RESEARCH ARTICLE

Do trade openness and institutional quality contribute to carbon emission reduction? Evidence from BRICS countries

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Abstract

The quest for rapid economic development by modern nations has led to an unprecedented increase in carbon emissions. Knowledge spillovers from increasing trade activities and effective environmental regulations have been suggested as viable means of controlling these rising emissions. To that end, this study aims to examine the impact 'trade openness' and 'institutional quality' had on CO_2 emissions in BRICS countries from 1991 to 2019. Three indices, namely, institutional quality, political stability, and political efficiency, are constructed to measure the overall institutional impact on emissions. A single indicator analysis is conducted for a deeper investigation of each index component. Given the existence of cross-sectional dependence among variables, the study uses the modern dynamic common correlated effects (DCCE) method to estimate their long-run relationships. Confirming the pollution haven hypothesis, the findings reveal that 'trade openness' indeed is a cause of environmental degradation in the BRICS nations. Through reduced corruption, improved political stability, bureaucratic accountability, and better law and order, 'institutional quality' is found to be contributing positively to environmental sustainability. It is also confirmed that renewable energy sources do have a positive environmental impact; however, it is found to be insufficient to offset the adverse effects caused by non-renewable sources. Based on the results, it is advised that BRICS countries should strengthen their cooperation with developed countries so that positive spillovers of green technologies may occur. Moreover, renewable resources should be aligned with firms' profits so that sustainable production practices can become the new norm.

Keywords CO_2 emissions · Trade openness · Institutional quality · BRICS · DCCE

Introduction

Over the last few decades, human activities have led to a drastic increase in the global emissions of greenhouse gases (GHGs), causing unprecedented environmental degradation. The rapid increase in carbon dioxide emissions (CO_2), one of the main GHGs, has piqued the interest of many researchers

and experts worldwide. Since the 1900s, in order to meet energy consumption requirements, the combustion of coal and fossil fuels has dramatically accelerated global carbon emissions. In the last three decades, total global CO_2 emissions have enormously increased by almost 63.91 percent till 2019 (International Energy Agency (IEA) 2022). Besides, the COVID-19 crisis has increased carbon emissions even further by forcing power plants to use coal and fossil fuels at full blast to meet the elevated energy consumption requirements and restore economic growth to its pre-pandemic pace. This has resulted in a strong rebound of carbon emissions, with the largest increase ever seen in global history, of more than 2 billion tonnes (International Energy Agency (IEA) 2022).

Numerous economic variables influence such emissions, where trade openness, institutional quality, economic growth, renewable energy consumption, and non-renewable energy consumption are the most prominent ones. Trade openness influences carbon emissions through

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scale, composition, and technology effects. If the combined technology and composition effects (oriented towards clean goods) outweigh the scale effect, trade openness improves the environmental quality (Fakher 2019). In contrast, manufacturing goods composition oriented towards polluting products tends to deteriorate environmental quality. Therefore, no theoretical consensus can be achieved. For this purpose, several studies investigated the relationship between trade openness and carbon emissions on the empirical front, but due to mixed results, no clear consensus can be drawn. For instance, some studies show that trade openness upsurges carbon emissions and degrades the quality of the environment (Kuik and Gerlagh 2003; Dogan and Seker 2016; Ertugrul et al. 2016; Le et al. 2016). These studies argue that strict environmental regulations in developed countries cause pollution-intensive industries to relocate to developing countries, transforming developing countries into 'pollution havens' via composition and scale effect. On the contrary, Omri (2013), Yu et al. (2019), Dauda et al. (2021), and Khan et al. (2022) argue that the positive effects of trade openness through knowledge and technology spillovers improve environment quality. However, Sun et al. (2019) argue that the impact of trade openness on carbon emissions is conditional to the country's economic growth. Thus, no universal relationship exists between trade openness and carbon emissions which motivates further investigation into the effects of trade openness on the environment.

Apart from trade openness, institutions have been one of the primary drivers in mitigating carbon emissions and their economic and social consequences. Through stringent and effective environmental policy choices, higher-quality institutions promote renewable energy that aids in developing green technologies and encourages knowledge spillovers, thereby reducing environmental degradation. The empirical evidence confirms that effective institutions create environment-conducive policies that reduce carbon emissions and promote a cleaner environment (Ali et al. 2019; Salman et al. 2019; Shahbaz et al. 2019; Wawrzyniak and Doryń 2020; Haldar and Sethi 2021; Khan and Rana 2021). On the other hand, poor institutional quality characterised by corruption, disrupted law and order, and existing internal and external conflicts increase environmental degradation (Abid 2016; Azam et al. 2021; Teng et al. 2021). This obstructs the remodeling of production activities away from renewable resources and creates barriers to achieving sustainable development. Not only does it have an impact on environmental quality, but it also increases both economic and environmental costs. Ineffective energy planning and policy-making weaken the institutions and make combating rising carbon emissions difficult. This increases the likelihood of political instabilities and inefficiencies that creates lax environmental regulations. Therefore, it will not be wrong to state that, in association with carbon emissions, the impact of institutional quality remains unclear for developing countries, particularly BRICS. This makes it hard to answer whether strong institutions contribute to lower carbon emissions. Is the institutional quality in these countries strong enough to effectively implement environmental policies?

This ambiguity pertaining to the trade openness-emissions nexus and institutions-emissions nexus captivates the interest of many researchers, particularly in the case of developing countries and groups such as BRICS. Most of the literature on environmental issues in BRICS countries emphasises the potential impact and causal dynamics of energy consumption, economic growth, innovations, and foreign direct investments on the ecological footprints (Sebri and Ben-Salha 2014; Danish et al. 2019; Khattak et al. 2020; Wang et al. 2021). However, only a handful of studies have looked into the impact of institutional quality on carbon. This motivates a deeper dive into the effects of institutional quality in BRICS countries. With a 24 percent share of total global GDP, the BRICS are among the world's largest and fastest-growing developing economies, driving global economic growth. BRICS has experienced unprecedented growth in terms of GDP and trade in recent years, accounting for nearly 16 percent of total international trade. Furthermore, in 2019, the majority of the BRICS countries were identified among the top 10 CO_2 emitters in the world (as shown in Fig. 1). BRICS accounted for nearly 38.25 percent of global primary energy consumption, with China acing the race with a total primary energy consumption of 24.27 percent. With one-fourth of global growth and one-third of global energy consumption, the BRICS countries play an important role in determining the global implications of climate-related policies. This enlists these countries among the highest polluting countries worldwide.

Against the above backdrop, this study presents fresh evidence for the impact of trade openness and institutions on CO_2 emissions in BRICS countries. To the best of the authors' knowledge, very few studies have examined the influence of institutions on environmental degradation in BRICS. However, these studies either evaluated the impact of institutions using the governance index as a whole or focused on only one element, such as corruption or the legal and regulatory framework. None of the studies investigated the segregated impact of governance indicators, especially for BRICS. Therefore, rather than focusing on just one facet of an institution's quality, it's vital to dissect the effect of all the variables separately for a more complete view (Egbetokun et al. 2020; Haldar and Sethi 2021; Chaudhry et al. 2022). Hence, this study contributes by conducting a single indicator analysis to examine the impact of each indicator of institutional quality separately on carbon emissions in BRICS countries. It will show if openness and democracy electorate pressure the government. Second, it will assess whether democratic nations are more likely to deliver public

Fig. 1 Worldwide carbon emissions in 2019. Source: Author's computation

Carbon Emmissions 2019
High
Mid
Low
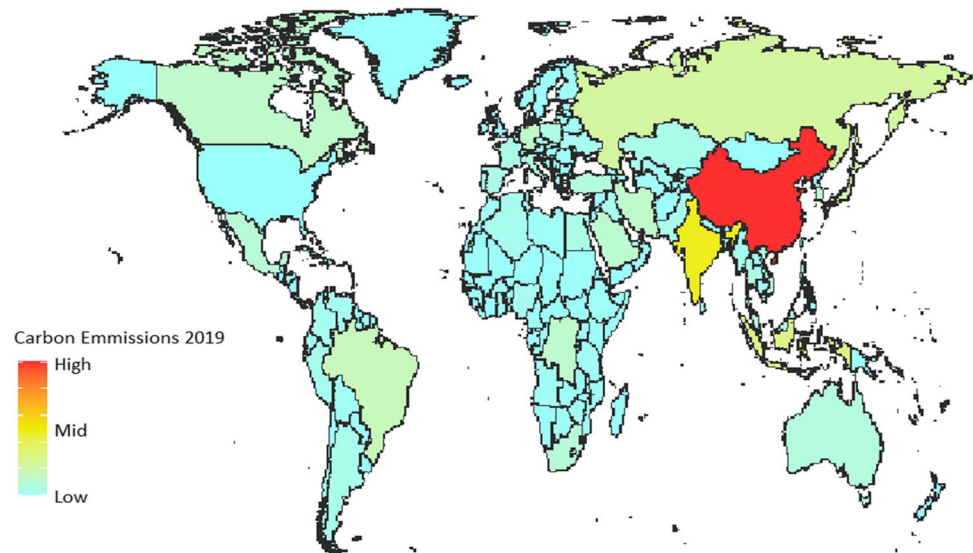
goods like environmental protection (Hughes and Lipscy 2013). It will also improve policy implications, particularly by identifying which institutional indicator reduces sustainability in these countries. Furthermore, this study investigates the vital relationship between trade openness and CO_2 emissions because, via its technological effect, trade has introduced the economies to innovative environmental cannons, effectively improving the environmental quality by reducing the emissions. On the contrary, its impact in developing countries is still in ambiguity and lacks unanimity Dou et al. (2021), Cai et al. (2018), Yu et al. (2019), Sun et al. (2019). Therefore, it is essential to analyse the impact of trade openness on the environment. To fill the void, this study contributes by analysing the impact of trade openness on carbon emissions for BRICS. In addition, most of the established results by the previous studies assume unrelated error terms, and thereby, no cross-sectional dependence is considered (Egbetokun et al. 2020; Hassan et al. 2020a; Khan et al. 2022). Due to rising mutual dependence among the countries, it is impractical in today's real world to ignore the issues of cross-sectional dependence, heterogeneity, and endogeneity. This makes it essential to consider these issues, as ignoring them may lead to inaccurate and biased results. Therefore, this study employs a novel DCCE approach that addresses cross-sectional dependence, endogeneity, and heterogeneity among countries. Lastly, the study contributes to the existing literature by analysing the synchronisation hypotheses among trade openness, institutional quality, economic growth, renewable energy consumption, non-renewable energy consumption, and carbon emissions.

The rest of the paper is structured as follows: "Review of literature" presents a brief review of the literature on the relationship between all the respective variables, "Data and methodology" provides an outline of the data and empirical

strategy, "Results and discussions" exhibits the analysis and discussion of the obtained outcomes, and finally, "Conclusion" reports the conclusions and policy implication.

Review of literature

Trade openness and CO_2 emissions

The ever-debated relationship between trade and environment has allured the attention of many scholars over a long period. The disaggregated impact of trade openness on the environment can be hypothesised through three key channels—scale, technology, and composition. The scale effect exhibits that an upsurge in energy consumption with trade for higher production causes higher CO_2 emissions. The technological effect improves production techniques and innovations via trade that induces energy efficiency and a cleaner environment. The composition effect mentions the re-assignment of resources and traded commodities either towards pollution-intensive or environment-friendly goods. In addition, it is essential to reserve special attention for the leakage phenomenon while assessing the impact of trade on the environment. The leakage phenomenon is a process where GHG emissions are reduced by shifting the pollution-intensive production activities from developed to developing countries (Kuik and Gerlagh 2003; Dogan and Seker 2016; Ertugrul et al. 2016). Due to the strict environmental regulations, the pollution-intensive industries refuge their location that upsurges the pollution and gives rise to the pollution haven hypothesis. In this context, Cai et al. (2018) highlighted that China is a host to the pollution of almost 22 developed countries, while it has transformed nearly 19 underdeveloped countries into pollution havens. Le et al.

(2016) emphasised that the trade may degrade the quality of the environment, but its effect may vary in different regions. Moreover, Ertugrul et al. (2016) found that trade openness and energy consumption are one of the main determinants of carbon emissions that result in an upsurged pollution in the top ten developing countries. Similarly, Zhang et al. (2017) examined the link in ten countries and found that trade openness negatively influences carbon emissions. In support, a recent study by Dou et al. (2021) for China-Japan-ROK FTA countries found that trade surges the GHGs in these countries, where the signing of the FTA agreement may reduce this upsurging effect. Moreover, Omri (2013) studied the trade openness and carbon emission nexus in 14 North American and Middle East countries and highlighted an inverse impact of trade openness on GHG. In recent evidence by Dauda et al. (2021) and Khan et al. (2022), and Appiah et al. (2022), the studies found a significant negative impact of trade on environmental sustainability. On the other hand, Yu et al. (2019) indicated that while trade openness increases emissions overall, it has a double-edged effect by decreasing them indirectly in CIS countries. While in Belt and Road countries, Sun et al. (2019) found both positive and negative impacts of trade on emission conditional to the varying country samples. As a result, no consensus can be drawn on the effects of trade openness on carbon emissions.

Institutions and CO_2 emissions

With the increasing economic growth, the impact of the quality of institutions on environmental quality has become mainstream (North 1990). No matter the GDP level of the country, the quality of the environment depends on the institutions within. Less effective institutions cause lax environmental regulations leading to increased pollution. On the other hand, strong and effective institutions promote a cleaner environment. Institutions are connected to the environment via possible legal rules and procedures. The linkage between these two is partially based on the 'Porter hypothesis' which states that strict regulatory policies motivate to innovate of pollution-reducing technology to attain a competitive advantage, which will eventually compensate for the negative externalities to the environment and lead to better efficiency in growth (Zhang et al. 2018). Moreover, the studies argue that a stronger negative association between the rule of law and environmental pollution demonstrates an EKC turning point at a much lower country income level, thus lowering carbon emissions (Castiglione et al. 2012). Regulations affect the environmental quality via four channels, i.e. by reducing the use of non-renewables, increasing the barriers to entry for pollution-intensive industries, encouraging the development of energy-saving products, and investing in pollution-reducing technology (Zhang et al. 2018). Meanwhile, corruption creates a direct as well

as indirect impact on the environment, where direct impact refers to the impact on pollution through environmental rules and rules, and indirect impact refers to the impact on pollution through the effect of corruption on per capita income levels, thus effecting environment (Welsch 2004). It affects three bottom lines of sustainability (i.e. social, economic, and environmental), creating a roadblock to adopting green solutions and cleaner resources (Silvestre et al. 2018). On the other hand, political and bureaucratic inefficiencies come up as distorting channels that weaken environmental governance (Welsch 2004).

When it comes to empirical evidence, their impact is still up for debate. Phuc Canh et al. (2019), Salman et al. (2019), and Shahbaz et al. (2019) highlighted in their study of G-7 economies that effective environmental policies improve environmental sustainability. Salman et al. (2019) examined the effect of institutions on CO_2 emissions in Indonesia, South Korea, and Thailand and found that institutional quality facilitates the reduction of CO_2 emissions. Furthermore, Khan and Rana (2021) researched the link for 41 Asian economies and found that institutions are conducive to the mitigation of CO_2 emissions. Similarly, Ali et al. (2019), Haldar and Sethi (2021), and Wawrzyniak and Doryń (2020) documented that greater efficiency of institutions reduces GHG emissions in emerging and developing economies. On the other hand, some studies mention that a weak institutional environment creates loops for economic inefficiencies, resulting in degraded environmental quality. A recent study by Azam et al. (2021) documented that institutional quality impacts CO_2 emissions positively in developing countries. Similarly, Teng et al. (2021) highlighted a significant increase in carbon emissions due to institutional quality. Analysing the components of institutional quality separately, Abid (2016) found that control of corruption, political efficiency and stability, democracy, and governance efficiency mitigates carbon emissions, whereas law and regulatory quality induces a boost in carbon emissions. Later, Akhbari and Nejati (2019) highlighted that corruption might create an insignificant impact on environmental quality in both developed and developing countries. As a result, a strong institutional environment is an optimum choice to tackle increasing GHG emissions, yet no empirical unanimity exists for its impact on emissions, particularly in BRICS.

Economic growth and CO_2 emissions

The relationship between economic growth and pollution has been widely acknowledged via the environmental Kuznets curve (EKC) hypothesis by Panayotou (1994). The hypothesis posits that in the early stages of development, countries are more concerned about higher income and economic growth than any environmental issues, which results in degraded environmental quality. While in the later stage,

when the income rises to a certain level, the countries shift their concern towards a cleaner environment and increase the awareness for using renewable energy resources and less polluting goods, resulting in better environmental quality. A modified version of EKC consists of more than two variables that include institutional quality and globalisation. However, the studies have mentioned that local pollutants decline with higher per capita income, but the emissions of pollutants still increase (Stern 2018). The studies also confirm that emissions rise with per capita income when other factors are kept constant (Stern 2018). The statement is supported by many empirical evidence over time. In a study by Le and Ozturk (2020), the results confirmed the existence of EKC in emerging countries utilising institutional quality, globalisation, and government expenditures. Egbetokun et al. (2020) also revealed the presence of EKC in Nigeria but further suggested strengthening the institutional structure to reduce carbon emissions with higher economic growth. Similarly, Lawson (2020) analysed the economic growth-emissions nexus for Sub-Saharan African countries and confirmed that the effect of economic growth significantly mitigates carbon emissions. Danish et al. (2019) examined the economic growth-emissions nexus and found that EKC holds in BRICS countries. Furthermore, Chhabra et al. (2022) highlighted the existence of EKC in selected high- and low-middle-income countries. On the other hand, Asongu et al. (2020), in their study on African countries, found that EKC does not hold and higher economic growth does not ensure lower pollution levels. Wawrzyniak and Doryń (2020) investigated the nexus with institutional quality and indicated that the effectiveness of government institutions alters the impact of economic growth on carbon emissions in developing countries. In addition, Aust et al. (2020) found that higher economic growth due to modern industrialisation, infrastructural activities, and population growth increases the consumption of non-renewable resources and causes a rise in carbon emissions in developing countries. Osadume (2021) found that economic growth creates a positive impact on carbon emissions in West African countries in the long run as well as in the short run. Similarly, Ostic et al. (2022) indicated a positive and significant relationship between economic growth and carbon emissions in OPEC countries. Hence, no consensus can be made for the effects of economic growth on pollution.

Renewable energy resources, non-renewable resources, and CO$_2$ emissions

The stifling stress of global warming on the climatic conditions necessitates to take a leap towards modulating the anomalies emitting enormous greenhouse gases. One possible way to harmonize such anomalies is a shift towards renewable resources. It is a widely believed fact that the

consumption of non-renewable resources, such as fossil fuels, exacerbates carbon emissions, causing severe environmental issues (Li and Haneklaus 2022). Thus, De La Peña et al. (2022) highlight that using solar, wind, geothermal, and other renewable resources is crucial in reducing the consumption dependence on fossil fuels and promoting a cleaner environment. Moreover, the studies highlight that keeping the increase in global temperatures below 1.5° C and lowering carbon emittances to net zero is essential to halt any damages from global warming (Kenner and Heede 2021; Obobisa 2022). Subsequently, Acheampong et al. (2019) revealed that higher use of renewable resources reduces carbon emissions in Sub-Saharan Africa. In a study for South Africa, Sarkodie and Adams (2018) conclude that diversification in the energy usage portfolio to include renewable resources reduces carbon emissions. Bilan et al. (2019) assessed the impact of renewable resources on CO$_2$ emissions and found that adopting renewable resources enhances the quality of the environment by lowering CO$_2$ emissions in EU states. Similarly, Awosusi et al. (2022) investigated the association between renewable resources, globalisation, and CO$_2$ emissions and found that renewable energy sources reduce carbon emissions in Columbia. Furthermore, Fatima et al. (2021) found that economic growth moderates the effect of renewable energy on carbon emissions Furthermore, Szetela et al. (2022) indicated that the shift to renewable energy consumption helps in a faster reduction in CO$_2$ emissions.
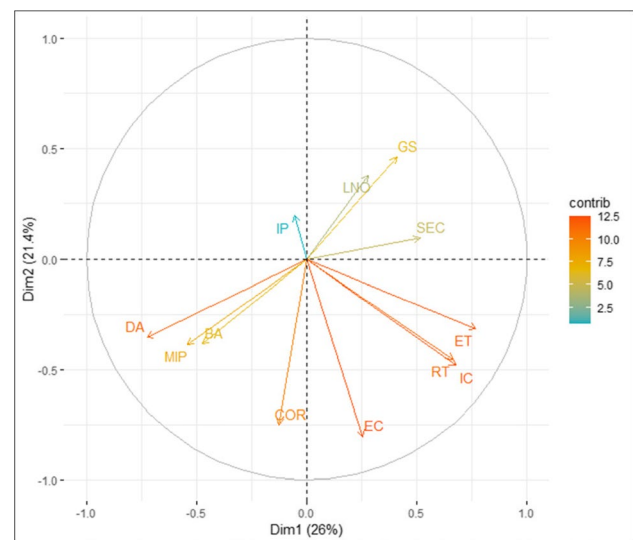

Fig. 2 Effect of institutional quality variables under PCA. Note: here, IP internal politics, LNO law and order, GS government stability, SEC socio-economic conditions, ET ethnic tension, IC internal conflict, EC external conflict, RT religious tensions, COR corruption, BA bureaucratic accountability, DA democratic accountability, MIP military in politics. Source: Author's computation

To sum up, very few studies have examined the trade openness-emissions nexus with a special focus on the role of institutional quality. Most such studies also fail to consider the effect of renewable and non-renewable resources on the nexus for BRICS countries. As a result, this paper adds to the existing literature by incorporating the role of institutional quality, renewable resources, and non-renewable resources in the openness-emissions nexus in BRICS.

Data and methodology

Model development

The study aims to examine the impact of trade openness and institutional quality on carbon emissions for BRICS countries. For this purpose, the model also includes other explanatory variables, such as economic growth, renewable resources, and non-renewable resources. The model proposed to analyse the impact of these respective variables on carbon emissions can be expressed as

$$CO_2 = f(TO, IQ, GDPC, REN, NON) \tag{1}$$

where CO_2 shows carbon emissions, TO denotes trade openness, IQ represents institutional quality, GDPC refers to GDP per capita, REN signifies renewable resources, and NON is non-renewable resources.

All the variables have been converted into natural logarithms to reduce the sharpness of data and control heterogeneity. As a result, the converted model can be presented as

$$lnCO_2 = \beta_0 + \beta_1 lnTO_{it} + \beta_2 lnINS_{it} + \beta_3 lnGDPC_{it}$$
$$+ \beta_4 lnREN_{it} + \beta_5 lnNON_{it} + \varepsilon_{it} \tag{2}$$

where $\beta_1, \beta_2, ..., \beta_5$ denotes the elasticities of trade openness (TO), institutional quality (INS), economic growth (GDPC), renewable energy (REN), and non-renewable energy (NON) to carbon emissions (CO_2). In function, 'i' represents the country and 't' means the time. To investigate the impact of institutional quality on environmental quality, the study utilises different measures following Khan et al. (2022). Based on existing evidence, the study uses numerous institutional indicators from International Country Risk Guide (ICRG) database. The effect of all the variables can be observed in Fig. 2, which shows the directions and magnitude of the impact of all these variables under PCA. Firstly, the study constructs an Institutional Quality index (IQI) using government stability, law and order, democratic accountability, bureaucratic accountability, corruption, ethnic tension, internal conflict, external conflict, and religious tensions in model 2a. Secondly, the political stability index (PSI) has been constructed using ethnic tensions, religious tensions, government stability, internal conflicts, and external

conflicts in model 2b. Thirdly, the political efficiency index (PEI) has been devised using law and order, democratic accountability, bureaucratic accountability, and corruption in model 2c. As a result, the study uses three proxy indices to represent institutional quality and investigate its impact on environmental sustainability more profoundly. Following Boateng et al. (2021), the study conducts a KMO test to check the validity of IQI, PSI, and PEI. The KMO results provide statistical values of 0.638, 0.600, and 0.7872 for IQI, PSI, and PEI, with eigenvalues of 2.48, 2.61, and 1.88 explaining the total variation of 71, 73, and 75 percent, respectively. Thus, the PCA is appropriate and creates valid indices. The econometric models for this can be presented as

$$lnCO_2 = \beta_0 + \beta_1 lnTO_{it} + \beta_2 lnIQI_{it} + \beta_3 lnGDPC_{it}$$
$$+ \beta_4 lnREN_{it} + \beta_5 lnNON_{it} + \varepsilon_{it} \tag{2a}$$

$$lnCO_2 = \beta_0 + \beta_1 lnTO_{it} + \beta_2 lnPSI_{it} + \beta_3 lnGDPC_{it}$$
$$+ \beta_4 lnREN_{it} + \beta_5 lnNON_{it} + \varepsilon_{it} \tag{2b}$$

$$lnCO_2 = \beta_0 + \beta_1 lnTO_{it} + \beta_2 lnPEI_{it} + \beta_3 lnGDPC_{it}$$
$$+ \beta_4 lnREN_{it} + \beta_5 lnNON_{it} + \varepsilon_{it} \tag{2c}$$

where CO_2 shows carbon emissions, TO denotes trade openness, GDPC refers to GDP per capita, REN signifies renewable resources, NON is non-renewable resources, IQI is an institutional quality index, PSI represents the political stability index, and PEI denotes the political efficiency index for 'i' cross-section over time 't.' In order to get a clearer picture, the study performs a single indicator analysis, in which the impact of each governance indicator has been examined separately.

Econometric techniques

While handling the panel data, heterogeneity and cross-sectional dependence arise as two prime issues that may lead to inconsistent estimates. As a result, checking for these issues is the foremost priority before selecting appropriate econometric methods for analysis.

Therefore, to begin with empirical estimation, the study first examines the heterogeneity among the panels using delta test statistics ($\widetilde{\Delta}$ and $\widetilde{\Delta}_{adj}$) by Hashem Pesaran and Yamagata (2008), which is an improved version of Swamy's slope homogeneity test. The method assumes the null hypothesis of homogeneity among slope coefficients. The results in Table 1 reject the null hypothesis and show that the coefficients of slope for all the models signify the existence of heterogeneity. Furthermore, the study applies the cross-sectional dependence (CD) test by Pesaran (2004) to examine whether the countries in the sample illustrate the characteristics of cross-sectional dependence. The test will

Table 1 Slope homogeneity test results

Models	$\widetilde{\Delta}$	$\widetilde{\Delta}_{adj}$
$CO_2 = f$ (TO, IQI, GDPC, REN, NON)	2.122**	2.451**
$CO_2 = f$ (TO, PSI, GDPC, REN, NON)	1.440	1.704*
$CO_2 = f$ (TO, PEI, GDPC, REN, NON)	2.304**	2.727***

Here, * means < 10%, ** means < 5%, *** means < 1%. The results confirm the heterogeneity among the panel coefficients

assist in selecting the appropriate tests for panel unit root and panel cointegration that may provide better estimates in the presence of CD. The test assumes the null hypothesis of mutually exclusive independent countries and the alternate of mutually dependent countries among the panel. The outcomes in Table 2 confirm the rejection of the null hypothesis and highlight these countries are significantly dependent among the panel. This proves the presence of CD among the panels.

Therefore, the above results confirm that the selected country panel consists of cross-sectional dependence and is heterogeneous. As a result, in the next step, the study applies the second-generation unit root test, which allows assuming CD and heterogeneity among the panels instead of the first unit root test. The study examines the stationarity of variables using cross-sectional augmented Dicky-Fuller (CADF) and cross-sectional Im-Pesaran-Shin (CIPS) tests by Pesaran (2004). The tests assume the null hypothesis of no stationarity among the variables in the presence of CD and heterogeneity. For the robustness check, the study implements the first-generation unit root test that includes Im, Pesaran, and Shin (IPS) by Im et al. (2003) and Levin, Lin, and Chu (LLC) test by Levin et al. (2002).

Furthermore, the study examines the presence of cointegration using the (Westerlund 2007) panel cointegration test. The cointegration test ensures the existence of long-run comovement between two variables. Unlike Pedroni and Kao panel cointegration tests, the Westerlund cointegration test allows CD and heterogeneity among the variables and produces reliable outcomes. Based on the suggestions by Westerlund (2007), the study implements these four formulas to check cointegration consisting of both panel statistics and mean statistics, represented as

$$G_T = \frac{1}{N} \sum_{i=1}^{N} \frac{\epsilon_i}{Se(\widehat{\epsilon}_i)} \tag{3}$$

$$G_\alpha = \frac{1}{N} \sum_{i=1}^{N} \frac{T\epsilon_i}{\epsilon_i'(1)} \tag{4}$$

$$P_T = \frac{\widehat{\epsilon}_i}{Se(\widehat{\epsilon}_i)} \tag{5}$$

$$P_\alpha = T\widehat{\epsilon} \tag{6}$$

where ϵ_i represents the error correction speed towards its original equilibrium level, *Se* is the least square estimate, and *T* denotes the time dimension. The results from the former two equations confirm whether or not there is cointegration in at least one cross-sectional unit, while the latter two exhibits whether or not cointegration exists in the whole panel.

The presence of long-run cointegration among the variables stimulates estimating the long-run parameters. For this purpose, the study uses a contemporary dynamic common correlated effects (DCCE) approach by Chudik and Pesaran (2015). The approach copes with the issues of CD and generates more reliable and unbiased results. The method runs on the basic principle of the mean group (MG) approach, pooled MG approach, and common correlated effects (CCE) approach by Pesaran and Smith (1995) and Pesaran (2006). It provides efficient estimates for the dynamic panels and covers the issues of heterogeneity, CD, and issues within the CCE approach. This DCCE approach by Chudik and Pesaran (2015) consists fourfold benefits over other traditional econometric approaches as (1) it resolves the CD issue using average values and lags of cross-sectional units altogether, (2) it controls for heterogeneity, (3) it is appropriate for small sample case, (4) generate reliable outcomes in the condition of structural breaks and unbalanced data (Ditzen 2018). This proves DCCE is an ideal approach to examine the trade openness-emissions nexus, represented as

$$lnCO_{2it} = \alpha_i lnCO_{2it-1} + \beta_i X_{it} + \sum_{p=0}^{pT} \gamma_{xip} \overline{X_{t-p}} + \sum_{p=0}^{pT} \gamma_{yip} \overline{Y_{t-p}} + \mu_{it} \tag{7}$$

Table 2 Cross-sectional dependence test results

Models	Breusch-Pagan LM	Pesaran scaled LM	Pesaran CD
$CO_2 = f$ (TO, IQI, GDPC, REN, NON)	87.6540***	17.3639***	− 2.4093**
$CO_2 = f$ (TO, PSI, GDPC, REN, NON)	90.4944***	17.9991***	− 1.9086*
$CO_2 = f$ (TO, PEI, GDPC, REN, NON)	87.6102***	17.3541***	− 2.4108**

Here, * means < 10%, ** means < 5%, *** means < 1%. The results confirm the cross-sectional dependence among the panels for all the models

where, $lnCO_2$ and $lnCO_{2it-1}$ denote the dependent variable and its lag to be used as an independent variable, X_{it} is the set of explanatory variables, that is, trade openness, institutional quality, economic growth, renewable resources, and non-renewable resources, γ_{xip} and γ_{xip} shows the common unobserved factors, pT represents cross-section averages, and μ_{it} is the error term in the model. The subscripts i and t show the time and cross-sectional dimensions.

Thus, it can be rightly said that the DCCE approach generates reliable long-run estimates for the dynamic models. However, the study further employs the Driscoll-Kraay standard error method to check the robustness of DCCE results. While these models provide robust estimates for the models, they do not provide any information on the causal links among the variables. Therefore, the study employs the Dumitrescu and Hurlin (D-H) panel causality test (Dumitrescu and Hurlin 2012) to examine the causal relationship among the variables. Compared to other conventional methods, the D-H panel causality test produces more consistent results in the presence of CD and heterogeneity. The model for the D-H causality test can be expressed as

$$Y_{it} = \alpha_i + \sum_{k=1}^{K} \gamma_{ik} Y_{i,t-k} + \sum_{k=1}^{K} \beta_{ik} X_{i,t-k} + \varepsilon_{it} \qquad (8)$$

where Y_{it} and X_{it} are the stationary variables. The method assumes the same lag order for each variable with panel stability. Equation 8 determines whether or not x causes y. The fundamental idea is that if the past values of x significantly anticipate the present value of y while including the past value of y in the model, then x deploys a causal impact on y (Lopez and Weber 2017).

Data

This study analyses the relationship between trade openness and carbon emissions with institutional quality for BRICS countries from 1991 to 2019. The selection for the study period is purely based on the availability of data for all the variables used in the study. The description of the variables has been briefly discussed in Table 3. For the dependent variable, the study used CO_2 emissions in metric tons (CO_2) as a proxy for carbon emissions in compliance with previous studies (Stern 2004; Shahbaz and Sinha 2019; Chhabra et al. 2022). For independent variables, the study uses trade-to-GDP (TGDP) to represent trade openness. The inclusion of the variable is significant due to the persisting leakage phenomenon in developing countries. Furthermore, three institutional indices are constructed using PCA to represent the quality of institutions in compliance with Khan et al. (2022). The construction of these indices will help us to identify whether transparency and democracy electorate exert policy pressure on the government. Secondly, it will check whether democratic countries are more likely to provide public goods, such as environmental protection (Hughes and Lipscy 2013). In addition, the study conducts a single indicator analysis for each governance indicator. It will provide a better picture of the individual effects of institutional quality variables. The other explanatory variables for the analysis include GDP per capita (GDPC) indicating economic growth, fossil fuel consumption per capita denoting non-renewable energy, and renewable resource consumption per capita representing renewable energy. Since fossil fuels play a crucial role in high carbon emissions and are a major source of energy consumption in these countries, it is vital to analyse the role of non-renewable energy and its modulators (renewable energy) on carbon emissions. In line with the existing empirical evidence, the study expects a negative sign for trade openness (Zhang et al. 2017; Yu et al. 2019; Dauda et al. 2021), renewable energy (Fatima et al. 2021; Awosusi et al. 2022; Szetela et al. 2022), and economic growth (Danish et al. 2019; Lawson 2020) on carbon emissions whereas, a positive sign is

Table 3 Data description

Variables	Measurement Units	Data Sources
Economic Growth (GDPC)	Constant (2010 US$)	WDI
Trade Openness (TGDP)	Percentage	WDI
Institutional Quality (INS)	Panel Principal Component Analysis	ICRG
Institutional Quality Index (IQI)		
Political Stability Index (PSI)		
Political Efficiency Index (PEI)		
CO_2 emissions (CO_2)	Metric tons	CAIT
Renewable resource consumption per capita (REN)	Kilowatt-hour	Our World Data
Fossil fuel consumption per capita (NON)	Kilowatt-hour	Our World Data

Note: The table exhibits the data sources and the unit of measurement for all the selected variables in the study. Here WDI means World Development Indicator, ICRG means International Country Risk Guide, and CAIT means Climate Analysis Indicators Tool

Fig. 3 Correlation statistics results. Note: the degree of correlation between the variables varies from −1 to +1, where a value near 1 indicates a strong correlation, and a value near 0 indicates a weak correlation. The results show that all the correlation estimates are within the limit for all the variables. Source: Author's computation
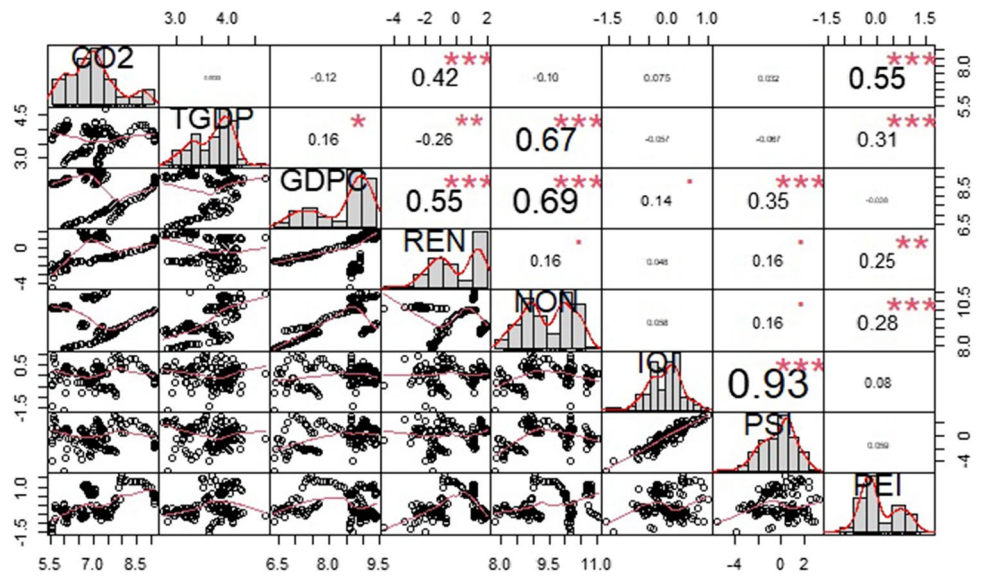
expected from non-renewable energy on carbon emissions in BRICS countries (Fatima et al. 2021). To avoid any empirical issues, the study checks the correlation statistics among the variables, as shown in Fig. 3.

Results and discussions

For the empirical analysis, the study initially checked the presence of unit root stationarity using second-generation unit root tests, namely, CADF and CIPS. The results from both CADF and CIPS tests in Table 4 reveal that the variables are stationary at mixed order. All variables are stationary at the first difference, while trade openness, economic growth, non-renewable resources, and institutional quality proxies are stationary at the level as well. Furthermore, the first-generation unit root tests, namely IPS and LLC tests, reject the null

hypothesis and confirm that all the variables are stationary at first difference. As a result, the robustness check validates the outcomes of second-generation unit root tests.

The results in Table 5 present the outcomes of three separate models, one for each institutional quality proxy variable, IQI, PSI, and PEI. The cointegration results reject the null hypothesis of no cointegration for all the models. As a result, the findings support the existence of a long-run relationship between carbon emissions, trade openness, institutional quality, renewable resources, and non-renewable resources.

Furthermore, the study employs the DCCE estimator to estimate the long-run parameters for all the explanatory variables concerning carbon emissions. The results in Table 6 show that trade openness aggravates CO_2 emissions in BRICS countries. The findings reveal that a one percent change in openness to trade causes a 0.27 percent increase in

Table 4 Unit root test results

Variables	First-generation unit root				Second-generation unit root			
	LLC		IPS		CADF		CIPS	
	At level	At 1st diff	At level	At 1st diff	At level	At 1st diff	At level	At 1st diff
CO_2	−2.4386**	−3.7491***	−0.3969	−4.4001***	−2.157	−3.396***	−2.202	−4.172***
TO	−1.6732**	−8.6918***	−1.7155**	−4.5149***	−2.836**	−3.741***	−3.259***	−5.291***
GDP	−0.8824	−1.5245*	1.4291	−2.4871**	−2.462*	−2.078	−2.614***	−2.684***
REN	1.3013	−6.0138***	1.7693	−7.4465***	−1.484	−3.714***	−1.451	−5.269***
NON	−0.5052	−1.9849**	0.1813	−3.1084***	−2.632**	−2.433*	−2.570**	−3.588***
IQI	−0.8012	−5.5923***	−2.0031**	−6.0762***	−2.423*	−4.846***	−2.649***	−4.647***
PSI	8.2205	−4.5331***	−2.1682**	−6.2205***	−2.347*	−3.871***	−2.788***	−4.687***
PEI	−1.6998**	−2.8822***	−1.1598	−4.1746***	−2.149	−4.163***	−2.831***	−5.165***

The table shows *t*-statistics and *t*-bar values. * means < 10%, ** means < 5%, *** means < 1%. The results reject the null hypothesis and confirm the stationarity at the first order

Table 5 Westerlund cointegration results

Models	Gt	Ga	Pt	Pa
$CO_2 = f$ (TO, IQI, GDPC, REN, NON)	− 1.910***	− 4.803***	− 3.962	− 6.926***
$CO_2 = f$ (TO, PSI, GDPC, REN, NON)	− 2.047***	− 5.402***	− 4.362***	− 6.934***
$CO_2 = f$ (TO, PEI, GDPC, REN, NON)	− 1.098	− 2.184***	− 3.147***	− 2.753***

The table shows the significance of results at robust p-values, where *** means < 1%. The results confirm the long-run cointegration for all the models

carbon emissions in the model (1). The results are in accordance with Zhang et al. (2017), Phong (2019), Le and Ozturk (2020), and Dou et al. (2021). This indicates that energy-hungry production techniques feed a voluminous amount of economic output in these countries. As a result, it confirms an overpowering effect of scale production that offsets the benefits of technology and composition effects absorbed from global trade, resulting in higher carbon emissions. According to the theoretical literature, trade stimulates the environment-conducive and advanced innovative technologies in developing countries, like BRICS, that improve the standard of living and economic growth. But these imports include antiquated technologies from developed countries that increase the consumption of dirty energy sources (non-renewable source) and emits high carbon contents. This intensifies and confirms the existence of the pollution haven hypothesis, where a boost in trade escalates CO_2 emissions. However, the effect reduces with the introduction of the

institutional quality index in the model (2). The findings show that the environment-degrading effect of trade openness reduces with an effective institutional setting, where a one percent change in trade openness triggers carbon emissions by 0.16 percent in the case of the institutional quality index. This reveals that the combined effect of all the institutional variables is more effective in improving trade's negative impact on environmental quality.

Also, a significant negative impact of economic growth can be evidenced on CO_2 emissions. The findings show that a one percent change in the institutional environment increases carbon emissions by 0.37 percent in the model (2). With political stability and efficiency, the impact of economic growth rises to 0.46 percent and 0.47 percent, respectively. The findings are consistent with Amuakwa-Mensah and Adom (2017), Adams and Nsiah (2019), and Muhammad (2019). This demonstrates that the pursuit of greater well-being through economic development has increased the

Table 6 Long-run estimation results from DCCE and Driscoll-Kraay standard errors

Variables	DCCE results				Driscoll-Kraay standard errors results		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
L.CO_2	− 0.6783***	− 0.5198***	− 0.4503***	− 0.5131***	–	–	–
	(0.0927)	(0.0786)	(0.0516)	(0.0392)			
TO	0.2763*	0.1684*	0.3282*	0.2976**	0.5265***	0.3252**	0.4122***
	(0.1522)	(0.9204)	(1900)	(0.1339)	(0.1014)	(0.1233)	(0.1180)
GDPC	0.3610	0.3732**	0.4660*	0.4703**	0.4865*	0.3005*	0.3724*
	(0.2833)	(0.1812)	(0.2431)	(0.2051)	(0.2855)	(0.1709)	(0.1905)
REN	− 0.1180	− 0.2719**	− 0.2580**	− 0.2819**	− 0.1537	0.0561	− 0.0912
	(0.1155)	(0.1154)	(0.1217)	(0.1289)	(0.4347)	(0.721)	(0.0572)
NON	0.8301*	0.7755**	0.5969	0.5841	0.6292***	0.5859**	0.6779*
	(0.4883)	(0.3749)	(0.4983)	(0.5167)	(0.1029)	(0.2477)	(0.3502)
IQI	–	− 0.1399**	–	–	− 0.1044	–	–
		(0.0714)			(0.0775)		
PSI	–	–	− 0.0422*	–	–	− 0.0367	–
			(0.0220)			(0.1033)	
PEI	–	–	–	− 0.0882*	–	–	− 0.0731
				(0.0482)			(0.1698)
R sq	0.63	0.62	0.65	0.57	0.68	0.69	0.67
CD stat	− 0.20	0.13	− 0.10	− 0.25	–	–	–
p-value	0.8448	0.8990	0.9224	0.8013	–	–	–

The parentheses for models (1), (2), (3), and (4) show standard error values, whereas parentheses for models (5), (6), and (7) show Driscoll-Kraay's standard error values. * means < 10%, ** means < 5%, *** means < 1%. The findings show that while trade openness degrades environmental quality, institutions work diligently to mitigate its negative effects

consumption of energy-hungry technologies emancipating substantial CO_2 emissions. The growth trends in the industrial, transportation, and manufacturing sectors perpetuate massive consumption of non-renewable energy sources such as fossil fuels. As a result, a large number of carbon particles are emitted, which degrades the environmental quality in BRICS. This indicates that economic growth triggers CO_2 emissions and creates severe environmental damage. Therefore, policies promoting renewable source consumption and energy-saving innovative technologies should be prioritised to mitigate enormous carbon emissions.

Similarly, non-renewable resources exert a significant negative impact on carbon emissions. The results disclose that a one percent change in non-renewable resources exacerbates carbon emissions by 0.91 percent. The findings are consistent with those of Appiah et al. (2019), Asongu et al. (2020), and Khan et al. 2022) for developing countries. This highlights that the economic activities in BRICS countries rely highly on the consumption of fossil fuels for both domestic and industrial purposes, which increases the emancipation of carbon gases. On the other hand, renewable energy consumption shows a significant positive impact on carbon emissions, where a one percent change in renewable energy consumption lowers carbon gas emissions by 0.11 percent. When combined with an effective institutional environment, renewable energy resources contribute more significantly towards cleaner environmental quality. Under improved political efficiency and stability, renewable energy consumption significantly lowers carbon emissions by an average of 0.26 percent in models (3) and (4). The findings for positive renewable energy impact are in agreement with the results of Akram et al. (2020) and Hassan et al. (2020b) for BRICS countries analysis and with Acheampong et al. (2019), Dauda et al. (2021) De La Peña et al. (2022), and Khan et al. (2022) for developing countries analysis. Compared to the impact of renewable energy sources, the negative impact of non-renewable resources is almost triple in model (2) and double in models (3) and (4). This indicates that the environmental degradation effects outweigh any environmental benefits from renewable energy sources. This validates the critical need for an institutional framework that promotes alternatives to traditional energy sources, like fossil fuels, which are less harmful to the environment. The transition to renewable energy sources will not only improve the environmental quality but will also reduce the dependence on other countries for the supply of non-renewable energy sources Since the generation of solar, geothermal, hydro, and other renewable energy source involves massive energy projection projects, it may not be possible to shift towards renewable resources in a jiff entirely, but an increased use will immensely reduce the carbon emissions in BRICS countries. Therefore, as the major hosts of the leakage phenomenon, India and China are suggested to strengthen their resilience to renewable energy sources.

This indicates that the quality of institutions is inextricably related to reducing carbon emissions. The results are in line with the findings of Danish et al. (2019) and Chaudhry et al. (2022) and exhibit that with a one percent improvement in the institutional quality index, carbon emissions reduce by 0.13 percent in the sample countries. Moreover, the positive impact of PSI and PEI on carbon emissions highlights that political stability and efficiency lay the groundwork for an effective environmental regulatory framework that takes the edge off the higher emissions. A one percent change in political stability and efficiency will bring a 0.04 percent and 0.08 percent reduction in emissions of CO_2. This indicates that a stronger institutional environment controls any political instability, conflicts, and corruption, which improves government regulations' effectiveness. One reason behind this is that the political environment in these countries is becoming aware of general public issues like pollution. Another possibility is the adoption of new initiatives and changes in the bureaucratic mindsets that focus on environmental issues. This highlights that along with higher economic growth, environmental problems are also the among the top priorities of the institutions. Improved bureaucratic control over implementing stringent environmental policies may encourage using environment-conducive and less carbon-emitting technologies. This brings several projects to BRICS countries that not only aim to maximise profit but also boost knowledge spillovers. The transfer of green innovations and technology using renewable energy sources will aid in the reduction of carbon emissions. This will illustrate domestic and foreign investment expeditions towards green production activities, inducing a cleaner environment.

The results of the single indicator analysis to investigate the impact of institutional quality on carbon emissions more thoroughly will provide a clear picture of the indicators degrading or restoring environmental quality. Table 7 shows that government stability, military involvement in politics, and bureaucratic accountability reduce CO_2 emissions significantly. The results confirm the classic statement of Graham Allison that "where you stand depends on where you sit," which means the bureaucratic awareness towards the environment changes policy formulation and preferences accordingly. It implies that the higher awareness in these countries is resulting in stronger environmental protection policies. Moreover, stability brings environmental improvements by avoiding any jeopardies in the education system, which also increases ecological awareness, thus leading to sustainable development.

However, these countries remain vulnerable to high corruption levels. Higher corruption degrades environmental quality by reducing the efficiency of institutions. Moreover, it reveals that corruption practices in these countries impede the smooth application and implementation of cleaner energy due to weak environmental laws, hence lower

Table 7 Single Indicator analysis results for institutional quality using DCCE

Variables	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
L.CO_2	−0.8588*** −0.0889	−0.0648 −0.0397	−0.5340*** −0.0634	−0.4587*** −0.0452	−0.4616*** −0.0518	−0.5557*** −0.0584	−0.6944*** −0.0326	−0.5715*** −0.0736	−0.4818*** −0.0227	−0.5011*** −0.0551
TO	0.2009** −0.0825	0.4295*** −0.1306	0.1023* −0.0531	0.3753*** −0.1429	0.0563** −0.1556	0.6238** −0.2638	0.4332*** (−0.1582)	0.1564*** −0.0357	0.1251*** (−0.0457)	0.5876** −0.2404
GDPC	−0.4479 −0.4479	−1.1312** (−0.5621)	−0.2048 −0.3718	0.5325 −0.6757	−1.0507** −0.5002	0.2555 −0.6322	−1.2043* −0.5877	0.3869* −0.2213	−2.6468* −1.4791	−0.3777 −0.7028
REN	−0.2178 −0.1631	−0.3170** −0.1393	−0.2247* −0.1339	−0.1925** −0.0937	−0.3068** −0.1431	−0.4795*** −0.1718	−0.3691** −0.1677	−0.2564* −0.1315	−0.2160** −0.0951	−0.2452** −0.1094
NON	0.7172** −0.355	0.9414* −0.552	0.445 0.3134	0.3827*** −0.0587	0.3731** −0.1851	0.6362 −0.5242	1.0547* −0.5872	1.2499** −0.5637	1.7206* −1.019	0.4473 −0.4087
COR	0.0762** −0.032									
LNO		−0.0558* −0.0288								
IP			0.0307** −0.0151							
IC				0.0771 −0.1033						
EC					0.0029 −0.0342					
DA						0.0061 −0.0962				
BA							−0.3147 −0.2486			
GS								−0.0175** −0.0076		
MIP									−0.0725* −0.0403	
ET										0.0834 −0.0651
R sq	0.68	0.61	0.64	0.61	0.63	0.58	0.58	0.56	0.6	0.59
CD stat	−0.55	−0.26	−0.13	0.32	0.33	0.3	−0.4	−0.67	−0.12	−0.19
p-value	0.583	0.7979	0.8983	0.7456	0.7378	0.7648	0.6897	0.5017	0.9045	0.8465

The parentheses show standard error values. * means <10%, ** means <5%, *** means <1%. The findings show that government stability, military involvement in politics, and bureaucratic accountability have a positive impact on carbon emissions. On the other hand, corruption and law and order have a negative impact on carbon emissions in the BRICS

sustainability (Ren et al. 2018). Corruption results in lower environmental standards that may boost the GDP slightly in the short run by high energy consumption. In addition, a lack of focus on quality will reduce efficiency and increase economic and environmental costs, resulting in higher carbon emissions in the long run. It impedes the development process of economies and causes delays in meeting CO_2 emission reduction targets.

The findings also demonstrate a negative relationship between CO_2 emissions and law and order in BRICS countries. This implies that enforcement of government regulations does support growth irrespective of its drivers, such as non-renewable and renewable sources. The results validate the effects of the Porter hypothesis and confirm that environment-friendly technology compensates for the environmental cost and leads to efficient economic growth (Zhang et al. 2018). It increases the likelihood of absorbing more benefits from the compounding effect, where enforcing multiple environmental laws helps to attain the green environment goals more swiftly (Hargrove et al. 2019). The results reveal that conflicts, such as internal conflicts, external conflicts, and ethnic tensions, accelerate carbon emissions and curtail economic growth. Active conflicts, such as wars, damages energy infrastructure and natural resources when the demand for fuel remains static. This forces a shift towards more harmful and inefficient alternatives contributing to carbon emissions. The reports have shown that the countries undergoing conflicts cannot deal with these climatic changes efficiently due to their weakened adaptability. The results are in line with Sekrafi and Sghaier (2018), Akhbari and Nejati (2019), Ren et al. (2018), and Zhang et al. (2018).

To check the robustness of these results, the study uses Driscoll-Kraay standard error method. The results in Table 5 indicate that the outcomes are consistent with the estimates of the DCCE method. It emphasises that as economic growth increases, so does the consumption of non-renewable resources, which aggravates the emissions of carbon gases and thus harms environmental quality. On the other hand, an efficient and stable political system contributes to lower carbon emissions and a cleaner environment y promoting renewable energy consumption instead of non-renewable energy consumption.

Dumitrescu-Hurlin causality test results

After confirming the long-run relationship between the variables, the study proceeds to the results for D-H causality. The results in Table 8 confirm the bidirectional relationship between CO_2 and economic growth, non-renewable resources, and political efficiency index. This indicates that the economic activities in these countries are highly inclined towards using non-renewable manufacturing resources, which is continuously increasing pollution. As a result, carbon emissions have reached unprecedented levels, causing severe environmental damage. The results also reveal uni-directional causality from CO_2 to institutional quality index and political stability index. This highlights that environmental issues affect institutional policies and are a significant part of any regulations in maintaining political stability. Similarly, a uni-directional causal relationship can be evidenced from economic growth to renewable resources, trade openness, institutional quality index, and political

Table 8 Dumitrescu-Hurlin causality test results

Dependent variables	Dumitrescu-Hurlin causality test							
	CO_2	TO	GDPC	REN	NON	IQI	PSI	PEI
CO_2	–	2.7579 (0.6080)	5.1457 (0.0068)	1.7053 (0.6493)	5.9027 (0.0007)	2.6015 (0.7120)	2.0365 (0.8805)	4.1583 (0.0718)
TO	1.5768 (0.5667)	–	7.9784 (1.E−07)	4.4166 (0.0416)	10.6684 (7.E−15)	3.3991 (0.2703)	3.7964 (0.1422)	3.7506 (0.1540)
GDPC	7.3885 (2.E−06)	4.8835 (0.0136)	–	1.0982 (0.3111)	8.5224 (6.E−09)	4.4749 (0.0365)	1.1282 (0.3245)	5.9549 (0.0006)
REN	3.5476 (0.2154)	2.5962 (0.7157)	5.1309 (0.0070)	–	3.3672 (0.2832)	3.3769 (0.2792)	2.3618 (0.8817)	2.2210 (0.9846)
NON	4.6601 (0.0237)	3.4280 (0.2589)	6.5094 (8.E−05)	4.1812 (0.0685)	–	3.2965 (0.3134)	4.2697 (0.0571)	4.4591 (0.0378)
IQI	4.0456 (0.0897)	2.8669 (0.5398)	2.4061 (0.8497)	1.7076 (0.6508)	2.2284 (0.9818)	–	3.6486 (0.1829)	3.3782 (0.2805)
PSI	5.0830 (0.0080)	0.8751 (0.2232)	5.8005 (0.0009)	6.4232 (0.0001)	4.669 (0.0232)	2.4071 (0.8490)	–	1.3148 (0.4158)
PEI	5.0188 (0.0096)	1.4638 (0.4986)	5.6579 (0.0015)	5.4742 (0.0026)	5.9486 (0.0006)	2.8041 (0.5787)	3.8658 (0.1256)	–

The parentheses show *w*-stat with probability values. The results show uni-directional causality from CO_2 to the institutional quality and political stability indexes. Moreover, the feedback relationship between CO_2 and economic growth, non-renewable resources, and political efficiency index can also be observed

stability index. With the increasing economic growth, people have become more aware of the environment and seek a cleaner environment. This leads to additional investments in capital to promote the adoption of green and environment-friendly technologies. In addition, the results present a uni-directional relationship from economic growth to the political efficiency index and non-renewable resources. This demonstrates that higher income disturbs the efficiency of environmental regulations and leads to greater use of non-renewable resources, trapping developing countries on the environmentally damaging side of the Kuznets curve (EKC). In addition, the results show a feedback effect between the political stability index and non-renewable resources, and the political efficiency index and non-renewable resources. This signifies non-renewable resources as a harmful factor in maintaining political stability and efficiency, which results in loose environmental regulations. Moreover, one-way causation can be observed from renewable and non-renewable energy sources to trade openness in Table 8. This shows that the consumption of renewable and non-renewable resources significantly affects trade. The higher consumption of fossil fuels will increase the share of imported non-renewable resources in the trading basket, whereas adapting to renewable sources will encourage the import of new innovative modern technologies that are conducive to the environment. Therefore, the government should focus on improving the institutional environment and limiting non-renewable energy consumption to reduce CO_2 emissions. The graphical representation of these causality results can be observed in Fig. 4.

Conclusion

Over the last few decades, the voracious burning of fossil fuels has resulted in high carbon emissions, intensifying the concentration of greenhouse gases in the atmosphere. To achieve environmental balance and long-term economic growth, trade openness, stable institutions, and innovative regulatory paradigms are required. This study looks into whether and how trade openness and institutional quality impact carbon emissions in BRICS countries from 1991 to 2019. First, the study constructs three indices, using principal component analysis, to measure the institutional impact on CO_2 emissions: institutional quality index, political stability index, and political efficiency index, respectively. For deeper investigation, the study conducted a single indicator analysis for each component representing the quality of institutions. Owing to the existence of cross-sectional dependence, the study used CADF and CIPS second-generation unit root tests and the Westerlund cointegration test revealing stationarity and long-run cointegration among the selected variables. Furthermore, imperative to the existence of cross-sectional dependence, the modern econometric approach
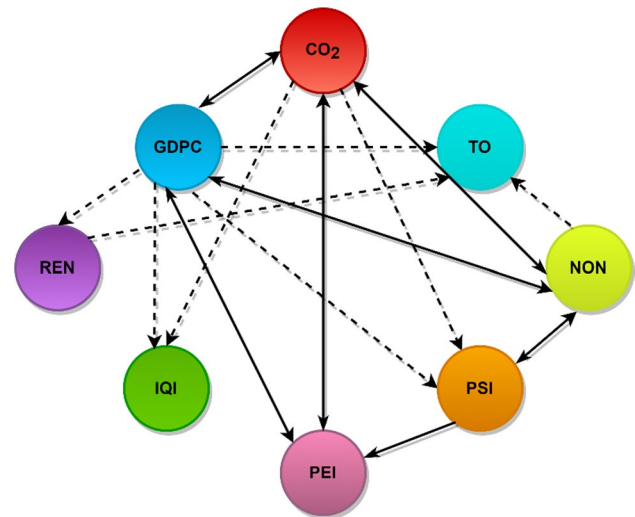

Fig. 4 Dumitrescu-Hurlin causality test results. Note: The bold line shows the bidirectional relationship, whereas dotted lines show the uni-directional relationship between the variables. Source: Author's Computation.

of DCCE was employed to estimate the long-run linkages between the variables.

The findings indicate that trade openness induces an environment-degrading effect that exacerbates carbon emissions in BRICS. The dominance of the scale effect over the technological and composition effect reduces the overall environmental quality. Similarly, the results show that economic growth is associated with increased carbon emissions, confirming these countries' role as pollution havens. In accordance with the theoretical evidence, the results indicate that consumption of non-renewable energy sources like fossil fuels and crude oils upsurges the release of carbon dioxide. While renewable energy help to reduce CO_2 emissions to some extent, the harm caused by conventional sources still outweighs them. In addition, political stability and efficiency improve bureaucratic control that encourages the use of green technologies and innovations. In addition, the findings show that with stringent environmental regulations, good institutional quality promotes a cleaner environment. Although institutions and carbon emissions constitute a negative relationship, the impact of institutions on combating deteriorated environmental quality is very low. Out of all the indicators of institutional quality, control of corruption, better law and order, and government stability promote sustainable growth and reduced CO_2 emissions. Any internal and external conflicts or tensions are harmful to the environment.

Based on the above results, the study concludes that policy actions are required to lower carbon emissions via post-combustion control technologies. To procure that, BRICS should strengthen their cooperation with the developed

countries that are recognised for leading modern clean technologies. Secondly, policymakers should incentivise the use of cleaner and renewable energy sources to cut the emissions of GHGs. The use of renewable resources should be aligned with industrial policies so that firms' adoption of green technologies does not lead to extra costs but tangible profits. Since several indicators of governance in the study show a negative impact on carbon emissions, this indicates the existence of a wide gap between policy formulation and implementation. As a result, policymakers should concentrate on enhancing the institutional structure to control corruption by conducting periodic reviews of environmental regulations and assessing their effectiveness in all economic sectors, especially the industrial sector, which is a significant source of surging CO_2 emissions in these countries. Furthermore, it is proposed that the BRICS economies pursue and encourage more environmentally friendly industrial technologies that drive knowledge spillovers to mitigate the adverse effects of trade openness. To realise these ends, with advanced, cleaner, and more sustainable development, it is recommended that policies be established that stimulate the adaption of new technologies. Regarding the institutional impact in BRICS, the study suggests that a tighter grip on corruption and more implementation of environmental laws will positively influence institutions in the BRICS countries. Since enhancing environmental quality is always a democratic choice, it is imperative that the bureaucratic control prioritise educating the public and its employees on the importance of protecting the planet's natural resources to spur greener economic expansion via green policy formulation. Thus, it is vital to fortify both institutions and a democratic framework to foster long-term viability.

Declarations

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