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RESEARCH ARTICLE

Decarbonization pathways: the roles of foreign direct investments, governance, democracy, economic growth, and renewable energy transition

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Abstract

The Paris Agreement has united the global nations to embark on pathways to the decarbonization of their respective economies. However, the objective of achieving low-carbon growth is not as straightforward as it seems since the rapidly emerging and fossil fuel-dependent world economies are focused on expediting economic growth at the expense of poorer environmental consequences. Against this background, this study aims to explore the effects of foreign direct investments, governance, democracy, renewable energy use, and economic growth on carbon dioxide emissions in the context of the BRICS countries over the period from 2006 to 2017. The estimation strategy involved in this study specifically accounts for addressing the issues of cross-sectional dependency and slope heterogeneity in the data set utilized for analysis. The associated findings reveal cointegrating associations between the study variables. Besides, the regression outcomes reveal that good governance (achieved by controlling corruption) and strong democracy (achieved by ensuring greater freedom for journalists) help to reduce carbon dioxide emissions in the long run. More importantly, the results also confirm that both good governance and stronger democracy further reduce carbon dioxide emissions by mediating between emission-inhibiting effects of foreign direct investment inflows in the BRICS countries. In addition, good governance and stronger democracy exert moderating effects to reduce the emission-stimulating impacts associated with higher economic growth. Lastly, it is also witnessed that forgoing non-renewable energy use and adopting renewable energy instead help to curb the carbon dioxide emission levels further. Accordingly, considering these key findings, it is recommended that the BRICS countries should enhance the quality of governance and democracy, attract clean foreign direct investments, promote renewable energy use, and adopt clean economic growth strategies to decarbonize their respective economy.

Keywords Carbon dioxide emissions · Governance · Democracy · Corruption control · Freedom of journalism · Foreign direct investments

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Introduction

In today's world, maintaining an equilibrium between economic growth and environmental well-being has become a major challenge for world economies (Jahanger et al. 2022). In this regard, the implementation of appropriate policies to achieve environmentally-sustainable economic growth is the call of the hour (Ali et al. 2022). Hence, to attain the objective of low-carbon economic growth, it is imperative to discover the relevant factors that can detach economic growth from carbon dioxide (CO2) emissions (Al Mamun et al. 2014; Wang and Zhang 2020; Wang and Su 2020). It is often believed that inappropriate economic growth-stimulating policies are the major factors responsible for the aggravation of environmental quality (Salahuddin et al. 2018; Murshed 2022; Shakib et al. 2021). Emphasizing economic growth, the decarbonization challenges are more complex for emerging countries since these nations are at the stage in which economic welfare is likely to be prioritized over environmental welfare. For instance, the BRICS[1] countries are referred to as the leading emerging nations in the world. These nations are said to collectively contribute to about one-third of the global gross value added figure and are also the leading polluted world economies (He et al. 2020). Therefore, the BRICS nations can be ideal candidates for identifying factors that can help to promote economic growth at low levels of CO2 emissions.

The BRICS countries have attracted attention within the environmental economics narrative due to their rapid economic growth and the corresponding environmental issues. This study is important since the largest BRICS nations, India and China, have been under intense pressure to reduce their respective CO2 emission figures (Murshed 2018; Ma et al. 2021). Besides, the BRICS nations have traditionally been reliant on both local and imported fossil fuels, which can be referred to as the central driver of the surging trends in their emission figures (Baloch et al. 2019). In addition, due to their limited resources, the majority of these nations, much like all global developing countries, find it challenging and costly to invest in environmental protection-related projects (Seetanah et al. 2019). Consequently, neither could the BRICS nations manage to lessen their fossil fuel dependency nor reduce the energy use-related CO2 emissions by adopting proactive pollution control initiatives.

Apart from the acute dependency on fossil fuels, the large inflows of foreign direct investments (FDI) can be assumed to be an additional influencer of CO2 emissions. Accordingly, several of the prior studies have explored the FDI inflow-CO2 emissions nexus in the context of the members of the BRICS (Qin and Ozturk 2021; Balsalobre-Lorente et al. 2021a; Li et al. 2022). Besides, by and large, these countries are considered a global economic force that attracts hefty amounts of FDI. According to World Bank statistics, Brazil, China, Brazil, India, Russia, and South Africa received FDI worth 170.3, 74.65, 43.96, 30.45, and 1.37 billion US dollars, respectively, in 2018 (World Bank 2018). Although the effects of FDI inflows are favorable in the context of stimulating higher economic growth, the corresponding effects on CO2 emissions are uncertain (Solarin et al. 2017; Balsalobre-Lorente et al. 2021b; Musah et al. 2022).

Moreover, it is often believed that FDI inflows degrade the environment of the host nations in which the environmental protection policies are not strong enough (Nathaniel et al. 2021; Murshed et al. 2021). In the context of the BRICS nations, the mean environmental policy stringency indices of these countries in 2019 were three times lower than the average level of the Organization for Economic Cooperation and Development (OECD) nations. Only for the case of China, the nation's environmental policy stringency index was close to the average level of the OECD countries. Under such circumstances, it can be assumed that foreign investors are likely to exploit the weak environmental protection arrangements of the BRICS nations and invest in pollution-intensive production processes. Consequently, FDI inflows can be hypothesized to worsen environmental quality in these countries. If this assumption is verified, it is imperative to look for solutions that can effectively neutralize such adverse environmental consequences associated with FDI flowing into the BRICS countries.

Concerning environmental regulation, governance is also a widely recognized political economy-related factor that can be expected to influence environmental quality. In general, good governance within the economy can be linked with higher institutional quality, which makes it easier for the governments to enact pollution control litigations (Liu et al. 2020). Besides, good governance has also been acknowledged as a means of enhancing the efficiency of energy use whereby the energy-related emissions can be contained to a large extent (Apergis and Garćıa 2019). Specifically, in the context of the BRICS nations, Danish et al. (2019) showed that better environmental governance can enable these countries to control the rise in their annual CO2 emission figures.

Alongside good governance, democratic quality is also assumed to influence environmental quality. For example, better demonstration of democratization within an economy enables the common people to use their voices against environmental malpractices, which, in turn, pressurizes the government to implement effective environmental protection policies (Lv 2017). Furthermore, better democracy has also been referred to as a credible mechanism of tackling CO2 emission-induced climate change problems (Povitkina

[1] BRICS abbreviates for Brazil, Russia, India, China, and South Africa.

2018). Against this backdrop, this study aims to explore the effects of FDI inflows, governance, and democracy, controlling for renewable energy consumption and economic growth, on the CO2 emissions levels of the BRICS nations over the period from 1996 to 2016. The outcomes from this study are assumed to assist the BRICS countries in designing appropriate decarbonization policies and enable them to achieve their Paris Agreement commitments. In the COP15 in France, the BRICS nations, along with almost all other world economies, have pledged to control their greenhouse gas emission levels in order to limit global warming (Rauf et al. 2018; Ullah et al. 2021; Rehman et al. 2021).

Although previous studies have explored the effects of the aforementioned explanatory variables on CO2 emissions in the context of the BRICS nations, this current study makes some innovative contributions to the literature. Firstly, this is the only study that simultaneously controls for governance and democracy levels on the CO2 emissions figures of the BRICS countries. Since both these macroeconomic variables are equally important in influencing the environmental quality indicators, it is imperative to include both these variables within the environmental impact assessment model. Secondly, this study also evaluates whether governance and democracy can exert moderating/mediating effects to influence the relationships between CO2 emissions and other macroeconomic factors. Identification of these effects is pertinent for formulating comprehensive policies that are relevant for assuring environmental development. Lastly, as opposed to using the conventional proxies, this study uses data on the degree of freedom enjoyed by the journalists as an indicator of democratic quality in the BRICS countries. Hence, the associated outcomes can be expected to add a new dimension to the democracy-environmental quality narrative.

The rest of the study is organized as per the following order. In the next section, the trends in the CO2 emission figures of the BRICS nations are analyzed. This is followed by the presentation of the empirical model and the estimation strategy considered in this study. Subsequently, the findings are presented and discussed, while the last section concludes with relevant policy suggestions.

Trends in CO2 emissions in the BRICS countries

Environmental problems have always been a concern for the BRICS nations since these nations have not been able to limit their annual CO2 emission levels. Figure 1 depicts the trends in the CO2 emission figures of the BRICS nations over the period considered in this study. As far as the cumulative CO2 emission figures are concerned, it can be seen, that on average, the annual volume of per capita CO2 emissions has steadily gone up with time. Similar annual per capita CO2 emission trends are also observed for the individual BRICS nations (as perceived from the upward sloping trend lines shown in Figure 1). Regarding Brazil, it can be seen that annual per capita CO2 emission figures of the nation peaked at around 2013–2014 before starting to decline from then onwards. On the other hand, the per capita CO2 emission figures of Russia have depicted the highest degree of volatility among the BRICS countries. Besides, Russia also observed to have the highest per capita CO2 emission level.

In the cases of both India and China, the trends show that their annual per capita CO2 emissions levels have grown at a steady pace, and these trends are evidenced to be less volatile compared to the corresponding CO2 emission trends in Brazil, Russia, and South Africa. However, although depicting steady trends, the per capita CO2 emission figures of China are way more than the per capita CO2 emission levels of India. Lastly, the annual per capita CO2 emission levels of South Africa also portray highly volatile trends like Russia. Besides, South Africa holds the second position among the BRICS nations in rank of the per capita level of annual CO2 emissions. Therefore, these trends tend to indicate that all the BRICS nations have, by and large, not managed to safeguard their environmental well-being and, therefore, can be assumed to have followed inappropriate decarbonization paths. In this regard, the findings generated from this current study can be expected to mend the conventional decarbonization pathways in order to assist these nations to comply with both local and domestic commitments regarding environmental development.

Literature review and hypothesis buildup

This section systematically summarizes the findings of the previous studies that have looked into the impacts of FDI inflows, governance, democracy, renewable energy consumption, and economic growth on CO2 emissions. Besides, this section also aims to justify the decision to consider the explanatory variables to assess their impacts on the CO2 emission figures on the BRICS countries.

The literature on FDI inflows and CO2 emissions

The effects of FDI inflows on environmental quality in the FDI-hosting nations can be both favorable and adverse. In this regard, two alternative hypotheses explain the equivocal environmental effects associated with FDI inflows. Firstly, highlighting the adverse environmental consequences of hosting FDI, the pollution haven hypothesis states that as foreign investments flow into the host nations, the environmental quality tends to deteriorate (Al-Mulali et al.

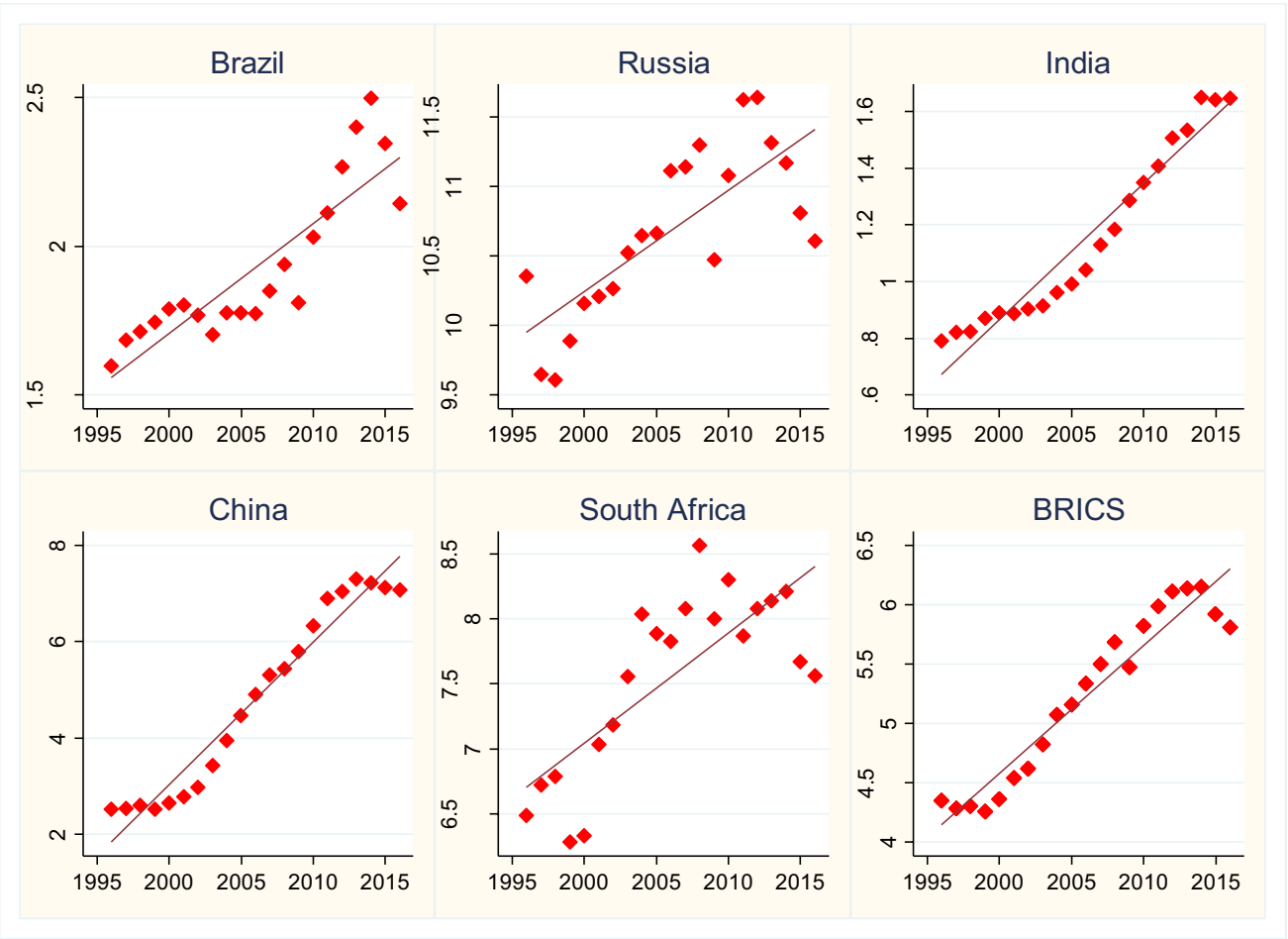

Fig. 1 The per capita annual CO2 emission trends in the BRICS countries. Note: The figures are annual levels of per capita CO2 emissions in metric tons. Source: World Development Indicators (World Bank 2021a)

2015; Danish and Ulucak 2022). This phenomenon can be explained from the understanding that the incoming funds are likely to be invested in dirty industries whereby the energy demand within these industries is likely to go up; consequently, the level of CO2 emissions increases as well. Secondly, the pollution halo effect hypothesis highlights the favorable environmental consequences associated with FDI (Azam et al. 2019; Wang and Wang 2021). In this regard, these FDI are assumed to be invested in clean industries within the host nations, whereby the possibility of FDI contributing to higher CO2 emissions is minimized.

Accordingly, the FDI inflows-CO2 emissions nexus has been tested in light of these two hypotheses. Among the related studies supporting the pollution haven hypothesis and highlighting the harmful environmental effects of FDI inflows, Khan et al. (2020a) used data from the BRICS nations from 1986 to 2016 and found that higher FDI inflows contribute to higher emissions of CO2. Besides, the country-specific outcomes showed that apart from Russia, the pollution haven hypothesis hold for the other BRICS countries. In another study on the BRICS between 1991 and 2018, Muhammad et al. (2021) also concluded that the pollution haven hypothesis is valid. In contrast, several studies have also claimed that the pollution haven hypothesis does not hold for these countries. Among these, Shao et al. (2019) used annual data from 1982 to 2014 from the BRICS and MINT[2] countries and discovered that the pollution haven hypothesis does not hold for both these groups of countries. Similarly, Pradhan et al. (2021) used annual data from 1992 and 2014 and stated that FDI inflows help to curb CO2 emissions, whereby the pollution halo effect hypothesis is valid for the case of the BRICS nations. Hence, it can be seen that the effects of FDI inflows on the CO2 emission figures of the BRICS nations are uncertain. Moreover, since these studies have controlled for different macroeconomic variables, it can be claimed that the FDI inflows-CO2 emissions nexus is influenced by other macroeconomic variables as well.

[2] MINT abbreviates for Mexico, Indonesia, Nigeria, and Turkey.

Among the other related studies, Sapkota and Bastola (2017) stated that incoming FDI is harmful to the environment in the Latin American countries since a 1% influx of these foreign funds tends to increase CO2 emissions by 0.04%. In another recent study on 21 developing and developed countries, Singhania and Saini (2021) remarked that FDI inflows boost the level of carbon intensity; hence, the authors concluded that the pollution haven hypothesis hold for these countries, especially the developing ones. In addition, the authors also pointed out that institutional factors and financial development play a key role in influencing the environmental effects associated with FDI inflows. Similarly, in the context of five Southeast Asian states, namely Indonesia, Malaysia, Philippines, Singapore, and Thailand, Guzel and Okumus (2020) also advocated in favor of the pollution haven hypothesis to hold. The pollution haven hypothesis concerning the FDI inflows-CO2 emissions nexus was also validated in the studies by Assamoi et al. (2020) for Cote d'Ivoire, Bulut et al. (2021) for Turkey, and Gyamfi et al. (2021) for the Sub-Saharan African nations.

On the other hand, Kurramovich et al. (2022) reported that the pollution haven hypothesis does not hold for Japan since higher FDI inflows could not influence the CO2 emission levels of the country. Likewise, in another study on selected Asian nations, Kisswani and Zaitouni (2021) also concluded that FDI inflows are ineffective in influencing the CO2 emissions level of Thailand; however, the pollution halo effect was affirmed for the cases of Malaysia and Singapore as FDI influx into these nations were associated with higher CO2 emissions. Besides, Chen et al. (2022) stated that FDI inflows do not harm the environment in China by stimulating CO2 emissions and rather enhance energy efficiency to pin down the Chines CO2 emission figures. Therefore, although the findings from the previous studies show heterogeneity, keeping into consideration the rising trends in both the levels of FDI inflows and CO2 emissions of the BRICS nations over the study period, we hypothesize that:

H1: FDI inflows harm the environment by boosting CO2 emissions in the BRICS countries

The literature on governance and CO2 emissions

Governance, through its impact on institutional quality, can significantly impact a country's environmental quality, and they are critical for economic stability (Abid 2017). There are several governance-related indicators which include corruption, rule of law, regulatory quality, voice and accountability, and political violence, in particular (World Bank 2021b). These factors can be linked with environmental governance, whereby a decline in the quality of governance can be assumed to degrade the environment while better governance can lead to desirable environmental consequences. For example, corruption exerts negative influences on the environment by undermining environmental welfare-related projects whereby CO2 emissions are likely to surge (Damania et al. 2003). As a result, controlling corruption is often referred to as a credible means of mitigating CO2 emissions (Abid 2017). On the other hand, the establishment of a strong rule of law is likely to ensure proper implementation of regulations and oblige firms to follow ecological safety standards; consequently, the associated CO2 emissions can be contained (Zebro and Darne 2019; Muhammad et al. 2020).

The empirical literature on the nexus between governance and CO2 emissions is pretty limited. Among the few studies in this issue, Danish et al. (2019) used annual data from 1996 to 2017 and concluded that better governance across the BRICS countries helps to curb their CO2 emission figures in the long run. In another study on five highly polluted global nations (China, Japan, India, Russia, and the USA), Liu et al. (2020) found evidence of better political, economic, and institutional governance being favorable for the environment since these exert CO2 emission-inhibiting effects. Using government effectiveness as an indicator of governance quality for 170 global economies, Al-Mulali et al. (2021) opined that better governance helps to abate emissions of CO2. Besides, the CO2-impeding effect of governance is more prominent in countries with high and moderate levels of government effectiveness but not quite so for nations with low levels of government effectiveness. Since the majority of the preceding studies have emphasized the requirement of good governance in respect of, we hypothesize that:

H2: Good governance reduce CO2 emissions in the BRICS countries

The literature on democracy and CO2 emissions

In respect of the environment, democracy is commonly associated with the extent of freedom whereby economic agents can exercise their rights to ensure better environmental quality. For instance, in the presence of a sound democratic environment, citizens can exercise their freedom of expression to pressurize the government to enact strict environmental protection laws. In contrast, relatively autocratic regimes hamper freedom of expression whereby the governments serve the vested interests of certain groups; consequently, agents of pollution-intensive industries can look to exploit the democratic loopholes and continue to pollute the environment (Li and Reuveny 2006). Among the empirical studies on the democracy-CO2 emissions nexus, Usman et al. (2019) used the Polity2 index as a proxy for democracy in India and found that better democracy helps to curb CO2 emissions in the short-run but not in the long run. Similarly,

using a global panel data set, Haseeb and Azam (2021) measured democracy using the democracy index provided by the Freedom House database and remarked that better democracy helps to curb CO2 emissions in middle-income and high-income countries but not in low-income countries. Besides, the CO2 emission-inhibiting effect of democracy was relatively higher for the upper-middle-income nations.

Although several aspects of governance have been considered within the environmental economics narrative, the freedom of press dimension has largely remained overlooked. It is believed that in the presence of freedom of the press and other media, environmental governance tends to be more efficient in limiting pollution (Bruch and Czebiniak 2002; Umudov 2021). This is because, when the reporting agencies are let to work freely, there is transparency in the management of environmental protection policies both at the private and the public levels and, therefore, enhances accountability against environmental pollution (Blair 2008). However, despite the strong theoretical settings, empirical works on the media freedom-CO2 emissions nexus have been very limited. Among the very few previous studies, Uzar (2021) used data from the Emerging Seven (E7) countries and found evidence of better freedom of the press is efficient in impeding emissions of CO2. Besides, the authors also concluded that freedom of the press helps to reduce the adverse effects of economic growth on CO2 emissions. In another relevant study on the top ten global economies with the highest degrees of freedom of the press, Riti et al. (2021) also documented evidence of higher press freedom resulting in lower levels of CO2 emissions. Therefore, based on these findings, it can be hypothesized that:

H3: Better democracy reduce CO2 emissions in the BRICS countries

The literature on renewable energy use and CO2 emissions

Energy use is a central driver of both economic growth and CO2 emissions (Bhattacharya et al. 2016; Wang and Zhan 2019; Ozcan and Ozturk 2019). Hence, preceding studies have extensively explored the environmental effects accompanying higher use of energy. Initially, these studies most analyzed the energy-pollution nexus using aggregate levels of energy consumption (Ozturk and Acaravci 2010; Ozturk et al. 2010). However, later on, considering the heterogeneous environmental effects associated with different types of energy, researchers have focused on exploring the impacts of clean and unclean energy on CO2 emissions (Ben Jebli et al. 2015; Ahmad et al. 2021). The majority of these studies have concluded that although all forms of energy homogenously contribute to higher economic growth (Zachariadis 2007; Wang and Wang 2020), clean energy use helps to reduce CO2 emissions, while unclean energy consumption is associated with higher CO emissions.

In a study on 74 global economies, Sharif et al. (2019) concluded that renewable and non-renewable energy consumption contributes to lower and higher CO2 emissions, respectively. Adedoyin et al. (2021) used data from Sub-Saharan African nations and discovered that higher production of non-renewable energy boosts CO2 emissions in these countries. In the context of the BRICS nations, Danish et al. (2019) stated that renewable energy helps to curb CO2 emissions. In contrast, Chishti and Sinha (2022) stated that higher consumption of fossil fuels leads to higher emissions of CO2 in the BRICS countries. In another relevant study on 15 Asian economies, Anwar et al. (2021) asserted that renewable energy use inflicts better environmental outcomes by reducing the CO2 emissions levels across the Asian continent. Zafar et al. (2021) analyzed the impacts of biomass consumption on the CO2 emission figures of selected Asia–Pacific Economic Cooperation (APEC) countries. The results indicated that the use of biomass energy, which is an unclean energy source, expectedly results in a greater discharge of CO2 emissions into the atmosphere. Therefore, based on the opposing views presented in the literature and considering the fossil fuel dependency of the BRICS countries, it can be hypothesized that:

H4: Renewable energy consumption boosts CO2 emissions in the BRICS countries

The literature on economic growth and CO2 emissions

Economic activities, especially those fueled by fossil fuel consumption, resulting in emissions of CO2 (Salahuddin et al. 2016). On the other hand, technological innovation can help to phase out the economic growth-CO2 emissions trade-off to restore environmental quality (Bakhsh et al. 2017). This heterogeneous environmental effect of economic growth is conventionally explained using the environmental Kuznets curve (EKC) hypothesis proposed by Grossman and Krueger (1995). According to this hypothesis, the economic growth-CO2 emission nexus depicts an inverse *U*-shape to justify the initial adverse and ultimate favorable impacts of economic growth on the environment (Murshed et al. 2020; Khezri et al. 2022). In a study on the BRICS countries from 1990 to 2018, Caglar et al. (2022) documented evidence of higher economic growth accompanying higher CO2 emissions in the long run. Similarly, using data for the BRICS countries from 1990 to 2014, Sarwat et al. (2021) remarked that the EKC hypothesis for CO2 emissions is valid. Recently, Cheng and Hu (2022) used annual data for China from 1997 to 2018 and discovered that economic growth initially degrades environmental well-being by boosting CO2

emissions but eventually reinstates environmental welfare by curbing the emissions levels; consequently, the EKC hypothesis was sad to hold for China.

Salahodjaev et al. (2022) also explored the environmental effects of economic growth in the context of selected European and Central Asian nations. The results showed that the relationship between economic growth and CO2 emissions is inverted *U*-shaped based on which the authors affirmed the authenticity of the EKC hypothesis for these countries. Similarly, in the context of certain Middle Eastern and North African (MENA) countries, Cheikh et al. (2021) asserted that economic growth boosts CO2 emissions only in countries that have registered high growth in their energy consumption profiles. Although several studies have tested the authenticity of the EKC hypothesis, a couple of them have also condemned the use of a quadratic term to assess the non-linearity between economic growth and environmental quality indicator (Yıldırım et al. 2021; Aydin et al. 2021). As a result, several studies have evaluated the effects of economic growth on CO2 emissions using linear model specifications such as the Stochastic Impact by Regression on Population, Affluence, and Technology (STIRPAT) model developed by (Dietz and Rosa 1997). This technique expresses CO2 emissions as a linear function of population size, economic growth (affluence), and technological innovation. Several studies have used the STIRPAT model to verify the economic growth-CO2 emissions nexus (Wang et al. 2022; Xue et al. 2022). Therefore, as per the findings of these abovementioned studies and the issue of fossil fuel dependence among the BRICS nations, it can be hypothesized that:

H5: Economic growth boosts CO2 emissions in the BRICS countries

Model, data, and econometric methods

Empirical model specification and data

As per the objectives of this study, we consider an augmented-STIRPAT model to identify the determinants of CO2 emissions in the BRICS countries. Accordingly, the baseline model can be shown as

$$\mathrm{LCO2PC_{it}} = \delta_{\mathrm{o}} + \delta_1 \mathrm{FDI}_{it} + \delta_2 \mathrm{GOV}_{it} + \delta_3 \mathrm{DEMOC}_{it} + \delta_4 \mathrm{REC}_{it} + \delta_5 \mathrm{LRYPC}_{it} + \varepsilon_{it} \quad (1)$$

where i represents the individual BRICS countries; t refers to the period of the study (1996–2017); ε is the error term. The prefix L indicates the natural logarithm of the respective variable which is done to predict the elasticities of CO2 emissions in response to marginal positive shocks to the explanatory variables. δ_0 is the intercept parameter and $\delta_k (k = 1, 2, \ldots 5)$ are the elasticity parameters that are to be predicted. The outcome variable CO2PC stands for the per capita annual CO2 emission figures of the BRICS nations (measured in terms of metric tons). Several preceding studies have that have been recently published have considered CO2 emissions as an indicator of environmental well-being (Espoir et al. 2022; Mirza et al. 2022; Shahbaz et al. 2022). The explanatory variables are as follows:

- FDI refers to the percentage share of net FDI receipts in the gross domestic product (GDP) of the respective BRICS country. A rise in this share can be interpreted as a rise in the level of influx of FDI into these countries. If the predicted sign of the elasticity parameter δ_1 is positive and statistically significant, then the pollution haven hypothesis would be validated for the BRICS countries (Danish and Ulucak 2022). In contrast, if it is negative and statistically significant, then the pollution hale effect hypothesis would be affirmed (Xiahou et al. 2022).
- GOV refers to governance which is proxied by the control of the corruption index. This index ranks the BRICS countries in terms of their respective degrees of corruption control initiatives; the higher the value of the index, the lower the corruption, the better the level of governance and vice versa (World Bank 2021b).
- DEMOC refers to democracy which is innovatively proxied using the freedom of journalists index that assesses whether the journalists across the BRICS nations feel that they are harassed and are deprived of their freedom of expression; the higher the value of the index the higher the freedom for journalists (the better the democratic environment) and vice-versa (Coppedge et al. 2019).
- REC stands for the percentage share of renewable in the total final energy consumption level of the respective BRICS nations (World Bank 2021a). Therefore, a rise in this share can be interpreted as a decline in the level of fossil fuel dependency and vice-versa. In relation to the STIRPAT model, this variable represents technology since renewable energy consumption is conditional on technological advancement (Ahmed et al. 2021).
- RYPC stands for the annual per capita GDP level of the respective BRICS nation (measured in constant 2015 US$), which is used to proxy for economic growth. A rise in the value of this variable can be interpreted as economic growth and vice-versa. In relation to the STIRPAT model, this variable represents affluence.

Further, to test the potential mediation/moderating role of governance and democracy on the relationships between CO2 emissions and other major macroeconomic variables, we introduce some interaction terms in our baseline model which can be shown as follows:

Table 1 The Pesaran (2004) cross-sectional dependency outcomes

Variable	LCOPC	FDI	GOV	DEMOC	REC	LRYPC
Pesaran (2004) test stat	−2.443** (0.034)	2.775*** (0.001)	−0.799 (0.424)	−3.114*** (0.001)	−4.114*** (0.000)	−3.224*** (0.002)

The test statistics are estimated under the null hypothesis of cross-sectional independence; *** represents statistical significance at 1% and 5% levels

$$\mathrm{LCO2PC}_{it} = \delta_o + \delta_1 \mathrm{FDI}_{it} + \delta_2 \mathrm{GOV}_{it} + \delta_3 \mathrm{DEMOC}_{it} + \delta_4 \mathrm{REC}_{it} + \delta_5 \mathrm{LRYPC}_{it} + \delta_6 (\mathrm{FDI} * \mathrm{GOV})_{it} + \varepsilon_{it} \quad (2)$$

$$\mathrm{LCO2PC}_{it} = \delta_o + \delta_1 \mathrm{FDI}_{it} + \delta_2 \mathrm{GOV}_{it} + \delta_3 \mathrm{DEMOC}_{it} + \delta_4 \mathrm{REC}_{it} + \delta_5 \mathrm{LRYPC}_{it} + \delta_7 (\mathrm{FDI} * \mathrm{DEMOC})_{it} + \varepsilon_{it} \quad (3)$$

$$\mathrm{LCO2PC}_{it} = \delta_o + \delta_1 \mathrm{FDI}_{it} + \delta_2 \mathrm{GOV}_{it} + \delta_3 \mathrm{DEMOC}_{it} + \delta_4 \mathrm{REC}_{it} + \delta_5 \mathrm{LRYPC}_{it} + \delta_8 (\mathrm{LRYPC} * \mathrm{GOV})_{it} + \varepsilon_{it} \quad (4)$$

$$\mathrm{LCO2PC}_{it} = \delta_o + \delta_1 \mathrm{FDI}_{it} + \delta_2 \mathrm{GOV}_{it} + \delta_3 \mathrm{DEMOC}_{it} + \delta_4 \mathrm{REC}_{it} + \delta_5 \mathrm{LRYPC}_{it} + \delta_9 (\mathrm{LRYPC} * \mathrm{DEMOC})_{it} + \varepsilon_{it} \quad (5)$$

where the variable FDI*GOV represents the interaction term between FDI inflows and governance, FDI*DEMOC represents the interaction term between FDI inflows and democracy, LRYPC*GOV represents the interaction term between economic growth and governance, and LRYPC*DEMOC represents the interaction term between economic growth and democracy.

Annual data for all the above-mentioned variables are taken in annual frequencies from 1996 to 2016. Since governance-related data was unavailable before 1996 and CO2 emission data was unavailable after 2016, the period of this study had to be kept short. The data for CO2 emissions, economic growth, renewable energy consumption, and FDI inflows are compiled from the World Development Indicators database of the World Bank (2021a). The control for corruption data is sourced from the Worldwide Governance Indicators database of the World Bank (2021b). Lastly, the freedom of journalist data is derived from the Varieties of Democracy database (Coppedge et al. 2019).

Estimation strategy

The estimation strategy is classified into two categories. In the former, some pre-estimation tests are conducted to design the estimation techniques. In the latter, the subsequent methods are designed keeping into consideration the outcomes generated in the pre-estimation analysis.

As far as the pre-estimation tests are concerned, we conduct the cross-sectional dependency and slope heterogeneity analysis. Both these panel data problems, if left unaccounted for, have been recognized to generate biased and inconsistent outcomes (Dong et al. 2018; Khan et al. 2020b). Therefore, firstly, we use the Pesaran (2004) method for assessing the possible dependency amid the cross-sectional units (i.e., BRICS nations). Since the BRICS nations are connected through various globalization activities, the issue of cross-sectional dependency is most likely to be found. Table 1 presents the outcomes of the Pesaran (2004) analysis. It is evident that all the predicted test statistics are statistically significant; consequently, the null hypothesis of cross-sectional independence does not hold. The cross-sectional dependency analysis is followed by the analysis of slope heterogeneity.

Since the different cross-sectional units (i.e., BRICS nations) have certain unique features, hence it can be assumed that the predicted slope coefficients are heterogeneous across the respective cross-sections. Under such circumstances, the issue of slope heterogeneity can exist. To test this hypothesis, we employ the Pesaran and Yamagata (2008) test for slope homogeneity. The corresponding outcomes, as presented in Table 2, show that for all five models, the predicted test statistics are statistically significant. Thus, the statistical significance rejects the null hypothesis of homogeneous slope coefficients to affirm the issue of slope heterogeneity in the data.

Since the results affirm that the data set used in this study is cross-sectionally dependent and heterogeneous, the unit root, cointegration, regression, and causality methods should be designed including techniques that consider these issues. For conducting the unit root analysis, we employ the cross-sectionally adjusted Im-Psaran-Shin (CIPS) method proposed by Pesaran (2007). This technique predicts the integrating properties of the variables considering cross-sectional dependence. Similarly, considering the cross-sectional dependency concerns, we use the Westerlund (2007) cointegration technique to predict the long-run relationships among the variables in all five models. Following the unit root and cointegration analyses, the panel regression analysis is performed using the augmented mean group (AMG) estimator of Eberhardt and Teal (2010). This method is believed to be efficient in handling cross-sectional dependency, slope heterogeneity, and endogeneity (İnal et al. 2022; Wolde-Rufael and Mulat-Weldemeskel 2022). Finally, the Dumitrescu and Hurlin (2012) panel causality estimation technique is utilized for identifying the causal direction among the variables of concern. This method is also efficient in handling

Table 2 The Pesaran and Yamagata (2008) slope homogeneity outcomes

Test stat	Model 1	Model 2	Model 3	Model 4	Model 5
$\hat{\Delta}$	30.150***	31.125***	26.130***	31.125***	29.154***
$\widehat{\Delta_{adj.}}$	33.146***	33.780***	29.255***	34.309***	32.478***

The test statistics are estimated under the null hypothesis of homogeneous slope coefficients; *** represents statistical significance at a 1% level

Table 3 The outcomes from the CIPS panel unit root analysis

Variable	Test statistic	Variable	Test statistic	Decision
LCO2PC	− 1.424	ΔLCO2PC	− 2.842***	Stationary at first difference
FDI	− 2.682	ΔFDI	− 4.742***	Stationary at first difference
GOV	− 2.140	ΔGOV	− 3.028***	Stationary at first difference
DEMOC	− 0.977	ΔDEMOC	− 3.172***	Stationary at first difference
REC	− 1.755	ΔREC	− 3.475***	Stationary at first difference
LRYPC	− 1.802	ΔLRYPC	− 2.751***	Stationary at first difference

The test statistics are estimated considering trend and under the null hypothesis of non-stationarity; Δ stands for first difference; the Bayesian information criterion (BIC) is considered for optimal lag selection; *** represents statistical significance at 1% level

Table 4 The outcomes from the Westerlund (2007) cointegration analysis

Test statistic	Model 1	Model 2	Model 3	Model 4	Model 5
Gt	− 4.150***	− 3.500***	− 3.299***	− 3.600***	− 3.950***
Ga	− 15.139	− 12.300	− 13.145	− 12.200	− 12.762
Pt	28.150***	24.244***	26.009***	24.205***	25.230***
Pa	16.130***	15.508***	16.130***	15.209***	15.111***

The test statistics are estimated considering the null hypothesis of no cointegrating relationship among the variables in the respective model and are calculated using 5000 bootstrapped replications; the BIC is considered for optimal lag selection; *** represents statistical significance at 1% level

heterogeneous and cross-sectionally dependency issues in panel data sets (Iqbal et al. 2022).

Empirical results and discussion

The outcomes from the CIPS panel unit root analysis are presented in Table 3. This technique predicts test statistics to verify the null hypothesis of no unit root of the series of concerns. Hence, it can be seen that the test statistics for all variables are insignificant at the level form but significant at the first difference. Therefore, in light of these findings, we can claim that the variables are homogeneously integrated at the first difference.

In Table 4, the outcomes from the Westerlund (2007) cointegration analysis are presented. This technique estimates four test statistics for each model under the null hypothesis of no cointegration among the variables of concern. Hence, the statistical significance of these test statistics affirms long-run relationships between CO2 emissions, governance, democracy, renewable energy consumption, and economic growth. Consequently, the long-run effects of the explanatory variables on the CO2 emission figures of the BRICS countries are predicted by conducting the panel regression analysis.

Table 5 presents the outcomes from the AMG analysis on all five models. The results from the baseline model (i.e., model 1) show that influxes of FDI into the BRICS countries do not influence their per capita CO2 emission figures. This statement is certified by the positive sign but statistical insignificance of the predicted elasticity parameter attached to the variable FDI in all five models. Therefore, this finding neither verifies the pollution haven hypothesis nor the pollution halo effect hypothesis for the BRICS countries. This finding contradicts the conclusions put forward by Marques and Caetano (2020), where the authors asserted that FDI inflows help to curb CO2 emissions in developed countries in the long run. The dissimilarity of the findings can be due to the BRICS countries do not fall under the developed country classification. As a result, these nations are likely

Table 5 The outcomes from the AMG panel regression analysis

Dependent variable: LCO2PC					
Regressors	Model 1	Model 2	Model 3	Model 4	Model 5
FDI	0.020	0.030	0.055	0.049	0.052
	(0.035)	(0.053)	(0.037)	(0.039)	(0.041)
GOV	−0.899***	−0.917***	−0.781***	−0.685***	−0.686***
	(0.199)	(0.139)	(0.102)	(0.123)	(0.131)
DEMOC	−0.055***	−0.053***	−0.056***	−0.071***	−0.076***
	(0.007)	(0.008)	(0.014)	(0.012)	(0.016)
REC	−0.490***	−0.434***	−0.438***	−0.506**	−0.512***
	(0.147)	(0.105)	(0.114)	(0.250)	(0.210)
LRYPC	0.143***	0.155***	0.149***	0.130***	0.141***
	(0.011)	(0.012)	(0.013)	(0.022)	(0.025)
FDI*GOV		−0.145**			
		(0.071)			
FDI*DEMOC			−0.085**		
			(0.042)		
LRYPC*GOV				−0.150***	
				(0.034)	
LRYPC*DEMOC					−0.095***
					(0.023)
Constant	0.402***	0.289**	0.322***	0.410***	0.445***
	(0.101)	(0.114)	(0.124)	(0.151)	(0.162)
Observations	90	90	90	90	90

The standard errors are provided within the parentheses; *** and ** represent statistical significance at 1% and 5% levels

to be unable to make use of foreign investments for abating CO2 emissions.

Besides, the results point out that better governance can improve environmental well-being by curbing CO2 emissions in the BRICS nations. The corresponding elasticity estimate (associated with the variable GOV) shows that if the control for corruption index (denoted by GOV) increases by 1%, then the per capita CO2 emission levels on the average decline by around 0.9%, *ceteris paribus*. Therefore, this finding justifies the assumption of good governance within emerging economies being effective in facilitating environmental governance. This is because it is believed that corruption undermines environmental welfare-enhancing initiatives to exert adverse consequences (Damania et al. 2003). Our findings corroborate the views presented in the study by Abid (2017) in which the author claimed that reducing the incidence of corruption can help to impede higher emissions of CO2.

Similar to governance, the baseline model findings show that better democracy is associated with better environmental conditions for the BRICS nations. The corresponding elasticity estimate (associated with the variable DEMOC) indicates that a 1% rise in the degree of journalism freedom helps to reduce the per capita CO2 emission levels on average by 0.06%, *ceteris paribus.* This could be because if the journalists within the BRICS nations are less harassed or reporting environmental malpractices at both public and private domains, pollution activities can be brought in front of the public. Consequently, the economic agents responsible for polluting the environment can be penalized. As a result, the CO2 emission growth can be contained through efficient monitoring of environmental misconduct. Thus, creating a democratic environment by letting the journalist exercise their freedom of expression and by shielding the media from undemocratic practices can be assumed to complement the carbon-neutrality agenda of the BRIC nations. The role of better democracy in safeguarding environmental well-being has also been mentioned in the preceding studies by Uzar (2021) for the E7 countries, Haseeb and Azam (2021) for high-income and middle-income countries, and Usman et al. (2019) for India.

Among the other major findings, we can see that transitioning from unclean to clean fuel consumption can impose better environmental effects in the BRICS countries. This is because, the elasticity estimate (associated with the variable REC) shows that a 1% rise in the share of renewables in the total final energy consumption figures of the BRICS nations is seen to reduce their per capita CO2 emission figures on average by 0.5%, *ceteris paribus*. This is an expected finding but nevertheless a significant one from the perspective

of these fossil fuel-dependent emerging nations. Since these countries have heavily banked on both locally sourced and imported fossil fuels to perform their respective economic activities, the combustion of these hydrocarbon-intensive fuels has led to the surge in their CO2 emission levels as well. As a result, declining such traditional fossil fuel dependency is imperative for these nations to achieve their environmental development targets. Similar favorable environmental outcomes accompanying higher use of renewable energy resources were reported in the study by Anwar et al. (2021) for the selected Asian nations.

Furthermore, the baseline findings also highlight the economic growth-environmental degradation trade-off across the BRICS countries. The corresponding elasticity estimate (associated with the variable LRYPC) shows that a 1% rise in the real GDP figure of the BRICS countries boosts their per capita CO2 emission figures on average by 0.14%, *ceteris paribus*. Hence, this finding supports the view that these nations have not quite managed to decouple their favorable economic performances from adverse environmental consequences. This could be because the BRICS countries are probably at the development stage at which they are prioritizing to implement policies that can enable them to expand their respective economies at the expense of poorer environmental quality. This assertion is supported by China's stance of peaking its CO2 emissions up to 2030 and ultimately achieving carbon-neutrality by 2060 (Liu et al. 2021). Hence, it is imperative for the BRICS countries to identify relevant factors that can facilitate their decoupling strategies to achieve low-carbon growth. Caglar et al. (2022) also documented evidence of higher economic growth resulting in higher CO2 emissions in the BRICS countries.

Now analyzing the regression outcomes for models 2–5, it can be seen that both governance and democracy mediate between FDI inflows and CO2 emissions in the context of the BRICS countries. The negative signs of the statistically significant elasticity estimates (associated with the interaction terms FDI*GOV and FDI*DEMOC), in models 2 and 3, suggest that the inhibiting effects of FDI inflows on CO2 emissions are conditional on between governance and democratic settings. This can be explained from the point of view that strong institutional quality, led by better control of corruption and greater freedom for journalists, can restrict the inflows of unclean FDI into the BRICS nations. Therefore, these findings highlight the mediating roles of good governance and better democracy in validating the pollution haven hypothesis for these countries. The importance of stronger institutional quality in validating the pollution haven hypothesis was also acknowledged in the preceding studies by Solarin et al. (2017) for Ghana and Huynh and Hoang (2019) for selected developing countries across Asia.

Besides, the regression outcomes in the context of models 4 and 5 highlights that both governance and democracy perform the role of a moderator to reduce the adverse environmental effects of economic growth in the BRICS countries. The positive signs of the statistically significant elasticity estimates (associated with the interaction terms LRYPC*GOV and LYRPC*DEMOC) suggest that despite higher economic growth stimulating higher CO2 emissions, in the presence of good governance and a better democratic environment, these effects are likely to be reversed. These findings further reinforce the moderating role of good governance and better democracy in decoupling economic growth from CO2 emissions for the BRICS countries. This is because lowering corruption and reducing harassment of journalists can help to prevent the economic agents from polluting the environment due to the fear of getting penalized for their actions. Such apprehensions are likely to enhance accountability whereby these agents are likely to perform their economic activities using cleaner resources and also motivate them to invest in adopting pollution-control measures. The decoupling role of better institutional quality, achieved through good governance and better democratic arrangement, was also acknowledged by Nwani and Adams (2021) for a sample of 93 global economies. The authors asserted that institutional quality helps these nations to attain low-carbon growth by reducing the adverse environmental effects of natural resources employed for generating the national output.

Finally, the Dumitrescu and Hurlin (2012) panel causality test is performed to ascertain the causal associations between CO2 emissions and the explanatory variables of concern. The causality findings are presented in Table 6. The results show that unidirectional causalities are stemming from FDI inflows, governance, democracy, and renewable energy consumption to CO2 emissions. Therefore these findings support the corresponding long-run estimates derived from the regression analysis. Moreover, the causality outcomes also reveal bidirectional causal linkages between economic growth and CO2 emissions, which suggest the inter-linkages between these variables.

Conclusion and policy recommendations

The BRICS countries are five of the rapidly growing global economies. At the same time, these nations are also classified as highly polluted nations in the world. Hence, these contrasting characteristics indicate that these nations have not managed to attain low-carbon economic growth due to prioritizing economic gains over environmental losses. However, given the relevance of adopting credible environmental policies to tackle the issues of climate change, it has become essential for the BRICS countries to look for pathways that

Table 6 The outcomes from Dumitrescu–Hurlin causality analysis

Null hypothesis	*Z*-bar tilde statistic	Decision
FDI ≥ LCO2PC	9.349***	Causation exists
LCO2PC ≥ FDI	1.123	Causation does not exist
GOV ≥ LCO2PC	6.358***	Causation exists
LCO2PC ≥ GOV	0.129	Causation does not exist
DEMOC ≥ LCO2PC	8.114***	Causation exists
LCO2PC ≥ DEMOC	1.401	Causation does not exist
REC ≥ LCO2PC	4.0896**	Causation exists
LCO2PC ≥ REC	–0.045	Causation does not exist
LRYPC ≥ LCO2PC	6.134***	Causation exists
LCO2PC ≥ LRYPC	7.234***	Causation exists

Note: ≥ implies does not Granger cause; the BIC is used for optimal lag selection; the test statistics are estimated considering 5000 bootstrapped replications; *** and ** represent statistical significance at 1% and 5% levels

can enable them to decarbonize their respective economies without negatively affecting their growth momentums. Moreover, these nations are also committed to curbing their CO2 emission figures courtesy of ratifying the Paris Agreement. Against this background, this study aimed to check whether FDI inflows, good governance, a better democratic environment, higher renewable energy consumption, and greater economic growth can mitigate CO2 emissions across the BRICS nations over the 1996–2017 period. Besides, the potential mediating/moderating roles of governance and democracy are also investigated.

The overall findings revealed long-run cointegration among the study variables. Besides, the regression analysis showed that although FDI inflows directly cannot influence the emission figures, they tend to depend on good governance and a better democratic setting to mitigate CO2 emissions in the BRICS nations. Besides, both good governance (proxied by better corruption control) and stronger democracies (proxied by greater freedom of journalists) are witnessed to impede CO2 emissions. Similarly, a transition towards cleaner energy use is observed to reduce CO2 emissions further. However, in the context of economic growth, it was found that as the economies of the BRICS countries grow, the economic growth performances inflict a trade-off by boosting the CO2 emission levels. But interestingly, the results also revealed that good governance and better democracy help to curb CO2 emissions by mediating between FDI inflows and CO2 emissions. In addition, these variables are also found to act as moderators to reverse the adverse environmental consequences attached to economic growth within the BRICS nations. Therefore, these outcomes impose key environmental development-related policy recommendations for the associated governments.

Among several such policies, it is recommended that the BRICS countries should enhance the quality of governance by restricting corruption practices within their respective economies. In addition, they should also focus on building stronger democratic environments by proving better opportunities to the journalists for exercising their freedom rights. As a result, such policy initiatives can be assumed to strengthen the overall quality of institutions in the BRICS countries, which would not only directly contribute to lowering their CO2 emission figures but would also indirectly assist in curbing CO2 emissions via financial globalization and economic growth channels. Besides, the BRICS nations should also attract clean FDI so that influxes of such foreign funds can directly help to inhibit CO2 emissions. More importantly, these nations should attract FDI for the development of renewable energy technologies so that their conventional fossil fuel dependency can be eased out. Lastly, it is imperative for the BRICS nations to adopt and implement environmentally sustainable production and consumption strategies so that the target of low carbon economic growth can be realized.

Data limitation is the major issue faced in conducting this study. Consequently, the length of the study period could not be extended beyond 2016. Besides, since the analysis solely focused on the BRICS nations, the external validity of the findings cannot be ensured unless a similar study is conducted using a counterfactual sample of other global economies. Furthermore, this current study can be replicated using alternate environmental impact indicators to check the robustness of the findings taking into consideration the other dimensions of environmental well-being.

Author contribution IH conceptualized and wrote the original draft. MSA compiled the literature review and generated the graphical illustrations, reviewed and edited the final draft. AK wrote the introduction, compiled the literature review, and contributed to the methodology section. PKJ Supervised and reviewed the whole work. MM wrote the original draft, conducted the econometric analysis, analyzed the findings, and recommended the policy implications. RA provided computational support and contributed to the revision.

Availability of data and materials Data will be made available upon request.

Declarations

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