in a bivariate framework can also cause an absence of causality between variables (Triacca, 1998). Insertion of a third variable into the FDI-CO2 analysis will make the model more robust. The sign and size of the coefficient will be nearer to perfection and this is expected to estimate the direction of causality closer to the reality (Odhiambo, 2009). Against this backdrop, this paper developed a tri-variate framework by including economic growth to foreign direct investment and carbon emissions. The inclusion of economic growth in the study model is expected to better explain the relation between FDI and CO2 in BRICS economies. The model proposed in this paper is consistent with the literature, and is presented in Equation (1):

$$CO2 = f(FDI, GDP) \tag{1}$$

Based on theory and literature, the model presumes that carbon emissions (CO2) in the BRICS panel are partially governed by foreign direct investment inflow (FDI) and the level of economic growth (GDP). The CO2 represents the total carbon emissions in the panel of BRICS countries and it is measured in thousand tons. FDI denotes the foreign direct investment net inflows in current USD. The GDP is the proxy to economic growth of the BRICS panel countries, and it considers the real GDP estimated for 2015 USD. The tested model is presented in a specific equation as under Equation (2).

$$CO2_{\mathrm{t}} = \beta_0 + \beta_1 FDI_{\mathrm{t}} + \beta_2 GDP_{\mathrm{t}}\, e_{\mathrm{t}} \tag{2}$$

Where, βo is the constant term, β_1 and β_2 are coefficient terms of FDI and GDP, respectively, and e is the error term. The study uses annual data for all the variables under consideration, and the time series is represented by t.

The actual values of data series are converted to natural logarithm and this smoothens the data and facilitates more robust results from the model estimation. After the logarithmic transformation of the data series, the Equation (2) is re-written as presented in Equation (3):

$$lnCO2_{\mathrm{t}} = \beta_0 + \beta_1\, lnFDI_{\mathrm{t}} + \beta_2\, lnGDP_{\mathrm{t}} + e_{\mathrm{t}} \tag{3}$$

The data are panel in nature as the study is focussed on BRICS countries. In the Equation (3), cross-country factor is included and Equation (4) is thus the modified version.

$$lnCO2_{i,t} = \beta_0 + \beta_1 \, lnFDI_{i,t} + \beta_2 \, lnGDP_{i,t} + e_{i,t} \quad (4)$$

In Equation (4) i indicates the respective countries in the panel.

2. Data Description

The study covers BRICS countries (Brazil, Russia, India, China and South Africa) and annual data are collected for these countries from 1992 to 2018. Table 2 consolidates the study variables, their definitions and symbols used in the paper. The data of the different variables were collected from the World Development Indicators (WDI) of the World Bank.

Table 2. Description of the study variables

Variable	**Description**	**Symbol**
Response Variable		
Emission of carbon dioxide	Total carbon emissions measured in thousand of tons	CO2
Deterministic Variables		
Foreign direct investment inflow	Net inflows in the current USD	FDI
Gross Domestic Product	Real GDP estimated for 2015 USD	GDP

Table 3 provides descriptive statistics to study variables. It is denoted that the deviation of maximum value and minimum value from the mean value in each variable is short. The standard deviation is low and the data sets exhibit behaviour almost close to their respective average behaviour. From the coefficients of Skewness and Kurtosis, it appears that all the study variables are characterised by non-normal distribution. The skewness coefficient values of most of the variables are positive and they indicate that variables are skewed to the right. The coefficients of kurtosis show that the leptokurtic for all variables have the presence of a high peak or a fat-tailed in their volatilities.

In addition, the estimated coefficients of Jarque–Bera statistics are positive and their coefficient values are high. This indicates that the null hypothesis of normal distribution of the variables cannot be accepted and implies that the data series are not normally distributed at 1 per cent level of significance.

Table 3. Descriptive Statistics

Particulars	***In CO2 $_{it}$***	***In FDI $_{it}$***	***In GDP $_{it}$***
Mean	1946767	4.17E+10	1.93E+12
Median	1137740	1.90E+10	1.20E+12
Maximum	10313460	2.91E+11	1.35E+13
Minimum	208660.0	3358018	1.64E+11
Std. Dev.	2524459	6.27E+10	2.59E+12
Skewness	2.165136	2.394292	2.791785
Kurtosis	6.776410	8.418143	10.51319
Jarque-Bera	185.6955	294.1132	492.8863
Probability	0.000000*	0.000000*	0.000000*
Sum	2.63E+08	5.63E+12	2.61E+14
Sum Sq. Dev.	8.54E+14	5.27E+23	8.96E+26
Observations	135	135	135

* significant @1 % level.

3. Econometric Approaches

Guided by the past literature, the present study has employed panel estimation techniques. The literature highlights the efficiency of the panel estimation methodology and is considered to be the fourth generation or the latest estimation technique (Guttormse, 2004 and Mehrara, 2007). Osbat (2004, quoted from Hasanov, et al., 2017) highlights four advantages of panel estimation over other methodologies. First, it provides better and clear information when time series are combined with cross-sectional dimensions. Second, panel estimation result has the potential to mitigate collinearity among the explanatory variables and to increase degrees of freedom and thereby are more efficient. Third, it provides for controlling the individual heterogeneity. And lastly, the effects that are not identified in the time series or cross-section data, are detected by the panel estimation.

Since the study uses time series data, to begin with, they are tested for non-stationarity and order of integration through panel unit root test (PURT). If the data series are non-stationary at the level and attain stationarity in the first order, panel cointegration is estimated to test the impact of foreign direct investment and economic growth on carbon emission in the study region and it explores the long-run relationship among the variables. If the variables are found co-integrated, a panel vector error correction model (VECM) is estimated to study the short-run and long-run causal relationship between the variables. Suppose we find an absence of cointegration among the variables, a panel vector autoregressive model (VAR) will be estimated. Lastly, variance decomposition is performed as it is a better framework to summarise the dynamic relations between variables in a VAR. The selection of econometric methodology is guided by the literature of the past. The methodological details are presented below.

CO2, FDI and GDP are data series to be studied and they are examined for non-stationarity using three different panel unit root test (PURT) methodologies such as Levin, Lin & Chu test, (Augmented Dickey-Fuller) ADF – Fisher Chi-square test and (Phillips-Perron) PP – Fisher Chi-square test. If Levin, Lin & Chu test assumes a common unit root process across cross sections, ADF – Fisher Chi-square and PP – Fisher Chi-square tests assume individual unit root process. The null hypothesis across all three tests is that the panel data series have a unit root or non-stationarity. The general form of the equation estimated for PURT is as presented in Equation (5).

$$\Delta y_{i,t} = \alpha y_{i,t-1} + \sum_{k=1}^{Pi} \mu_{ik} \Delta y_{i,t-k} + \beta_i X_{i,t} + e_{i,t} \tag{5}$$

Where y is the variable to be tested, X is the exogenous variable/s, i denotes cross-section, which is country in our case, t represents the time element, e is the error term and Δ indicates the first difference operator. The null hypothesis of the unit root is $H_0 : \alpha = 0$. The alternative hypothesis of no unit root is $H_1 : \alpha = 0$ for all i = 1,2,3…N_1 and $\alpha < 0$ for all i = N1+1, N1+2, N1+3……N.

If data series of all variables are integrated in the same order, preferably I(1), a panel cointegration test (PCT) is performed to determine the long-run relations between the variables. The paper applies three different methods of PCT such as Pedroni Residual Cointegration Test, Kao Residual Cointegration Test and Johansen Fisher Panel Cointegration Test.

The superiority of the Pedroni method is its consideration of heterogeneity at two different levels. In the first level, it considers the heterogeneity across sections, while it is countries in our case. It is estimated by Equation (6).

$$y_{i,t} = \alpha_i + \delta_{i,t} + \beta_{1t} X1_{i,t} + \beta_{2t} X2_{i,t} + \cdots + \beta z_t XZ_{i,t} + e_{i,t} \tag{6}$$

It is assumed that variables Y and X are I(1) and $\alpha_i + \delta_i$ denotes individual and trend effects. In the second level, stationarity of the estimated residual, i.e. $\hat{e}_{i,t}$ is estimated by Equation (7):

$$\hat{e}_{i,t} = Q_i\hat{e}_{i,t-1} + e_{i,t} \tag{7}$$

Whereas, the Kao's methodology, unlike Pedroni, takes into account homogeneity in cointegration with only intercept without trend. Equation (8) is estimated to test cointegration under the Kao approach.

$$y_{i,t} = \alpha_i + \beta_{1t}X1_{i,t} + \beta_{2t}X2_{i,t} + \cdots + \beta z_t XZ_{i,t} + e_{i,t} \tag{8}$$

If the cointegration test detects at least one co-integrating equation, a panel vector error correction model (VECM) is estimated; otherwise, a panel vector autoregressive model (VAR) will be estimated. The objective is to study short run causal relationship between the variables. Since the study found a long-run co-integrating relation among the variables, Equation (4) for CO2 is represented in Equation (9).

$$InCO2_{i,t} = \alpha_i + \delta_{i,t} + \beta 1\ InFDI_{i,t} + \beta 2\ InGDP_{i,t} + e_{i,t} \tag{9}$$

Further, we measure the long-run residuals or error correction terms by estimating Equation (10).

$$e_{i,t} = ECT_{i,t} = \ \mathrm{In}CO2_{i,t} - (\alpha_i + \delta_{i,t} + \beta 1 InFDI_{i,t} + \beta 2\ InGDP_{i,t}) \tag{10}$$

The present paper estimates the panel VECM using a set of vectors that are presented in Equation (11).

$$\begin{pmatrix} \Delta InCO2_{i,t} \\ \Delta InFDI_{i,t} \\ \Delta InGDP_{i,t} \end{pmatrix} = \begin{pmatrix} b^1 \\ b^2 \\ b^3 \end{pmatrix} + \sum_{k=1}^{n} \begin{pmatrix} B_{11,k} & B_{12,k} & B_{13,k} \\ B_{21,k} & B_{22,k} & B_{23,k} \\ B_{31,k} & B_{32,k} & B_{33,k} \end{pmatrix} \begin{pmatrix} \Delta InCO2_{i,t\text{-}k} \\ \Delta InFDI_{i,t\text{-}k} \\ \Delta InGDP_{i,t\text{-}k} \end{pmatrix}$$

$$+ \begin{pmatrix} \tau_1 \\ \tau_2 \\ \tau_3 \end{pmatrix} ECT_{i,t\text{-}}{}^{1} + \begin{pmatrix} e^1{}_{i,t} \\ e^2{}_{i,t} \\ e^3{}_{i,t} \end{pmatrix} \tag{11}$$

In Equation (11), b represents the vector of intercept and τ denotes the vector of the speed of adjustment coefficients and it shows the speed at which the deviations from the long-run equilibrium are corrected. B indicates the metrics of short-run coefficients and e is the vector of serially independent residuals. Δ is the difference operator and $ECT_{i, t-1}$ is the lagged error term that is generated from long-run relation. A negative and statistically significant coefficient of the lagged ECT is the indication of the presence of a long-run causality running from deterministic variables to the response variable. If the coefficients of the first difference or second difference are significant, the short-run causality is confirmed.

Later, the study tried capturing the relative strength of causal relation between the variables beyond the selected period by estimating panel variance decomposition as VECM does not provide attention to this (Abosedra et al., 2015). The variance decomposition measures the magnitude of the predicted error variance for a series accounted for by innovations from each of the independent variables over different time-horizons beyond the selected time period (Abosedra et al., 2015). It is found in the literature (such as Engle & Granger, 1987 and Ibrahim, 2005) that with the VAR framework, the variance decomposition method provides more reliable results than conventional techniques.

Results

1. Panel Unit Root Tests (PURTs)

The PURTs using three different methods (Levin, Lin & Chu, ADF – Fisher Chi-square and PP – Fisher Chi-square) are applied to the natural logarithms of CO2, FDI and GDP data series at the level and first difference. The results, as displayed in Table 4, indicate that all three tests have consistent results. The data series of CO2, FDI and GDP have non-stationarity and unit root issues at level I(0). However, after the first difference I(1) all data series, i.e., ΔCO2, ΔFDI and ΔGDP attain stationarity. The non-stationarity of the data series at level I(0) indicates that measures adopted to control carbon emissions appear to have long-run effect on the CO2 emission levels; innovations in policies to attract more foreign investment will have a longstanding impact on FDI inflow; and economic reforms and revisions in policies like fiscal policy, monetary policy, industrial policy and trade policy etc. have a permanent effect on the growth of the economy. Thus, it implies that any shock, innovation or reform relating to the variable concerned has a transitory effect and the series returns to its trend path (Abosedra et al., 2015). While, in the first difference, reforms or innovations and policies in the domain of CO2, FDI and GDP will have only a temporary effect on them. Since all data series are integrated of order one I(1), the study proceeded with testing of cointegration among variables.

Table 4. Results of Panel Unit Root Tests

Variable	Method	Order	Statistic	Prob
$lnCO2_{it}$	Levin, Lin & Chu	Level	1.47518	0.9299
		1st diff	-5.72191	0.0000
	ADF - Fisher	Level	19.0693	0.0394
		1st diff	48.3635	0.0000
	PP - Fisher	Level	16.8168	0.0785
		1st diff	49.0953	0.0000
$lnFDI_{it}$	Levin, Lin & Chu	Level	-0.90459	0.1828
		1st diff	-9.36078	0.0000
	ADF - Fisher	Level	12.2076	0.2714
		1st diff	84.1903	0.0000
	PP - Fisher	Level	11.7493	0.3022
		1st diff	88.0649	0.0000
$lnGDP_{it}$	Levin, Lin & Chu	Level	9.30130	1.0000
		1st diff	-1.74221	0.0407
	ADF - Fisher	Level	1.25012	0.9995
		1st diff	22.5871	0.0124
	PP - Fisher	Level	0.95526	0.9999
		1st diff	21.9173	0.0155

2. Panel Cointegration Tests (PCTs)

To estimate the long-run relation between CO2, FDI and GDP, three different models of panel cointegration tests, such as Pedroni residual cointegration test, Kao residual cointegration test and Johansen Fisher panel cointegration test are applied. The result is sensitive to the lag length used in the estimation and this paper selects 2 lags based on the highly accepted Schwarz information Criterion (SC), which is guided by VAR Lag Order Selection Criteria and its detailed output is presented in Table 5. The results of all three models of cointegration test are presented in Table 6. Pedroni cointegration test assumes intercept and trend and presents two sets of cointegration: within-dimension and between-dimension.

The result indicates that CO2, FDI and GDP are moderately co-integrated in both within-dimension and between-dimension and hence have long-run relation. Whereas, the Kao test assumes individual intercept and no trend and as found from the result, the ADF statistic is significant and hence endorses the result of the Pedroni test. Even the findings of the Johansen Fisher test (that assumes intercept, no trend in CE & VAR) confirm the long-run co-integrating relationship between the variables. The statistic value in both the trace test and max-eigen test is statistically significant, implying the rejection of null hypothesis that there is 'none' number of co-integrating vectors between the three variables of the study. It thus indicates the presence of at the most one co-integrating equation between CO2, FDI and GDP in the panel of BRICS countries. Since the model variables have the long-run co-integrating relationship between them, the presence of a causal relationship and the direction of causality between the series is estimated by the panel error correction model.

Table 5. VAR Lag Order Selection Criteria

Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	-8104.8	NA	3.47e+57	141.0051	141.0767	141.0341
1	-7358.7	1440.273	9.40e+51	128.1862	128.4726	128.3024
2	-7295.7	118.3543	3.68e+51	127.2468	127.7481*	127.4503
3	-7282.8	23.46565	3.44e+51	127.1799	127.8959	127.4705
4	-7264.0	33.46181*	2.90e+51*	127.0083*	127.9392	127.3862*

* indicates lag order selected by the criterion. LR: sequentially modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion

Table 6. Results of Panel Cointegration Test

Method	**Test**	***Statistic***	***Prob***
Pedroni	*Within-dimension*		
	Panel v-Statistic	2.5483210 (0.882951)	0.0054 (0.1886)
	Panel rho-Statistic	-0.978166 (-0.589357)	0.1640 (0.2778)
	Panel PP-Statistic	-1.145282 (-1.584825)	0.1260 (0.0565)
	Panel ADF-Statistic	-1.436935 (-2.884284)	0.0754 (0.0020)
	Between-dimension		
	Group rho-Statistic	0.517768	0.6977
	Group PP-Statistic	-1.409205	0.0794
	Group ADF-Statistic	-4.118091	0.0000
Kao	ADF	-2.164776	0.0322
Johansen Fisher	*Trace Test*		
	None	28.57	0.0015
	At most 1	13.96	0.1749
	At most 2	10.14	0.4283
	Max-eigen test		
	None	24.99	0.0054
	At most 1	13.43	0.2009
	At most 2	10.14	0.4283

* $p < 0.01$, ** $p < 0.05$ & *** $p < 0.10$. Data in parentheses ( ) is a weighted value

3. Panel Vector Error Correction Model (VECM)

The long run and short run causality between the CO2, FDI and GDP for the panel of BRICS countries is estimated by VECM. The result of long-run causality is presented in Table 7. The error correction term (ECT) implies the speed of adjustment of the dependant variable towards long-run equilibrium for the shocks of determinants. The result indicates the absence of long-run causality among variables in any direction. The coefficients of the lagged ECT of CO2 is positive and not significant. It denotes that the imbalances caused to carbon emissions by FDI and GDP cannot be restored in the long run path, rather, the imbalance diverges. Similarly, fluctuations caused to economic growth due to changes in policies and practices of carbon emissions and foreign investment do not converge to stability in the long run. Though shocks to FDI administered by changes in GDP and CO2 restore at high speed to the pre-shock state, it does not appear to be statistically significant. Hence, we do not find long-run causality in any direction between the three variables in the panel of BRICS countries.

Table 7. Panel Vector Error Correction Model- Long Run Causality

	$\Delta lnCO2_{it}$	$\Delta lnFDI_{it}$	$\Delta lnGDP_{it}$
ECT(-1)	0.008332	-251.8205	20666.47
Std. Error	0.01071	1815.64	3867.16
t-Statistic	0.77798	-0.13870	5.34409
Prob.	0.4371	0.8898	0.0000*
R-squared	0.696126	0.308347	0.973782
Adj.R-squared	0.677134	0.265118	0.972144
S.E. of regression	1.12E+12	3.22E+22	1.46E+23
F-statistic	100019.5	1.70E+10	3.61E+10
Log-likelihood	36.65341	7.132978	594.2768
D-W stat			

* $p < 0.01$

The results of the short-run causality estimation under VECM are reported in Table 8. It is evident from the wald test that the joint impact of lag-1 and lag-2 of FDI on CO2 is statistically significant. It implies that there exists a short-run causality running from FDI to CO2. It is noteworthy that the coefficient values of FDI appear to be negative, indicating that increasing FDI may not necessarily cause a rise in CO2, and instead, it decreases in the BRICS region. Similarly, the lagged values of CO2 jointly cause positive changes in FDI in the short run. Hence, the causality flows from CO2 to FDI as well. Thus, a bidirectional short-run causal relationship is found between CO2 and FDI in the panel of BRICS countries. The lagged terms of CO2 jointly appear to be having direct causation towards GDP. This is evident from statistically significant chi-square statistic. And no reverse causality is found running from GDP to CO2. It implies a unidirectional causality between GDP and CO2 that flows from CO2 to GDP. Similarly, the study finds the absence of short-run causality running from GDP to FDI and GDP to CO2 as well.

Table 8. Short Run Causality and Joint Wald Test of Lagged Terms

Regressor & Lagged Terms	Coefficient	t-statistic	Chi-square	df	Prob	Decision
Dependent Variable: ΔlnCO2 $_{it}$						
ΔlnFDI-1	-1.34E-06	-1.92686	8.985564	2	0.0112	Reject Ho
ΔlnFDI-2	-1.87E-06	-2.80642				
ΔlnGDP-1	-3.76E-07	-1.25086	1.572370	2	0.4556	Accept Ho
ΔlnGDP-2	1.67E-07	0.60423				
Dependent Variable: ΔlnFDI $_{it}$						
ΔlnCO2-1	62862.18	3.55971	29.01478	2	0.0000	Reject Ho
ΔlnCO2-2	28396.60	1.46402				
ΔlnGDP-1	0.044790	0.87953	2.579250	2	0.2754	Accept Ho
ΔlnGDP-2	-0.075371	-1.60597				
Dependent Variable: ΔlnGDP $_{it}$						
ΔlnCO2-1	111461.3	2.96337	33.59228	2	0.0000	Reject Ho
ΔlnCO2-2	106413.2	2.57580				
ΔlnFDI-1	-0.357153	-1.42209	3.490739	2	0.1746	Accept Ho
ΔlnFDI-2	-0.387809	-1.61579				

Since the study used time series data, we should test whether VECM has spurious results caused by serial correlation among the variables and to detect the same, LM serial correlation test is applied. The result reported in Table 9 shows that the LM stat, in most of the cases, beyond lag 2 (optimal lag of the study) is not statistically significant at 5 per cent level. This rejects the null hypothesis of the presence of serial correction at higher lag order than the optimal lag order of the study and thus confirms the absence of a serial correlation problem and thus, VECM result is not spurious. Hence, the result of the model is reliable.

Table 9. VEC Residual Serial Correlation LM Tests

Lags	LM Stat	Prob.
1	20.94731	0.0129
2	27.29977	0.0012
3	16.05189	0.0658
4	24.59713	0.0035
5	16.66482	0.0542
6	24.13752	0.0041
7	16.72082	0.0533
8	16.15298	0.0638

4. Variance Decomposition

After examining the short-run and long-run dynamics of the relation between CO2, FDI and GDP, the variance decomposition technique to the VAR system is applied to ascertain the predicted changes in the given variable for the innovations or shocks in each of the regressors over a time path beyond the selected time period. Table 10 presents result of variance decomposition to the panel of BRICS countries. The shocks of GDP do not appear to cause any variation in CO2. The GDP accounts for less than 1 per cent of the total changes of CO2 in the long-time path of the 10^{th} period. Though, the variance caused by the fluctuations of FDI to CO2 is less, it has increased in the long run time path. The FDI is predicted to contribute nearly 10 per cent by the 10^{th} period to the total changes in CO2. Much of the changes in CO2 in the time path (nearly 90%) could be attributed to its own past shocks that are linked to the various exogenous factors. Furthermore, the innovations or shocks of GDP do not contribute to changes in FDI. However, CO2 appears to be the factor contributing the most variations in FDI. It is evident that the explanatory power of CO2 on FDI has increased from the time path of period 1 (9.1%) to period 10 (80.6%). It implies that innovation or policy reforms relating to CO2 are predicted to cause 80.6 per cent changes in its long run time path to the total changes in FDI inflows to BRICS countries. Whereas much of the variances in GDP could be attributed to the shocks in CO2 and FDI and their impact is predicted to grow stronger in the time path from period 1 to period 10. A shock in CO2 is predicted to cause 18 per cent change to the total changes of GDP in the 1^{st} year and it increases to 46.8 per cent by 4^{th} year. By 10^{th} year, 56.6 per cent of the total variation in GDP is attributed to the shock in CO2. If a shock in FDI is predicted to cause 3.5 per cent to the total changes in GDP in the 1^{st} year, it increases to 7.3 per cent by the 4^{th} year and to 25.4 per cent by the 10^{th} year. Whereas, the changes caused to GDP by its own factors that are linked to exogenous variables have reduced drastically and reached 17.8 per cent by the 10^{th} year.

Table 10. Results of Variance Decompositions

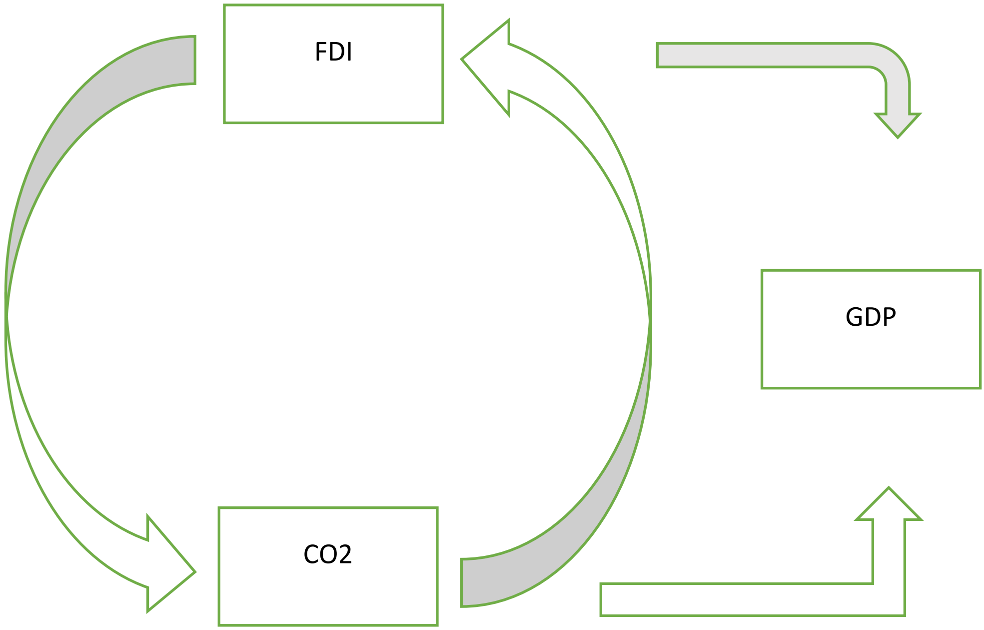
Period	S.E.	$lnCO2_{it}$	$lnFDI_{it}$	$lnGDP_{it}$
Variance Decomposition of $lnCO2_{it}$:				
1	100019.5	100.0000	0.000000	0.000000
4	400723.8	92.36473	6.688651	0.946621
7	704829.5	90.60052	8.434284	0.965193
10	988252.0	89.52439	9.595795	0.879813
Variance Decomposition of $lnFDI_{it}$:				
1	1.70E+10	9.114231	90.88577	0.000000
4	2.91E+10	52.99906	45.56330	1.437635
7	4.17E+10	72.26865	26.01930	1.712049
10	5.34E+10	80.66110	17.46845	1.870451
Variance Decomposition of $lnGDP_{it}$:				
1	3.61E+10	18.04959	3.541957	78.40845
4	1.38E+11	46.89598	7.317044	45.78698
7	2.76E+11	56.69275	17.46061	25.84664
10	4.41E+11	56.69168	25.44926	17.85906

Discussion

The econometric analysis denotes that there exists no association between the variables in the long run. This could be because the carbon emission, in the long run, would depend on several exogenous factors and this is how FDI and economic growth become less focused. However, the results indicate that in the short run, there exists a statistically significant relationship between FDI, CO2 and GDP in BRICS countries. The direction of the flow of causal relationship among them is summarised and presented in Figure 1. The econometric analysis confirms that increasing FDI inflows decrease the carbon emissions in the region in the short run. This could be partially due to the improved capacity of the emerging economies of the BRICS region to absorb innovative and eco-friendly technologies. Parallelly, the countries independently tightened the environmental regulations to the multi-national companies and forcing them to comply with high emission standards. This ensures an inflow of cleaner FDI. The industries in these countries, over the recent decades, are striving towards enhancing the skills of manpower and re-structuring their cost components to enable technological shifts in the operational processes and slant more towards green production. This could be possible only when the industries are aware of the emissions with present technology and the "know-how" of technological shifts in the developed world. The 'awareness' of BRICS countries, their tightened regulations and technique effect collectively would have contributed to the decreasing carbon emissions from the FDI. The panel of BRICS countries, thus, appear to have evidence to support the pollution halo hypothesis in the short run.

Interestingly, reverse causation flowing the direction of carbon emissions to foreign direct investment is also observed in the short run and the impact appears to be positive. It implies that the measures to control carbon emission will not affect the inflow of FDI to the BRICS region. More stringent environmental policies of the governments, and the need for innovations towards green technologies, though they have high-cost implications, the BRICS region continues to attract multi-national companies. BRICS countries are still preferred by the MNCs for higher investment as they still prove to be cost-effective when compared with the developed or western world. This could be attributed to the cheaper manpower and cost-effective raw materials of the BRICS region, on the one hand, and the very stringent environmental regulations of the developed countries, on the other.

It is also observed that FDI and CO2 impact GDP and the relationship appears to be positive. This denotes that increasing FDI and a high level of carbon emission will increase the economic growth of the BRICS countries in the short run. However, we could not find the persistence of such an impact in the long run. This raises the question of whether our finding corroborates with the exogenous growth model (Solow, 1957) as it argued that long-run growth is due to technical progress, not because of infusion of capital or investment. It cannot be discounted that in the short run, FDI results in the 'shared knowledge' (Shahbaz et al., 2015) and inflow of technologies (Mielnik and Goldemberg, 2002) to the host countries in BRICS and that drives economic growth. In view of the economic benefits of FDI, the BRICS countries have introduced policy measures of liberalisation and facilitation and promotion of FDI. These measures attracted multi-national companies to flow more into BRICS countries and invested on more economic ventures that in turn would have accelerated economic growth to the higher levels in the recent decades.



Source: Author.

Figure 1. Flow of relation between FDI, CO2 and GDP in the Panel of BRICS Countries

Conclusion and Policy Implications

This study aimed to evaluate the impact of foreign direct investment on carbon emission in the short run and long run in BRICS countries. The findings indicate that though no long-run association is found between the variables, the FDI decreases the carbon emission in the short run in the study region. It is also found that FDI happens to be a key driving factor of economic growth. Furthermore, the econometric analysis has evidence of unidirectional causality running from carbon emission to economic growth. The results imply that the BRICS countries have improved their capabilities of absorbing the new technologies and control the inflow of environmentally dirty FDI. However, the regulation of carbon emissions seems to affect the economic growth of these countries in the short run. Whereas such an impact may not last in the long run. The regulation of FDI appears to directly affect the economic growth as it might restrict the inflow of foreign capital. The current growth of the BRICS region is attributed to the FDI inflow on a large scale and such investments do not seem to affect the environment. The study, thus, appears to support the pollution halo hypothesis in the short run.

Since multi-national companies directly contribute to economic growth, the BRICS countries must work in the direction of furthermore liberalising the policies to attract

FDI. They may open up different sectors to the FDI that are currently restricted or regulated. However, the national governments in the BRICS region may also regulate the quality of foreign investment so as to ensure that FDI should accentuate environmental pollution. While attracting the FDI, environmental regulations need to be tightened and enforce the same to ensure prompt compliances by the foreign industries. In addition, the governments are expected to work towards creating awareness and enhancing the capabilities of the country to absorb new generation technologies that are more eco-friendly. The government policies in BRICS countries may provide special impetus to industries that shift energy-efficient technologies and less emitting equipment.

Conflict of interest

The author declares no conflict of interest.

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