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Foreign Direct Investment, Trade Openness and Carbon Emission Nexus: Brics Plus Analyses

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ABSTRACT

The international community has been experiencing global warming and climate change, such had a widespread impact on human and natural systems. The global carbon emission has exhibited a rapid increase over the years. Some of the BRICS plus countries are attempting to curb carbon emission, while conserving electricity and preserving economic growth. Hence, sustainable low-carbon economies are being developed by many countries especially as environmental pollution becomes increasingly severe. The study examines the nexus between foreign direct investment (FDI), trade openness, and carbon emissions in BRICS plus countries, namely Brazil, Russia, India, China, South Africa, United Arab Emirates, Iran, and Egypt. Panel econometric methods such as the panel autoregressive distributed lag was conducted on yearly data spanning from 2001 to 2020. FDI and trade openness were found to be positive and significant contributors to carbon emission in the BRICS plus countries in the long run. Based on the outcomes of this study, FDI and trade openness play a significant role in the BRICS plus countries. It is recommended that before the introduction of foreign investors, the environmental impact of FDI should be assessed first.

Keywords: BRICS Plus, Trade Openness, Carbon Emissions, Pollution Haven Hypothesis, Environmental Kuznets Curve, Porter hypothesis
JEL Classifications: C23, F18, F21, Q01, Q54, Q56

1. INTRODUCTION

Carbon emission subject have attracted substantial attention on a global scale given the growing concern with regards to global warming which have made countries to intensify their commitments toward low-carbon economic development (Khan et al., 2021). The foreign direct investment-trade openness-carbon emissions nexus in BRICS Plus countries is characterised by its complexity and the relationship remains contested in the academia (Chhabra et al., 2023). Specifically, trade openness has the potential to adopt cleaner technologies through foreign direct investment (FDI) which lead to the enhancement of environmental quality emanating from knowledge transfer (Rauf et al., 2023). Some scholars are cautious about the effect of trade openness that has the tendency to oscillate drastically since it is mostly dependent on the countries' economic growth path and the quality of institutions which calls for further investigation (Khan et al., 2021). Nevertheless, the interaction of FDI, trade openness and carbon emissions could be affected by the block's population (Apergis et al., 2023) through the scale effect, consumption patterns, urbanisation and resource demand which can influence carbon emissions positively or negatively in transitional economies represented in the BRICS Plus group and simultaneously reinforce the dynamics of development and environmental sustainability (Chhabra et al., 2023).

The investigation of the FDI-trade openness-carbon emission relationship is also underpinned by the fact that the BRICS plus countries represent a significant share of global trade, FDI inflows, and carbon emissions (Rauf et al., 2023). Therefore, untangling such dynamics is of paramount importance in addressing global environmental challenges. BRICS plus countries are endowed with diverse policy approaches, economic structures and development stages which lay an important foundation for interrogating the complex association of FDI, trade openness and environmental outcomes (Tian et al., 2020). Undoubtably, in their endeavour to boost economic growth as the BRICS plus countries, there is still room to synchronise the development goals with environmental sustainability, which can only be realised by conducting more robust empirical analysis in order to contribute to policy (Liu, 2022).

The interrogation of literature has revealed that some studies advocate for the pollution haven hypothesis where developed countries' high pollution industries locate in developing countries (Khan et al., 2020; Yılancı et al., 2020; Ullah et al., 2023), while others found no evidence (Tian et al., 2020; Wen et al., 2022; Boamah et al., 2023; Murshed, 2023). Other studies even suggested the existence of a direct relationship between trade openness and environmental improvement (Shao et al., 2019; Yu et al., 2019; Rahma et al., 2022). Such inconsistency in outcomes further support the need for more efficient empirical investigation in the context of the BRICS Plus countries.

The efficacy of environmental regulations in attracting or deterring polluting industries is central to the current debate. Some scholars maintain that strict regulations are meant to encourage innovation and attract cleaner FDI (Awodumi, 2022; Rauf et al., 2023), while others are of the belief that such strategy may exacerbate carbon leakage (Awodumi, 2022; Rahma et al., 2022; Wen et al., 2022). Hence, quantifying the degree to which FDI and trade contribute to the upgrading of technology and spill over effects that ameliorates C02 emissions remains a challenge (Rauf et al., 2023; Wang et al., 2024). Such may be the case because the conducive environment under which FDI and trade are expected to yield positive environmental spill overs are still incomprehensible (Marques & Caetano, 2020; Awodumi, 2022).

The study aims to interrogate the effect of FDI and trade openness on carbon emissions in order to contribute to policy formulation within the BRICS Plus countries in an endeavour to harmonise the promotion of economic growth and the realisation of environmental sustainability. The paper addresses the question: What role do FDI, and trade openness play towards the mitigation of carbon emission in BRICS Plus countries. Can such a role be leveraged by policy makers to have a clear understanding of the promotion of sustainable development?

The organisation of the rest of the paper is as follows: Literature review is interrogated in Section 2. Thereafter, Section 3 presents the methodology of the study. In addition, Section 4 discusses the results and finally in Section 5 presents the conclusion and policy implications.

2. LITERATURE REVIEW

2.1. Theoretical Literature

The relationship between FDI, trade openness, foreign direct investment, and carbon emission is underpinned by the Pollution Haven Hypothesis (PHH), the Environmental Kuznets Curve (EKC) framework and the Porter Hypothesis. The PHH postulates that trade liberalisation and FDI inflows can result in polluting industries originating from developed countries where strict environmental regulations are enforced will relocate to developing countries with relatively slack standards (Yu, 2019; Zhang & Wang, 2021; Wen et al., 2022). Such a shift is attractive since firms from developed countries will tend to incur lower production costs which accompany less strict environmental compliance and possibly increase carbon emissions in the host countries.

The EKC advocates for an inverted U-shaped relationship between income per capita and environmental degradation (Shao et al., 2019; Pata et al., 2022; Rahma et al., 2022) Initially when industrial activities and resource extraction intensify economic growth of nations is accompanied by environmental degradation. As economies grow eventually, they will be capable to enforce stricter regulations and invest in technological advancements thereby shifting their focus towards cleaner production processes. Hence, beyond a certain income per capita threshold, economic expansion or prosperity will curtail environmental degradation given an increase in demand for environmental quality associated with that growth.

The Porter Hypothesis maintains that strict environmental regulations have a tendency of stimulating innovation and technological advancements which can culminate into improved environmental performance and increased competitiveness (Rauf et al., 2023; Boamah et al., 2023). This implies that well-designed environmental policies can encourage firms to opt for cleaner technologies and practices which can ameliorate the negative environmental effects of trade and FDI. Furthermore, trade and FDI can be used to facilitate the transfer of cleaner technologies and knowledge from developed to developing countries, which potentially lead to carbon emissions reduction. Therefore, multiple theoretical perspective anchors the understanding the relationship FDI-trade openness carbon emissions relationship in BRICS Plus countries in this study.

2.2. Empirical Evidence

It can be highlighted on the onset that empirical studies which interrogated the effect of FDI and trade openness on carbon emissions yielded mixed results possibly due to methodologies applied, data employed, contexts of the respective countries and the transmission mechanisms at play.

2.2.1. FDI and carbon emission

Pata et al. (2022) used the panel ARDL estimator to determine the effects of renewable energy, tourism, trade openness, and foreign direct investment on CO_2 emissions using ASEAN countries data for the years 1995 to 2018. The results revealed that (*i*) tourism and FDI increase CO_2 emissions while real income and trade openness reduce environmental degradation. Given that the long-run income elasticity appeared to be lower than the short-run, such outcome justified EKC hypothesis to be valid. Other studies found that FDI inflows are positively related to CO_2 emissions (Chidiebere-Mark et al., 2022; Pata et al., 2022; Murshed, 2023; Rauf et al., 2023). Such outcomes are in support of the PHH, which suggests that polluting industries from developed countries tend to relocate to developing countries which are seeming associated with less strict environmental standards (Terzi & Pata, 2020; Marques & Caetano, 2020; Singhania & Saini, 2021; Xu & Li, 2021). In the same vein, the evidence from focused manufacturing in China indicated that FDI contributes to increased emissions, especially when environmental regulations are relaxed (Sung et al., 2018).

In contradiction to the PHH, other studies even found no significant relationship between FDI and CO_2 emissions (Mahmood et al., 2020; Gibba et al., 2024) while others reported a negative relationship, indicating that FDI can result in the reduction of carbon emissions (Leitão et ak, 2022; Apergis et al., 2023). Boamah et al. (2023) applied the pooled least squares, fixed and random effects models including General Method of Moments (GMM) on 41 African countries' data for the period 2005 to 2019. The results revealed that both the pollution haven and the halo hypothesis do not hold, despite the fact that FDI was still responsible for the rising and falling CO_2 emission levels.

The empirical evidence of the FDI-carbon emission nexus is summarised by Apergis et al. (2023) who got mixed results when General Method of Moments (GMM) was employed to analyse BRICS data for the period 1993 to 2012. The results showed that FDI inflows from Denmark and the UK intensified carbon emissions in the BRICS community and this confirmed the pollution haven hypothesis. However, FDI inflows from France, Germany and Italy reduced carbon emissions thereby supporting the pollution halo effect. Surprisingly, the same study revealed that an insignificant FDI-carbon emissions relationship still holds for the BRICS countries. Such outcome emanated from FDI inflows obtained from Austria, Finland, Japan, Netherlands, Portugal, and Switzerland. The mixed results from the disaggregated FDI inflows still reinforces the assertion that FDI-carbon emissions nexus is still a contested terrain, not only for the BRICS community but globally and the source of FDI inflows and related covenants matter.

2.2.2. Trade openness and carbon emission

Similarly, the interrogation of empirical literature revealed mixed results with respect to the effect of trade openness on carbon emissions. Also, some studies found that trade openness is positively related with carbon emissions, particularly in developing countries experiencing rapid economic growth and industrialization (Zameer, 2020; Nurgazina et al., 2021; A'yun & Khasanah, 2022; Tichá et al., 2024). In this case scale effect of trade are realised implying that enhanced production and consumption can accelerate carbon emissions while in the process any potential environmental benefits are outweighed. Nevertheless, other scholars found a negative association between trade openness and CO_2 emissions, indicating that trade openness can lead to environmental improvements (Lin, Zhao, Ahmad, Ahmed, Rjoub & Adebayo, 2021; Leitão et al., 2022; Pata et al., 2022; Wang et al., 2024). Such an outcome could be as a result of transfer of cleaner technologies, enforcement of improved environmental regulations through international agreements. Yet, some studies' outcome indicated that the trade openness-carbon emissions relationship could not be justified (Wang & Zhang, 2021).

2.2.3. Causal relationship

Pata et al. (2022) applied the Dumistrescu-Hurlin panel causality test on six ASEAN countries for the years 1995 to 2018 and obtained uni-directional outcome. The Dumistrescu-Hurlin panel causality test results revealed causality existed between CO_2 emissions and FDI, CO_2 emissions and trade openness but moving from CO_2 emissions to the other variables. Also, the results justified causality running from trade openness to FDI. The uni-directional causality running from CO_2 emissions to FDI was supported by Terzi and Pata (2020) who employed the Toda-Yamamoto Augmented Granger causality methodology on Turkish data for the period 1994 to 2011. On the contrary, Tichá et al. (2024)'s panel causality test results showed no causality between CO_2 emissions and trade, and CO_2 emissions and FDI when determining sustainable pathways using CO_2 emissions, FDI, trade and energy in post-Communist economies. Shobande and Asongu (2022) analysed the role of education and ICT in promoting environmental sustainability in Eastern and Southern Africa. The study used the third-generation panel unit root tests which showed that all the variables were stationary after first differencing. The panel cointegration tests revealed cointegration among the variables, after selection of 3 optimal lags. A short and long run association was found, however a slow movement of convergence back to equilibrium was found. The Granger causality results presented a bidirectional Granger causal association between population growth and carbon emissions.

3. RESEARCH METHODOLOGY AND DATA

The study examines the nexus between foreign direct investment, trade openness, and carbon emissions in BRICS plus countries, namely Brazil, Russia, India, China, South Africa, United Arab Emirates, Iran, and Egypt. The research methodology, where econometric methodologies used for empirical analyses are presented in this section.

3.1. Data and Model Specification

Panel secondary data from BRICS plus countries is used from 2001 to 2020. The BRIC plus countries, include, Brazil, Russia, India, China, South Africa, United Arab Emirates, Iran, and Egypt. The data was collected from the World Bank database, which is freely available, for carbon emissions (CO_2 emissions, kt), FDI (Foreign direct investment, net inflows as % of GDP), trade openness (Trade as % of GDP), economic performance (GDP at constant 2015 US$), and population growth (Population, total). All these variables were used in the panel regression model. Carbon emissions (CO_2) is the dependent variable, while FDI and trade openness are the independent variables. Control variables were included, namely, population growth (*POP*), and economic performance. Economic performance was measured by gross domestic product (GDP). An economy of a nation is influenced by the abundance of economic resources, such as the population, human capital, natural resources, infrastructure, and technology (Ridha & Parwanto, 2020). Shahbaz et al. (2018) stipulate that the increasing competition among developing and developed nations has been frequently understood through higher rates of economic growth which comes with increased usage of energy. When country's population grows, while becoming more urbanized and wealthier, the energy demand is expected to increase (Khan et al., 2021).

The regression model is used to assess the impact of FDI and trade openness on Carbon emissions in the BRICS plus countries. In the estimated regression model, Carbon emissions is the function of FDI, trade openness, economic performance, and population growth. The functional form of the model:

Carbon Emissions = f (FDI, Trade openness, Economic performance, Population growth) (1)

Equation 1 can further be expressed as:

$$CO2_{it} = f(FDI_{it}, Trade_{it}, GDP_{it}, GDP^2_{it}, POP_{it} \quad (2)$$

The linearized estimated regression model used in the study to achieve the objective of the study is expressed as follows:

$$LNCO2_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 LNTrade_{it} + \beta_3 LNGDP_{it} + \beta_4 LNGDP^2_{it} + \beta_5 LNPOP_{it} + \mu_{it} \quad (3)$$

In Equation 3 *LNCO2*, *LNTrade, LGDP*, $LNGDP^2$, and *LNPOP* were linearized, unlike FDI. $LNGDP^2$ represents the linearized squared GDP representing economic performance. In the regression model β_0 represents the constant, β_1-β_5 are the population parameters and μ_{it} the error term.

3.2. Estimation Techniques

Econometric techniques such as the cross-section dependence test, slope of heterogeneity test, panel unit root test, lag length criteria, panel cointegration tests, panel autoregressive distributed lag (PARDL), variance decomposition and impulse response function (IRF), and the diagnostic tests are discussed and conducted.

3.2.1. Cross-section dependence test

The cross-section dependence test is conducted in this study to check whether the cross-sections are independent or dependent of each other. Conducting this test will further assist in determining whether the first- or second-generation panel unit root tests should be used to check for stationarity and order of integration. When there is dependence of cross-sections among each other, the second-generation panel unit root tests will be applicable.

3.2.2. Slope of heterogeneity test

Testing for slope homogeneity in panels is also important. In panel data models, it is assumed that the slope coefficients of interest are homogeneous throughout individual units (Pesaran & Yamagata, 2008). The slope homogeneity hypothesis can be evaluated when the cross-section size (*N*) is relatively small and the time series dimension of the panel (*T*) is large. When there is slope heterogeneity, the heterogeneous panel estimation techniques can be conducted.

3.2.3. Panel unit root test

There is a substantial need to check the properties of stationarity among the variables after the analyses of the descriptive statistic. Second generation panel unit root test will be performed to ensure stationarity of the variables. Pesaran (2007) proposes a cross-sectional augmented IPS (CIPS), a modified Im, Pesaran and Shin (IPS) statistics based on the average of the individual cross-sectional augmented Dickey-Fuller (CADF). While panel unit root tests help uncover more information regarding the series, the panel second-generation tests help to deal with any deficiencies of the cross-section's dependence presented by the first-generation panel unit root tests. The assumption of cross-sectional independence, which is eased under the second generation of panel unit root tests, has been questioned in relation to the first generation of panel unit root tests (Albulescu et al., 2016). Pesaran-CIPS second generation panel unit root test is conducted in the study.

3.2.4. Optimum Lag Length Selection

Lag selection is crucial before testing for cointegration. The lag length must be specified in order to fit cointegration in the model (Kilaku et al., 2023). The number of lags that are associated with the lowest value of a criterion must be chosen, although small lag orders generate autocorrelation problems (Ozcicek, 1999; Lütkepohl, 2005). Selection of greater lag order increases the mean square variance of errors (Lütkepohl, 1993). Five criterions are used in the study to determine the appropriate lag, namely, the Sequential modified LR test statistic, Final prediction error (FPE), the Akaike Information Criterion (AIC), Schwarz Information Criterion (SC), and the Hannan-Quinn Criterion (HQ).

3.2.5. Panel cointegration tests

The panel unit root results allow realising the test for panel cointegration between carbon emissions, FDI, trade openness, population growth, and economic performance. The concept of cointegration was introduced by Engle and Granger (1987). Thus, cointegration refers to the long-term relation among variables (Küçükefe, 2020). Variables are considered to be cointegrated if they have a common stochastic trend and such that the linear combination is stationary (Warsono et al., 2020; Arunachalam & Pakkirisamy, 2022). For the purpose of this study the panel Pedroni and Kao cointegration test are performed to explore the long run equilibrium association between the variables.

3.2.6. Panel autoregressive distributed lag

The ARDL method can be applied if the underlying variables are integrated at the level $I(0)$ or first difference $I(1)$. The ARDL offers a number of benefits; it produces results that are robust against the effects of the sample size employed in a model, and it easily regulates the lags and produces unbiased estimates with reliable t-statistics for the long-run model (Mohsin et al., 2019). Thus, the panel ARDL test is conducted to check the kind of long and short run relation between carbon emissions, FDI, trade openness, population growth and economic performance. The ARDL also creates a dynamic unrestricted error correction model (ECM) using the basic linear transformation. The ECM depicts the historical disequilibrium in the current variable as well as the short- and long-term relationship.

3.2.7. Granger causality

The direction of causality will be assessed to check if some of the BRICS plus carbon emissions prosperities are partly Granger caused by its FDI, trade openness, population growth, and economic performance. Thus, the Granger causality has been conducted to evaluate the causality of the proposed variables

(Granger, 1969). Warsono et al. (2020) asserts that the notion of the causality test is that the present is caused by the past, not vice-versa. If Y_{it} causes Y_{2t} then it is assumed that past values of Y_{1t} will be useful in predicting present Y_{1t} (Sampson, 2001; Warsono et al., 2020).

3.2.8. Variance decomposition and impulse response functions

The variance decomposition test shows the change in the endogenous variable that occurs due to its own impulse. It further shows the change that occurs due to shocks to other endogenous variables (Khalid et al., 2021; Kelesbayev et al., 2022). In order to visually inspect the dynamic effects of all the endogenous variables on carbon emissions, the impulse response function (IRF) analysis is conducted in the study. Kelesbayev et al. (2022) refers to the IRF as the moving average coefficient that measures a variable response to a certain shock over time.

3.2.9. Diagnostic test

The Jarque-Bera normality test is used to test for normality of residual of the multivariate model. The Jarque-Bera normality test has a Chi-square χ^2 distribution with two degrees of freedom (Warsono et al., 2020). Normal distribution can be evaluated using two primary techniques, namely, numerical and graphical. The graphical representation of the normality test will be conducted and presented in this study. One benefit of graphical interpretation is that it can be used to assess normality in circumstances where numerical tests may be over or under sensitive (Mishra et al., 2019).

4. RESULTS AND DISCUSSION

The findings of the study are presented and discussed in the following section.

4.1. Cross-Section Dependence Results

The null hypothesis (H_0) is that there is no cross-section dependence (correlation) in the residuals, while the alternative hypothesis (H_1) proves cross-section dependence in the residuals (Table 1).

The Breusch-Pagan LM and Breusch scaled LM have a probability value (P-value) of less than 0.05 level of significance. Pesaran CD presents a P-value of 0.7178, that is greater than the 0.05 level of significance. It can be concluded based on the Breusch-Pagan LM and Breusch scaled LM that the null hypothesis is rejected, and the alternative hypothesis accepted at 5% significance level as there is presence of cross-sectional dependence. These results approve the implementation of the second-generation panel unit root tests.

4.2. Slope of Heterogeneity Results

The hypothesis rules: (H_0 - slope coefficients are homogenous and H_1 - slope of the coefficients are not homogenous but heterogenous.

It is evident from Table 2 slope heterogeneity findings that the P-values a below the 5% significance, allowing for approval of H_1 and rejection of H_0.It can be concluded from that the slope of the countries are not homogeneous but heterogenous. Slope heterogeneity is present.

4.3. Panel Unit Root Results

The second-generation panel unit root test, Pesaran-CIPS test, was conducted to test the stationarity of the variables. The panel unit root tests tested the null hypothesis against the alternative hypothesis of no unit root. The hypothesis rules: H_0 is that the variable is non-stationary and has a unit root; and H_1 is that the series is stationary and has no unit root. Table 3 shows the panel unit root results.

From the panel unit root results, carbon emissions, economic performance, squared economic performance, FDI and population growth were found to be stationary at levels. While trade openness had to be differenced once to induce stationarity. This implies that the null hypothesis of nonstationary is rejected at various levels of significance and the alternative hypothesis is accepted as there is presence of stationarity in the series. If the variable is not stationary at levels, the option is transformation, implying taking the first difference of the variable (Brooks, 2019).

4.4. Optimum Lag Selection Results

The variables have become stationary, indicating that testing for cointegration is important. However, before proceeding to check for cointegration of the series, lag selection is crucial. Specification of the lag length is important, in order to be able to examine the number of cointegration ranks. The lag length findings are shown in Table 4.

Several criterions are applied in the determination of the lag length statistic selection. It is evident from the results in Table 4 that the lag length selected is four lags as revealed by the AIC. The AIC criterion was selected as it shows the lowest value (−16.40865*) amongst other criterions.

Table 1: Residual cross-section dependence results

Test	Statistic	d.f	Prob.
Breusch-Pagan LM	53.70373	28	0.0024
Breusch scaled LM	3.434805		0.0006
Pesaran CD	−0.361340		0.7178

Source: Authors' own computations

Table 2: Slope heterogeneity summary

	Delta	P-value
	8.690	0.000
Adj.	10.779	0.000

Source: Authors' own computations

Table 3: Panel unit root summary

Variables	Pesaran-CIPS (test statistic)	Critical values (levels-CIPS)		
	Constant	1%	5%	10%
$LNCO2_{it}$	−3.05030***	−2.61	−2.35	−2.21
$LGDP_{it}$	−2.24022*	−2.61	−2.35	−2.21
$LNGDP^2_{it}$	−2.25830*	−2.61	−2.35	−2.21
FDI_{it}	−3.18448***	−2.61	−2.35	−2.21
$LNTrade_{it}$	−1.76068	−2.61	−2.35	−2.21
$D (LNTrade_{it})$	−3.33760***	−2.62	−2.35	−2.21
$LNPOP_{it}$	−3.05080***	−2.61	−2.35	−2.21

*'/'**'/'***' represents the rejection of the H_0 at the 10%, 5% and 1% levels of significance

Table 4: Lag length summary

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−876.7140	NA	0.098731	14.71190	14.85127	14.76850
1	867.9070	3285.703	4.24e-14	−13.76512	−12.78949	−13.36891
2	1016.060	264.2067	6.57e-15	−15.63434	−13.82247*	−14.89853
3	1083.626	113.7351	3.92e-15	−16.16043	−13.51231	−15.08502*
4	1134.519	80.58101*	3.13e-15*	−16.40865*	−12.92428	−14.99363
5	1158.020	34.86020	3.99e-15	−16.20034	−11.87972	−14.44572

Source: Authors' own computations. *Is the order of lag chosen by the criterion

4.5. Panel Cointegration Results

The optimal lag of four was selected and used for the panel cointegration tests. The panel cointegration results presented are based on the panel Pedroni and Kao cointegration results.

The panel Pedroni cointegration findings provided in Table 5, reveal that indeed there is cointegration as reflected by the group ADF-Statistic P-value (0.0443<0.05). Thus, the null hypothesis of no cointegration is rejected and the alternative hypothesis that there exists cointegration is accepted.

The panel Kao cointegration results show an ADF test statistic of −3.026323, with a P = 0.0012 which is <0.01 and 0.05 significance levels (Table 6). Based on the panel Kao and Pedroni cointegration findings it can be concluded that cointegration exists among the variables.

4.6. Panel Autoregressive Distributed Lag Results

Stationarity and cointegration in the model exist, as indicated by the panel unit root and cointegration tests. Including existence of long run equilibrium relationship among the variables. The panel ARDL is applied to estimate the long-run elasticities. The long- and short-run elasticities are presented in Table 7.

The long run elasticity equation is presented in equation 4:

$$LNCO2_{it} = \beta_0 - 2.457728LNGDP_{it} + 0.045097LNGDP^2_{it} + 0.021867FDI_{it} + 0.550005LNTrade_{it} + 0.843026LNPOP_{it} + \mu it \quad (4)$$

Equation 4 shows that squared economic performance, FDI, trade openness and population growth lead to an increase in carbon emission as they have a positive and statistically significant impact on carbon emission. Unlike economic performance which leads to a decline in carbon emissions. Thus, a 10% increase in squared economic performance results in 0.4% increase in carbon emissions; while in FDI that will lead to 0.2% increase in carbon emissions, which is a small increase. This finding is supported by Chidiebere-Mark et al. (2022), Pata et al. (2022), Murshed (2023), and Rauf et al. (2023), that FDI inflows are positively related to carbon emissions. Furthermore, that such a relationship is linked to the PHH. However, in contradiction with Mahmood et al. (2020), Leitão et al. (2022), Apergis et al. (2023), and Gibba et al (2024) study. When population growth increases by 10%, it is expected that carbon emission will go up by 8.4%. Carbon emission will also be expected to increase by 5.5% when trade openness increases by 10%. The positive relation between trade openness is supported by the study of Zameer (2020), Nurgazina et al. (2021), A'yun and Khasanah (2022), and Tichá et al. (2024). Unlike the findings of Lin et al. (2021), Leitão et al. (2022) Pata et al. (2022), and Wang et al. (2024). Economic performance possessing a negative sign and shows that if it was to increase by 10%, carbon emissions will be estimated to decline by 24% in the selected BRICS plus countries. All the variables impact are found to be statistically significant based on the p-values.

In the short run, trade openness positively affects carbon emissions, which is statistically insignificant based on the p-value. The findings prove that there is existence of short and long run relationship among the variables. However, looking at the

Table 5: Panel Pedroni cointegration

	Statistic	Prob.	Weighted statistic	Prob.
Panel v-statistic	−2.098981	0.9821	−2.412166	0.9921
Panel rho-statistic	3.297608	0.9995	3.357449	0.9996
Panel PP-statistic	1.246631	0.8937	0.837161	0.7987
Panel ADF-statistic	0.683487	0.7529	−0.775726	0.2190
Alternative hypothesis: individual AR coefs. (Between-dimension)				
	Statistic	**Prob.**		
Group rho-Statistic	4.421387	1.0000		
Group PP-Statistic	0.283521	0.6116		
Group ADF-Statistic	−1.702480	0.0443		

Source: Authors' own computations

Table 6: Panel Kao cointegration

ADF	t-Statistic	Prob.
	−3.026323	**0.0012**
Residual variance	0.001229	
HAC variance	0.001731	

Source: Authors' own computations

Table 7: Long run and short run elasticities

Variables	Coefficients	Standard error	t-Statistic	Prob.
Long Run				
LNGDP	−2.457728	1.213162	−2.025886	0.0447
$LNGDP^2$	0.045097	0.021012	2.146190	0.0336
FDI	0.021867	0.005743	3.807546	0.0002
LNTRADE	0.550005	0.063155	8.708833	0.0000
LNPOP	0.843026	0.048606	17.34407	0.0000
C	26.66886	16.72006	1.595022	0.1130
Short Run				
D (LNGDP)	36.36724	33.34033	1.090788	0.2773
D ($LNGDP^2$)	−0.674957	0.625343	−1.079338	0.2824
D (LNTRADE)	0.032905	0.098422	0.334328	0.7387
D (LNPOP)	−10.61797	6.643116	−1.598341	0.1123
COINTEQ	−0.302469	0.147876	−2.045426	0.0428

Source: Authors' own computations

estimated speed of adjustment, it is found to be -0.302469 and with a P = 0.0428 that is <0.05 significance level. Based on this finding it can be concluded that the convergence speed is relatively low at 30%, below 50%, indicating there might be a delay in the convergence of the variable to the long-term mean.

4.7. Panel Granger Causality Results

The panel causality test approach was performed to identity the direction of causality between carbon emissions, FDI, trade openness, population growth, and economic performance. The results are shown in Table 8.

The Granger causality results show that economic performance and carbon emission do not induce or cause each other as both P-values (0.2069 and 0.4510) are greater than the 5% significance level. It can be concluded that the null hypothesis is accepted as carbon emissions is not induced by economic performance, vice versa. Like the other variables, squared economic performance, FDI, trade openness, and population growth do not Granger cause carbon emissions in the selected BRICS plus countries, vice versa. This implies that the null hypothesis cannot be rejected, as there is no Granger causal association between those variables. Tichá et al. (2024) also found no causality between carbon emissions and trade, and carbon emissions and FDI. On the contrary, Pata et al. (2022) found unidirectional causality present from carbon emissions to FDI, and from carbon emissions to trade openness. In the study of Shobande and Asongu (2022) a bidirectional causal relationship between carbon emissions and population was found. This revealed that proportionate growth in population contributes to climate crisis.

The results further depicts that there are few one-way Granger relationships at the significance level of 5%. Especially from economic performance to population growth; squared economic performance to population growth; and FDI to population growth. Thus, there is a causality flow running from economic performance to population growth; squared economic performance to population growth; and FDI to population growth. In this case the null hypothesis is rejected at 5% significance level. In other words, there is no Granger causality of population growth to economic performance; and population growth to FDI.

4.8. Variance Decomposition and Impulse Response Function Results

The variance decomposition results are presented first, followed by the IRF results (Table 9).

It is evident from the variance decomposition results that in the short run (period 1), 100% of the forecast error variance decomposition in carbon emission is explained by the variable itself. This implies that other endogenous factors have a strong exogenous effect on carbon emissions. In the long run (period 10), it is 87% of the forecast error variance decomposition. The influence of economic performance on carbon emissions is gradually increasing from 0.5% to 5.5% over the years. The influence of FDI on carbon emission steadily increases from 0.01% to 1.5% over the periods. The influence of trade openness on carbon emission gradually rises from 0.03% to 0.4% towards the long run. The influence of population growth on carbon emissions in BRICS plus countries is significant, and its influence rises from

Table 8: Panel Granger causality

Null Hypothesis (H_0)	F-Statistic	P-value	Conclusion
LNGDP does not Granger Cause LNCO2	1.59369	0.2069	Do not reject H_0
LNCO2 does not Granger Cause LNGDP	0.80086	0.4510	Do not reject H_0
LNGDP^2 does not Granger Cause LNC02	1.67883	0.1904	Do not reject H_0
LNC02 does not Granger Cause LNGDP^2	0.79170	0.4551	Do not reject H_0
FDI does not Granger Cause LNC02	0.31132	0.7330	Do not reject H_0
LNC02 does not Granger Cause FDI	1.48618	0.2298	Do not reject H_0
LNTRADE does not Granger Cause LNC02	0.07259	0.9300	Do not reject H_0
LNC02 does not Granger Cause LNTRADE	2.63527	0.0753	Do not reject H_0
LNPOP does not Granger Cause LNC02	2.90357	0.0582	Do not reject H_0
LNC02 does not Granger Cause LNPOP	0.56486	0.5697	Do not reject H_0
FDI does not Granger Cause LNGDP	0.20786	0.8126	Do not reject H_0
LNGDP does not Granger Cause FDI	0.15975	0.8525	Do not reject H_0
LNTRADE does not Granger Cause LNGDP	0.68419	0.5062	Do not reject H_0
LNGDP does not Granger Cause LNTRADE	1.95662	0.1452	Do not reject H_0
LNPOP does not Granger Cause LNGDP	1.57159	0.2114	Do not reject H_0
LNGDP does not Granger Cause LNPOP	6.79629	0.0015	Reject H_0
FDI does not Granger Cause LNGDP^2	0.16754	0.8459	Do not reject H_0
does not Granger Cause FDI	0.15201	0.8591	Do not reject H_0
LNTRADE does not Granger Cause	0.70857	0.4941	Do not reject H_0
does not Granger Cause LNTRADE	1.91355	0.1514	Do not reject H_0
LNPOP does not Granger Cause LNGDP^2	1.47135	0.2332	Do not reject H_0
LNGDP^2 does not Granger Cause LNPOP	6.30741	0.0024	Reject H_0
LNTRADE does not Granger Cause FDI	1.20567	0.3026	Do not reject H_0
FDI does not Granger Cause LNTRADE	1.18522	0.3087	Do not reject H_0
LNPOP does not Granger Cause FDI	0.72215	0.4875	Do not reject H_0
FDI does not Granger Cause LNPOP	7.83614	0.0006	Reject H_0
LNPOP does not Granger Cause LNTRADE	1.83875	0.1629	Do not reject H_0
LNTRADE does not Granger Cause LNPOP	0.47732	0.6215	Do not reject H_0

Source: Authors' own computations. Observations 144.

0.2% to 4.76% over the periods. Squared economic performance also has an impact on carbon emissions, and it shows that the impact is rising from 0.1% to 1.1% as we move towards the long run. The IRF results are discussed next.

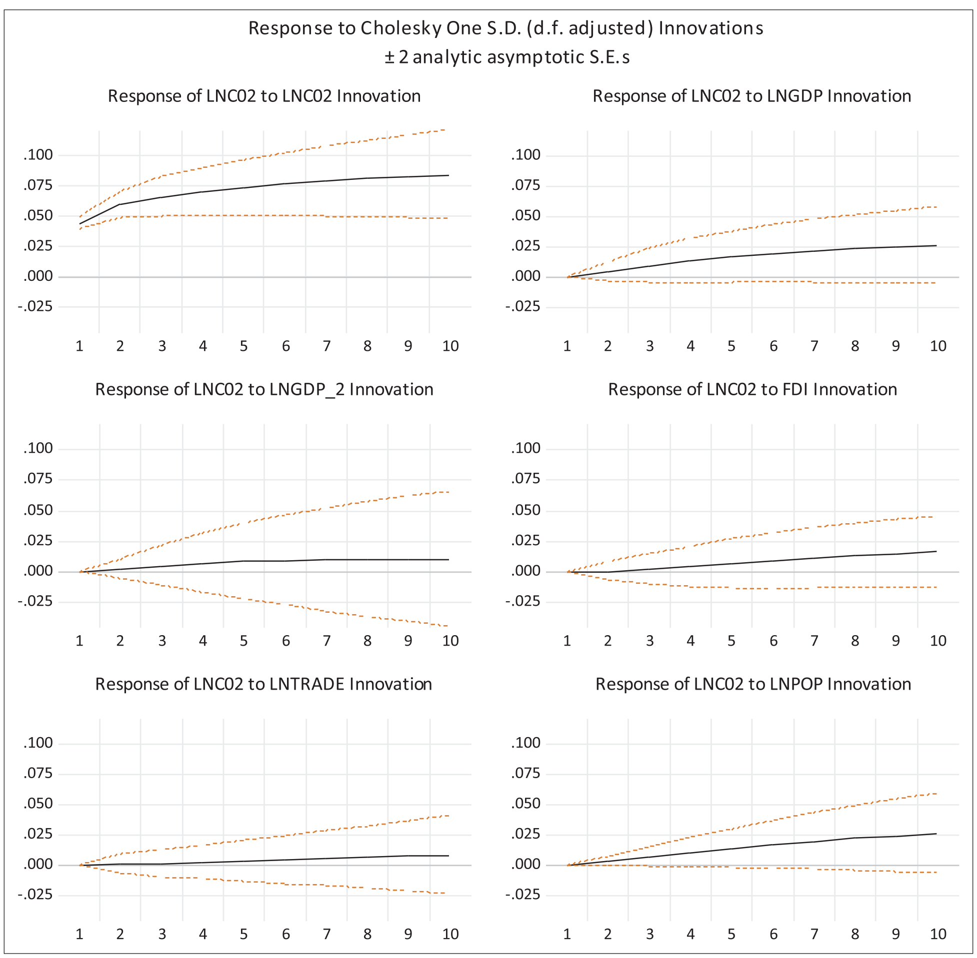
The dynamic effects of structural shocks on the endogenous variables used are traced by the IRF (Khalid et al., 2021). Thus, the dynamic effects of the different shocks are presented is presented in Figure 1.

Table 9: Variance decomposition findings

Period	S.E.	LNCO2	LNGDP	$LNGDP^2$	FDI	LNTRADE	LNPOP
1	0.045152	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
		(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
2	0.075380	99.19513	0.456602	0.110447	0.006308	0.028423	0.203094
		(1.06951)	(0.76171)	(0.49894)	(0.42212)	(0.33658)	(0.25923)
3	0.101511	97.73361	1.219409	0.313799	0.047120	0.053311	0.632755
		(2.39992)	(1.71592)	(1.42142)	(0.70910)	(0.59408)	(0.77397)
4	0.125328	96.01169	2.034303	0.534555	0.145555	0.081803	1.192090
		(3.77587)	(2.57414)	(2.47503)	(1.03879)	(0.82163)	(1.41661)
5	0.147756	94.23414	2.803156	0.726942	0.308410	0.118208	1.809150
		(5.09909)	(3.30174)	(3.51549)	(1.40681)	(1.04701)	(2.09957)
6	0.169248	92.50508	3.494012	0.874171	0.524487	0.163806	2.438446
		(6.33363)	(3.91146)	(4.48972)	(1.76542)	(1.28078)	(2.77404)
7	0.190003	90.87521	4.100832	0.976993	0.773225	0.218351	3.055388
		(7.46386)	(4.42218)	(5.37960)	(2.09300)	(1.52219)	(3.41804)
8	0.210107	89.36434	4.627889	1.043341	1.034378	0.280844	3.649212
		(8.48275)	(4.85176)	(6.17889)	(2.38439)	(1.77097)	(4.02497)
9	0.229595	87.97421	5.083420	1.082424	1.293055	0.349929	4.216958
		(9.39084)	(5.21548)	(6.88656)	(2.64229)	(2.03024)	(4.59525)
10	0.248491	86.69704	5.476758	1.102275	1.540442	0.424106	4.759383
		(10.1943)	(5.52584)	(7.50508)	(2.87193)	(2.30483)	(5.13175)

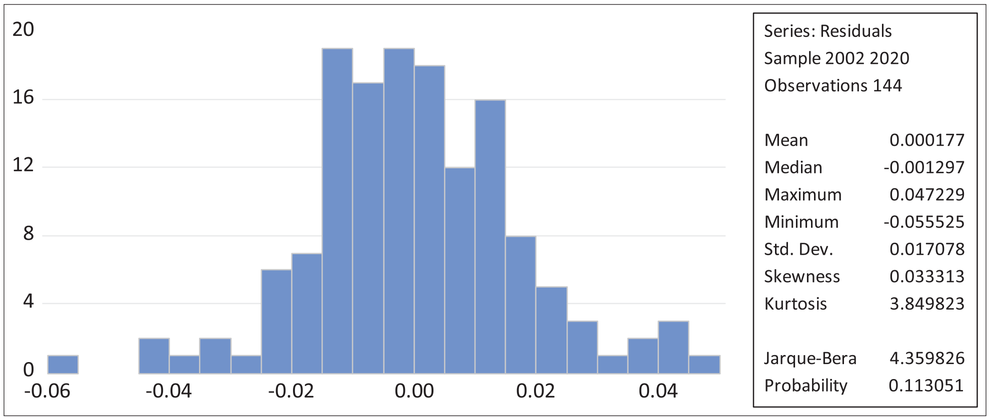
Source : Authors' own computations

Figure 1: Impulse response function for shock in variable LNCO2



Source: Authors' own computations

Figure 2: Jarque-Bera normality test



Source: Authors' own computations

The IRF results presented in figure show that, a one SD innovation to $LNCO_2$ will initially has a positive influence on $LNCO_2$ from period 1 to 10. The response rises until period 10 where it reaches the maximum point of the curve. The response of $LNCO_2$ to $LNCO_2$ shows that shocks to $LNCO_2$ will have a positive impact on $LNCO_2$ both in the short and long run. A one SD impulse to $LNGDP^2$ will increase $LNCO_2$, the response gradually rises from period 1 to 8, beyond period 8 the curve gradually rises towards a steady-state line. This implies innovations to $LNGDP^2$ will have a positive impact on $LNCO_2$ in the short run as well as in the long run.

A one SD innovation of $LNCO_2$ to FDI from period 1 to 3 is very low, however, stays in the positive region as the curve lies above the zero-line. Beyond period 3, the curve starts increasing towards period 10. The slope of the curve shows that shocks to FDI will have positive impact on $LNCO_2$ in the short-and long-term. One SD innovation of $LNCO_2$ to LNTRADE initially hits a steady-state value in the 1st and 2nd period, and then slowly starts to increase until it achieves a maximum point. The response of $LNCO_2$ to LNTRADE indicates that shocks to trade openness will have a completely positive influence on carbon emission in the BRICS plus countries. A one SD impulse to LNPOP initially increases $LNCO_2$ up to the 10th period. Shocks to population growth will positively influence carbon emissions in the short and long run. Furthermore, one SD impulse to LNEI increases $LNCO_2$ up to the 10th period.

It is stipulated by Warsono et al. (2020) that the response of a variable to shock other variables disappears when the IRF graph moves towards the equilibrium point or back to the line of the original equilibrium (zero). This kind of shock further has no permanent effect on the variable.

4.9. Diagnostic Test Results

Residuals in econometric analyses are usually expected to reflect normal distribution. Hence, after regression the Jarque-Bera test is conducted to assess the normality in the model (Figure 2).

The Kurtosis is found to be 3.849823 which is greater than 3. Based on the Kurtosis the residuals are normally distributed. There is regular distribution of the residuals.

5. CONCLUSION AND RECOMMENDATIONS

Based on the panel data of the BRICS plus countries, from 2001 to 2020, this study has explored and examined the nexus between FDI, trade openness, and carbon emissions in BRICS plus countries, namely Brazil, Russia, India, China, South Africa, United Arab Emirates, Iran, and Egypt. FDI and trade openness were used in the model as independent variables, while the dependent variable was carbon emission. Control variables were also added, namely population growth and economic performance. Existence of a cointegrating relation and stationarity was found, the study further concluded that in the long run FDI and trade openness have a positive, direct, and statistically significant influence on carbon emissions in BRICS plus countries. This clarifies that when FDI, and trade openness increases, it results in an increase in carbon emission. However, the different factors used in the study are evidently showing heterogenous effects on carbon emission. Some of the findings are linked to the Kuznets hypothesis, pollution haven hypothesis and the Porter hypothesis.

It is recommended based on the findings that before the introduction of foreign investors, the impact that FDI will have on the environment should be assessed first by host countries. Furthermore, with increasing economic growth and population size some countries with high emission will benefit. High rates of economic growth and improved population size could result in a reduction in carbon emissions. This study contributes to literature as it analyses the BRICS plus countries carbon emissions on how it is impacted by factors such as FDI and trade openness, which is not covered in most studies or literature.

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