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RESEARCH ARTICLE

Green economy design in BRICS: dynamic relationship between financial inflow, renewable energy consumption, and environmental quality

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Abstract
Foreign direct investment (FDI) and remittances are a source of financing that allows the environment to be clean by promoting green innovation. This study empirically examines the impact of financial inflow on renewable energy consumption and environmental quality in BRICS over the period of 1991–2019. The basic results emanate from the NARDL-PMG but robustness observed through FMOLS and DOLS. A positive change in FDI has a positive effect on CO2 emissions, whereas a negative change in FDI significantly reduces CO2 emissions in the long run, while positive and negative shocks to remittance increase the renewable energy consumption in the long run. A positive shock in remittance has no significant impact on CO2 emissions, while a negative shock in remittance leads to an increase in CO2 emissions in the long run. Our results are robust to different econometric methods. The findings of the study have some implications for devising renewable energy consumption and CO2 emission reduction policies in BRICS.

Keywords Financial inflow · Renewable energy consumption · Environmental quality · NARDL-PMG

Introduction

It is observed that the economic and social activities of human beings are the primary reason behind the rising greenhouse gas (GHG) emissions. Since the industrial revolution, the energy obtained from fossil fuels is the driver of economic growth; particularly, in the last half of the previous century, this process has gathered the pace. Consequently, the amount of GHG emissions in the environment increased manifold. Among the GHG emissions, CO2 emissions are the main contributor to polluting the environment and almost account for 75% of total GHG emissions (Ullah et at. 2021a). Environmental pollution due to rising CO2 emissions is not just affecting the air quality but also causing severe weather variations, droughts, floods, melting glaciers, rising sea level, etc. (Usman et al. 2020). To counter environmental pollution, many academics and researchers are trying to find the factors that can improve environmental quality without hampering the process of economic development (Herran et al. 2019 and Usman et al. 2021).

Raising the living standards of the present generation alongside protecting the environmental quality for the next generations is called the process of sustainable economic development. In order to achieve the goal of sustainable economic development, it is necessary to mitigate the level of CO2 emissions to a manageable level (Luo et al. 2017 and Yin et al. 2021). Several empirics and environmentalists have tested the environment-growth nexus in the presence of many other variables. In this context, the seminal work was performed by Grossman and Kreuger (1994) and found an inverted U–shaped relationship between economic growth and environmental quality which suggested that at the early stages of economic development, environmental quality

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deteriorates while at the later stages, it improves. After that, a plethora of studies have tested the EKC hypothesis for various countries; however, most of them have included energy consumption while capturing the EKC hypothesis and confirmed that it is one of the primary contributors to CO2 emissions (Apergis and Payne, 2009; Halicioglu, 2009; Apergis and Ozturk, 2015; Alola and Ozturk, 2021). Recently, several researchers have included the variables of industrialization (Ullah et al. 2021a), tourism (Chisti et al. 2020), information and communication technology (Usman et al. 2021), globalization (Chisti et al. 2020), technological innovation (Ullah et al. 2021a, b), and renewable energy (Usman et al. 2020) in the carbon emission functions of different countries and found mixed results.

The energy obtained from the sources such as biofuels, hydropower, wind, and solar is known as renewable energy sources. Renewable energy sources also known as clean and green energy sources are getting popularity as a pertinent factor to reduce the burden on the environment without slowing the pace of economic growth (Ozturk 2017 and Jafri et al. 2021). Apart from improving environmental quality, renewable energy may also reduce the energy dependency on non-renewable sources and improve the situation of energy security as well (Usman et al. 2020). Moreover, clean energy provides solutions to many other man-made problems such as weather change, global warming, melting glaciers, rising sea levels, acid rains, and water pollution due to its ability to reduce carbon emissions and other GHG emissions (Ozturk & Acaravci, 2010; Apergis and Payne 2012; Ullah et al. 2020). Furthermore, clean energy can replace non-renewable energy in the production function in the industrial, agriculture, and services sector; therefore, it can help to achieve sustainable development due to less energy-intensive production and operative methods (Azam et al. 2019). On one side, it contributes to the long-term economic growth of a country, and on the other side, it surges employment and living standards, and consequently, it can diminish poverty in emerging economies (Danish and Wang 2018).

Another factor that can affect the CO2 emissions significantly is a foreign direct investment (FDI) but the correlation between FDI and CO2 emissions is unidentified. Some researchers display that FDI influxes cause a rise in CO2 emissions (Al-Mulali 2012; Khan and Ozturk, 2020; Li et al. 2021). A positive association between FDI and CO2 emissions is supported by the famous "pollution haven hypothesis" (Copeland and Taylor 1994 and Salahuddin et al. 2018). This hypothesis says that the firms from advanced countries move their energy-intensive production techniques and obsolete machinery to the developing and underdeveloping economies where the environmental regulations are not that strict. As a result, the host countries become "pollution-havens" and the quality of their environment deteriorates (Solarin et al. 2017). Conversely, the "pollution halo" hypothesis says that FDI improves the environmental quality of the host countries because multinational firms from advanced countries bring in the latest technology with them which make the production process in the developing economies much more sophisticated and energy-efficient, thus emitting less carbon (Kim and Adilov 2012). According to Grossman and Krueger (1994), the relationship between foreign inflows and environmental quality is a complex one and not easy to analyze due to three effects, namely scale, composition, and technique effects. Scale effects can cause the CO2 emissions to rise in the host countries by flourishing the FDI-driven economic growth. On the other side, technique effects improve the environmental quality in the host countries via advanced technology that multinational and foreign firms export to the developing economies. The technology used by foreign firms is much cleaner, thus reducing CO2 emissions through improved energy efficiency. Lastly, the composition effect can impact the environmental quality in either way, i.e., positive or negative (Jalil and Mahmud, 2009). In developing economies, environment-related rules and regulations are not strict enough; thereby, such economies prove a safe place for foreign firms that emit more emissions. On the other side, cheap labor is abundant in developing economies which attract foreign firms that operate through less polluting labor-intensive techniques.

From the above discussions, we can deduce that foreign inflows such as FDI and remittances can mitigate the level of CO2 emissions by improving renewable energy sources. Hence, in this study, we have analyzed the nexus between foreign inflows, renewable energy, and environmental quality in the BRICS economies. BRICS economies are the fastest growing economies of the world and new havens for foreign inflows. FDI to BRICS countries helps effectively to obtain energy efficiency and control carbon emission with the application of modern technological transfer, as FDI is considered as the prime channel to transfer technology in the host economy. Therefore, it is very pertinent to examine this relationship in the context of BRICS economies and this is the first of its type. Therefore, it is more important to realize the non-linear impact of foreign capital on renewable energy consumption and also on the CO2 emissions of the BRICS nations. This empirical understanding is very crucial for governments and policymakers to determine the green economy. This study tries to enrich the knowledge about the role of financial foreign capital in promoting the green economy. Moreover, the study applied the panel NARDL-PMG which provides us with an opportunity to capture the impact of positive and negative shocks in independent variables on the dependent variable.

We have designed this study in various sections. In the next section, we have organized the "Model and methods". Results are to be presented in the "Results and discussion" section and the conclusions in the "Conclusion and implications" section.

Model and methods

The theoretical link between financial inflows and environmental quality can be determined by the fact that the vibrant and well-functioning financial sector can help to promote better environmental quality as compared to the financial sector which is underdeveloped and sluggish. A dynamic, vibrant, and well-functioning financial sector is essential for the fast growth of the economy. A progressive financial organization upsurges the size of investment by offering loans at a reduced rate, enhances the size of the money market, and provides upgraded risk supervisory arrangement, activates savings, advances the working of the firms, and points out firms to accept the technology that is more conducive to the environment (Doytch and Narayan 2016). Nasreen et al. (2017) contend that a vigorous financial structure stimulates economic growth by welcoming foreign firms for investment into the country. Hence, the machinery that comes into the country as a result of foreign investment is much more sophisticated and energy-efficient as compared to the local machinery. Additionally, a robust financial system has a provision to sophisticated and contemporary technology that has an effect on energy consumption and consequently CO2 emissions (Danish et al. 2018). Consistent with the above views, our main motive is to capture the impact of financial inflows on renewable energy consumption and environmental quality. To achieve that goal, we have borrowed a model from Doytch and Narayan (2016) and Li et al. (2021).

$$REC_{it} = \omega_0 + \varphi_1 FDI_{it} + \varphi_2 REM_{it} + \varphi_3 GDP_{it} + \varphi_4 Trade_{it} + \varepsilon_{it} \tag{1}$$

$$CO_{2,it} = \omega_0 + \varphi_1 FDI_{it} + \varphi_2 REM_{it} + \varphi_3 GDP_{it} + \varphi_4 Trade_{it} + \varepsilon_{it} \tag{2}$$

Specifications (1 and 2) are the renewable energy consumption and carbon emission function that rely on foreign direct investment (FDI), remittances (REM), gross domestic product (GDP), and trade openness (FDI). To convert this equation into panel ARDL-PMG, we need respectively Eqs. (1 and 2) into error correction format as described:

$$\begin{aligned}\Delta REC_{it} = \omega_0 &+ \sum_{k=1}^{n} \beta_{1k}\Delta REC_{it-k} + \sum_{k=0}^{n} \beta_{2k}\Delta FDI_{it-k} + \sum_{k=0}^{n} \beta_{3k}\Delta REM_{it-k} \\ &+ \sum_{k=1}^{n} \beta_{4k}\Delta GDP_{it-k} + \sum_{k=0}^{n} \beta_{5k}\Delta Trade_{it-k} + \omega_1 REC_{it-1} \\ &+ \omega_2 FDI_{it-1} + \omega_3 REM_{it-1} + \omega_4 GDP_{it-1} + \omega_5 Trade_{it-1} + \varepsilon_{it}\end{aligned} \tag{3}$$

$$\begin{aligned}\Delta CO_{2,it} = \omega_0 &+ \sum_{k=1}^{n} \beta_{1k}\Delta CO_{2,it-k} + \sum_{k=0}^{n} \beta_{2k}\Delta FDI_{it-k} + \sum_{k=0}^{n} \beta_{3k}\Delta REM_{it-k} \\ &+ \sum_{k=1}^{n} \beta_{4k}\Delta GDP_{it-k} + \sum_{k=0}^{n} \beta_{5k}\Delta FDI_{it-k} + \omega_1 CO_{2,it-1} + \omega_2 FDI_{it-1} \\ &+ \omega_3 REM_{it-1} + \omega_4 GDP_{it-1} + \omega_5 FDI_{it-1} + \varepsilon_{it}\end{aligned} \tag{4}$$

Arrangement (3 and 4) has now become panel ARDL-PMG of Pesaran et al. (1999 and 2001). The method is superior to most of the techniques because it provides both the short- and long-run estimates by analyzing a single equation. Moreover, we can add a mixture of I(0) and I(1) variables into our panel ARDL-PMG model. Furthermore, it is an efficient technique even if the sample size is small. However, in this study, we have also applied the non-linear panel ARDL-PMG model and for that purpose, we have decomposed the variables of FDI and remittance into its positive and negative components by using the partial sum procedures as shown:

$$FDI^{+}{}_{it} = \sum_{n=1}^{t} \Delta FDI^{+}{}_{it} = \sum_{n=1}^{t} max(FDI^{+}{}_{it}, 0) \tag{5a}$$

$$FDI^{-}{}_{it} = \sum_{n=1}^{t} \Delta FDI^{-}{}_{it} = \sum_{n=1}^{t} min(\Delta FDI^{-}{}_{it}, 0) \tag{5b}$$

$$REM^{+}{}_{it} = \sum_{n=1}^{t} \Delta REM^{+}{}_{it} = \sum_{n=1}^{t} max(REM^{+}{}_{it}, 0) \tag{5c}$$

$$REM^{-}{}_{it} = \sum_{n=1}^{t} \Delta REM^{-}{}_{it} = \sum_{n=1}^{t} min(\Delta REM^{-}{}_{it}, 0) \tag{5d}$$

The positive shocks in the series are represented by FDI^{+} and REM^{+}, whereas the negative shocks in the series are represented by FDI^{-} and REM^{-}. Next, we replace these partial sum variables in the place of original variables in Eq. (2) and the outcome of this action is shown:

$$\begin{aligned}REC_{it} = \omega_0 &+ \sum_{k=1}^{n} \beta_{1k}\Delta REC_{it-k} + \sum_{k=0}^{n} \beta_{2k}\Delta FDI^{+}{}_{it-k} \\ &+ \sum_{k=0}^{n} \delta_{3k}\Delta FDI^{-}{}_{it-k} + \sum_{k=0}^{n} \beta_{4k}\Delta REM^{+}{}_{it-k} \\ &+ \sum_{k=0}^{n} \delta_{5k}\Delta REM^{-}{}_{it-k} + \sum_{k=0}^{n} \beta_{6k} GDP_{it-k} \\ &+ \sum_{k=0}^{n} \beta_{7k} Trade_{it-k} + \omega_1 REC_{it-1} + \omega_2 FDI^{+}{}_{it-1} \\ &+ \omega_3 FDI^{-}{}_{it-1} + \omega_4 REM^{+}{}_{it-1} + \omega_5 REM^{-}{}_{it-1} \\ &+ \omega_6 GDP_{it-1} + \omega_7 Trade_{it-1} + \varepsilon_{it}\end{aligned} \tag{6}$$

$$\begin{aligned}\Delta CO_{2,it} = \omega_0 &+ \sum_{k=1}^{n} \beta_{1k}\Delta CO_{2,it-k} + \sum_{k=0}^{n} \beta_{2k}\Delta FDI^{+}{}_{it-k} \\ &+ \sum_{k=0}^{n} \delta_{3k}\Delta FDI^{-}{}_{it-k} + \sum_{k=0}^{n} \beta_{4k}\Delta REM^{+}{}_{it-k} \\ &+ \sum_{k=0}^{n} \delta_{5k}\Delta REM^{-}{}_{it-k} + \sum_{k=0}^{n} \beta_{6k} GDP_{it-k} \\ &+ \sum_{k=0}^{n} \beta_{7k} Trade_{it-k} + \omega_1 CO_{2,it-1} + \omega_2 FDI^{+}{}_{it-1} \\ &+ \omega_3 FDI^{-}{}_{it-1} + \omega_4 REM^{+}{}_{it-1} + \omega_5 REM^{-}{}_{it-1} \\ &+ \omega_6 GDP_{it-1} + \omega_7 Trade_{it-1} + \varepsilon_{it}\end{aligned} \tag{7}$$

The Eq. (6 and 7) is known as the panel NARDL-PMG model proposed by Shin et al. (2014) and this is an advanced form of the linear ARDL-PMG. Therefore, non-linear panel PMG can be dealt with the estimation procedure and diagnostic test of the panel ARDL-PMG. Moreover, the cointegration test and critical values are also the same for both models.

For robust analysis, this study used dynamic ordinary least squares (DOLS) and fully modified ordinary least squares (FMOLS) estimators in analysis. The DOLS and FMOLS are highly efficient in handling the issue of serial correlations in the error terms and endogeneity among regressors. The FMOLS is considered one of the non-parametric approaches that control autocorrelation and endogeneity problems (Pedroni 2000), whereas the DOLS approach eliminates the by adding leads and lags of the explanatory variables (Kao and Chiang 2001), while DOLS is one of the parametric approaches and gives better results in the case of small samples (Dogan and Seker 2016). Particularly, the DOLS method is capable to handle cross-sectional dependence (CD) based on the gaining of country-specific coefficients and produce unbiased, efficient, and consistent estimates. Pedroni (2004) noted that the panel DOLS is less bias than the FMOLS and DOLS estimators in small samples, and DOLS estimator has better sample properties rather than the FMOLS and DOLS estimators. The Dumitrescu and Hurlin (DH) causality test considers heterogeneity and cross dependence, while it produces a robust estimate for small data.

Data

The data are yearly for BRICS, and time span from 1991 to 2019. This emerging group is selected based on the high financial inflows. The data come from two famous sources named World Bank and Energy Information Administration (EIA). The key dependent variables are renewable energy consumption (REC) measured in quad BTU and CO2 emissions in kilotons. The source for renewable energy consumption variable is the EIA, while remaining all variables are collected from the World Bank. We follow the Qin and Ozturk (2021) method and use financial inflows, proxied by FDI and personal remittances. The detailed definitions and data descriptions are reported in Table 1.

Results and discussion

First of all, we apply three different panel unit root tests to confirm whether our variables are stationary at level or first difference because the application of NARDL requires that none of the variables in the model should be I(2). For that purpose, we have applied three-panel unit root tests Levin, Lin, and Chin (LLC); Im, Pesaran, and Shin (IPS); and ADF-Fisher. The results of these tests are reported in Table 2, which state that most of the variables are stationary at a level with all three tests except REC and CO2. After confirming that our variables are either I(0) or I(1), we can

Table 1 Definitions and data description

Variables	Symbol	Definitions	Mean	Std. dev
Renewable energy consumption	REC	Renewable energy is measured in quad BTU from the sum of wind energy, solar energy, nuclear energy, and biofuel energy	2.406	2.863
CO2 emissions	CO2	CO2 emissions (kt)	13.94	1.068
Personal remittances	REM	Personal remittances, received (% of GDP)	0.746	1.074
Foreign direct investment	FDI	foreign direct investment, net inflows (BoP, current US$	23.16	2.001
GDP per capita growth	GDP	GDP per capita growth (annual %	3.249	4.672
Trade openness	Trade	Trade (% of GDP)	42.23	15.68

Table 2 Panel unit root testing

	LLC			IPS			ADF		
	I(0)	I(1)	Decision	I(0)	I(1)	Decision	I(0)	I(1)	Decision
REC	−0.364	−1.587*	I(1)	−0.288	−5.342***	I(1)	0.016	−7.861***	I(1)
CO2	0.232	−1.372*	I(1)	−1.310	−6.259***	I(1)	−1.335*		I(0)
FDI	−2.994***		I(0)	−3.253***		I(0)	−4.016***		I(0)
REM	−2.625***		I(0)	−2.594***		I(0)	−3.242***		I(0)
GDP	−2.924***		I(0)	−3.409***		I(0)	−4.371***		I(0)
Trade	−2.184**		I(0)	−1.805*		I(0)	−2.378***		I(0)

Note: *** $p<0.01$; ** $p<0.05$; and * $p<0.1$

now apply NARDL and maximum two lags are imposed as our data is annual. For selecting an appropriate number of lags, we have applied Akaike information criterion (AIC).

The main objective of the study is to estimate the relationship between financial inflow, environmental quality, and renewable energy consumption. The empirical analysis is based on the linear and non-linear panel ARDL-PMG which are our baseline models. To check the robustness of our estimates, we have augmented our analysis with the help of linear and non-linear FMOLS and DOLS. First, we discuss the results of the baseline models and then the estimates of our robust models.

Besides the short- and long-run baseline results, the estimates of cointegration tests, i.e., ECM(-1) and Kao-cointegration, are provided in Table 3. Both the cointegration tests have confirmed that our long-run results are valid; i.e., cointegration exists among linear and non-linear models. Hence, we can now discuss our long-run estimates in detail. In the linear REC and CO2 models, the estimates of FDI are insignificant. However, the estimate of REM is significant in the REC model, whereas, insignificant in the CO2 model. Numerically, a 1% rise in the REM causes the REC to rise by 0.138%. Similarly, the estimated coefficients of GDP and trade are insignificant in the linear model.

On the other side, in the non-linear model, the estimates of FDI_POS and FDI_NEG are insignificant in the REC model. In the asymmetric CO2 model, the estimate of FDI_POS is insignificant and FDI_NEG is positively significant. More specifically, a 1% increase in the FDI does not have any significant impact on the CO2 emissions, whereas a 1% decline in the FDI causes the CO2 emissions to decline by 0.168%. In general, we can say that positive shock in FDI does not affect the CO2 emissions significantly, whereas the negative shock in CO2 emissions is beneficial for improving environmental quality implying that FDI in BRICS economies is augmenting the CO2 emissions, thus supporting the "pollution haven hypothesis" (Copeland and Taylor 1994). According to this hypothesis, the sector and industries from advanced economies, which are energy-intensive and emit CO2 emissions excessively, shift their operations to the developing countries where the laws with regard to environmental safety and protection are much more relaxed as compared to the advanced economies. This finding is also consistent with Chishti et al. (2020). For such pollution-friendly industries, it becomes really hard to operate in advanced economies because the environment-related laws in advanced economies are much strict and the government officials are much more sensitive on this topic. As a result, the government imposed heavy taxes and fines on such industries and forced them to innovate their production process and make it more conducive to the environment by adopting energy-efficient production methods (Ullah et al. 2021a, b). Further, to control the flow of CO2 emissions, such firms and industries are also forced to use clean and green energy sources which are much expensive as compared to traditional sources, particularly, at the initial stage. All these factors raised the cost of production for such pollution-friendly industries; hence, they move their operations to the developing economies which welcome them warmly because they want their economies to grow at a fast pace and FDI can give them a big push in this regard. These findings also imply that positive and negative shocks in FDI influence the CO2 emissions asymmetrically which is also confirmed by the estimate of WALD-LR-FDI in the CO2 model provided in Table 3.

As far as the asymmetric effects of REM are concerned, the estimate attached to REM_POS is significant and positive and the estimate attached to REM_NEG is negatively significant implying that a 1% increase in the REM causes the REC to rise by 0.116% and a 1% fall in the REM also causes the REC to rise by 0.602. Both positive and negative shocks in REM cause the REC to rise which suggests that the demand for renewable energy is inelastic that even the fall in the REM does not reduce the consumption of REC. On the other side, the estimate attached to REM_POS is positive but insignificant and the estimate attached to REM_NEG is negative and insignificant suggesting that a 1% rise in REM increases the CO2 emissions by 0.088% though insignificantly, whereas a 1% decline in the REM causes the CO2 emissions to rise by 1.054%. The general meaning of these findings is that remittances from abroad do not help to mitigate CO2 emissions as it promotes saving and consumption and hence the GDP growth (Nyeadi and Atiga 2014 and Li et al. 2021) and consequently CO2 emissions (Ahmad et al. 2019; Neog and Yadava 2020). Moreover, as BRICS economies mostly rely on non-renewable energy sources which are the primary sources of CO2 and other greenhouse gas emissions, hence, any activity that will positively impact the economic growth in these economies will push the CO2 emissions upward. The long-run asymmetric effects can be observed for both the variables; i.e., FDI and REM in both the models and the significant estimates of Wald-LR for both these variables, presented in Table 3, are also fortifying our observation.

Among the control variables, the estimate of the GDP is positively significant in the CO2 model, whereas the estimates of trade are positive and significant in both the REC and CO2 models. In the short run, both linear ARDL-PMG and non-linear ARDL-PMG provide mixed results, i.e. positive, negative, or insignificant, at various lags. However, the non-linear models provided more significant results which must be attributed to the introduction of asymmetry in our models.

Now, we will briefly discuss the estimates of our robust models provided in Table 4. The linear estimates of FDI are positively significant in both the REC and CO2 models

Table 3 ARDL-PMG and NARDL-PMG estimates of REC and CO2

	ARDL-PMG				NARDL-PMG			
	REC		CO2		REC		CO2	
Variable	Coefficient	*t*-stat	Coefficient	*t*-stat	Coefficient	*t*-stat	Coefficient	*t*-stat
Long-run								
FDI	0.010	1.235	0.357	0.746				
FDI_POS					0.005	0.322	0.088***	3.305
FDI_NEG					0.013	0.665	0.168***	5.186
REM	0.138*	1.742	−3.362	0.513				
REM_POS					0.116*	1.901	0.227	0.861
REM_NEG					−0.602***	8.747	−1.054***	5.017
GDP	0.003	1.123	0.504	0.481	0.004	0.827	0.019***	3.621
TRADE	0.000	0.020	−0.186	0.469	0.010***	4.024	0.035***	5.065
Short-run								
COINTEQ01	−0.377*	1.698	−0.366*	1.872	−0.318*	1.672	−0.450**	2.023
D(FDI)	0.091	0.738	0.011	1.144				
D(FDI(-1))	0.107	0.668						
D(FDI(-2))	−0.032	0.602						
D(FDI_POS)					0.028	0.538	0.031*	2.500
D(FDI_POS(-1))							0.029*	1.727
D(FDI_NEG)					0.383*	1.735	−0.089	1.315
D(FDI_NEG(-1))							−0.043	0.801
D(REM)	0.171	1.178	−0.129	1.027				
D(REM(-1))	0.126	0.621						
D(REM(-2))	0.026	0.300						
D(REM_POS)					0.118	0.505	0.141	0.689
D(REM_POS(-1))							−0.439**	2.141
D(REM_NEG)					0.104	0.550	−0.691	1.005
D(REM_NEG(-1))							0.723	1.140
D(GDP)	0.035*	1.657	−0.002	0.715	0.034*	1.732	−0.001	0.174
D(GDP(-1))	−0.005	0.967					0.005**	2.289
D(GDP(-2))	−0.002	0.257						
D(TRADE)	−0.012	1.005	0.001	0.737	−0.018*	1.669	0.002	0.743
D(TRADE(-1))	−0.013*	1.708					0.002	0.549
D(TRADE(-2))	−0.015	0.944						
C	0.680	1.413	0.099*	1.686	0.207**	2.251	0.505	0.594
Diagnostics								
Log likelihood	182.1		265.5		151.4		306.4	
Kao-cointegration	2.545***		2.545***		3.224***		3.365***	
Hausman	0.325		0.987		1.230		1.023	
Wald-LR-FDI					1.023		5.234***	
Wald-SR-FDI					1.322		1.023	
Wald-LR-REM					12.35***		11.30***	
Wald-SR-REM					2.012		0.325	

Note: ***$p<0.01$; **$p<0.05$; and *$p<0.1$

whether we apply FMOLS or DOLS. However, in our baseline models, the linear estimates are insignificant. The linear estimates of REM are positively significant only in REC models and positive but insignificant in the REC model irrespective of the estimation technique. The non-linear estimates of FDI are positively significant across all models of REC and CO2 which imply that a positive shock to FDI will increase the CO2 emissions, whereas the negative shock reduces the CO2 emissions. Likewise, the estimates attached to REM_POS are significant and positive in three out of four models suggesting that an increase in remittances causes the CO2 emissions to rise. However, the estimates attached

Table 4 Robust estimates of REC and CO2

	Models without asymmetry				Models with asymmetry			
	REC		CO2		REC		CO2	
	FMOLS	DOLS	FMOLS	DOLS	FMOLS	DOLS	FMOLS	DOLS
FDI	0.907***	1.290***	0.218***	0.220***				
	8.830	11.37	5.900	19.84				
FDI_pos					0.671***	0.380***	0.089*	0.130***
					3.850	8.860	1.680	34.40
FDI_neg					0.914***	1.670***	0.230***	0.090***
					4.640	12.40	3.860	11.00
REM	0.472***	0.210***	0.085	−0.050				
	2.770	2.900	1.390	1.580				
REM_pos					3.914***	0.410	0.191*	0.220***
					2.730	0.150	1.780	3.780
REM_neg					3.698**	0.270***	−0.307*	−0.020***
					2.480	8.490	1.670	7.040
GDP	0.037	0.020	0.072****	0.010***	0.028	0.040***	0.076***	0.001***
	0.830	1.620	4.480	5.590	0.620	3.210	5.570	3.050
Trade	0.037***	0.040***	0.021***	0.010***	0.038**	0.010***	0.034***	0.001
	3.240	3.890	5.060	7.540	2.510	2.570	7.910	1.640

Note: ***$p < 0.01$; **$p < 0.05$; and *$p < 0.1$

to REM_NEG are positively significant in the REC models both with the FMOLS and DOLS technique and negatively significant in the CO2 models both with FMOLS and DOLS techniques. These findings imply that a decline in the remittances causes the REC to decline whereas CO2 emissions to rise. In general, the findings of the robust model complement the findings of the baseline models with few exceptions. The results of panel causal analysis are provided in Table 5. From these estimates, we find uni-directional causality in the REC model, e.g., FDI_NEG → REC and REM_NEG → REC, and bi-directional causality in the CO2 model, e.g., FDI_POS ↔ CO2 and FDI_NEG ↔ CO2.

Conclusion and implications

This study investigates the impact of financial inflow on renewable energy consumption and CO2 emissions in BRICS economies for time period 1991–2019 by employing ARDL-PMG and NARDL-PMG approaches. The study used two proxies to measure financial inflow, i.e., FDI and remittances. There are very few studies that put the role of FDI and remittance in the context of renewable energy consumption and environmental quality. To the best of the authors' knowledge, no study has examined the symmetric and asymmetric impact of FDI and remittance on renewable energy consumption and pollution emissions in the case of BRICS economies. For confirming the robustness of findings, the study has employed FMOLS and DOLS approaches. To investigate the nexus between financial inflow, clean energy consumption, and environmental quality by using the role of GDP and trade as control variables in regression analysis. After the symmetric and asymmetric regression analysis, the study disclosed numerous new findings.

The findings of ARDL-PMG reveal that FDI has no significant impact on renewable energy consumption and carbon emissions in the long run. However, remittances encourage renewable energy consumption but it has no significant impact on environmental quality in the long run. On the other hand, the findings of the NARDL-PMG model reveal that positive and negative shocks in FDI have no significant effect on renewable energy consumption in the long run. However, the positive shock in FDI upsurges pollution emissions in BRICS economies revealing that the inflow of FDI is a harmful impact on the environment, while negative shock in FDI has a favorable impact on the environment in the long run. In the case of remittances, the positive shock in remittances enhances renewable energy consumption in the long run, but no significant impact is found on pollution emissions. The study obtained similar and robust findings in FMOLS and DOLS models.

Our study has some precious policy implications for governments, foreign investors, and other stakeholders. Although FDI and remittances are considered important drivers of renewable energy consumption, however, policymakers should promote environmental quality by putting constraints on environmentally unfriendly activities through strict financial regulations. Governments should formulate

Table 5 Panel asymmetric causality of REC and CO2 emissions

	REC				CO2		
Null hypothesis	*W*-stat	Zbar-stat	Prob	Null hypothesis	*W*-stat	Zbar-stat	Prob
FDI_POS → RE	3.387	1.070	0.284	FDI_POS → CO2	4.286	1.889	0.059
RE → FDI_POS	3.098	0.808	0.419	CO2 → FDI_POS	4.466	2.053	0.040
FDI_NEG → RE	4.683	2.250	0.024	FDI_NEG → CO2	4.268	1.872	0.061
RE → FDI_NEG	3.315	1.006	0.315	CO2 → FDI_NEG	5.089	2.619	0.009
REM_POS → RE	3.611	1.275	0.202	REM_POS → CO2	3.908	1.545	0.122
RE → REM_POS	1.967	−0.222	0.825	CO2 → REM_POS	7.304	4.635	0.000
REM_NEG → RE	7.876	5.157	0.000	REM_NEG → CO2	4.259	1.865	0.062
RE → REM_NEG	1.667	−0.495	0.621	CO2 → REM_NEG	3.141	0.847	0.397
GDP → RE	1.533	−0.614	0.540	GDP → CO2	1.700	−0.459	0.646
RE → GDP	2.024	−0.161	0.872	CO2 → GDP	5.203	2.761	0.006
TRADE → RE	4.594	2.201	0.028	TRADE → CO2	4.596	2.203	0.028
RE → TRADE	2.460	0.239	0.811	CO2 → TRADE	10.37	7.512	0.000
FDI_NEG → FDI_POS	8.420	5.651	0.000	FDI_NEG → FDI_POS	8.420	5.651	0.000
FDI_POS → FDI_NEG	6.481	3.887	0.000	FDI_POS → FDI_NEG	6.481	3.887	0.000
REM_POS → FDI_POS	3.480	1.156	0.248	REM_POS → FDI_POS	3.480	1.156	0.248
FDI_POS → REM_POS	16.15	12.69	0.000	FDI_POS → REM_POS	16.15	12.69	0.000
REM_NEG → FDI_POS	2.180	−0.027	0.978	REM_NEG → FDI_POS	2.180	−0.027	0.978
FDI_POS → REM_NEG	2.972	0.693	0.488	FDI_POS → REM_NEG	2.972	0.693	0.488
GDP → FDI_POS	2.518	0.280	0.780	GDP → FDI_POS	2.518	0.280	0.780
FDI_POS → GDP	2.039	−0.156	0.876	FDI_POS → GDP	2.039	−0.156	0.876
TRADE → FDI_POS	3.774	1.423	0.155	TRADE → FDI_POS	3.774	1.423	0.155
FDI_POS → TRADE	5.435	2.935	0.003	FDI_POS → TRADE	5.435	2.935	0.003
REM_POS → FDI_NEG	5.951	3.404	0.001	REM_POS → FDI_NEG	5.951	3.404	0.001
FDI_NEG → REM_POS	3.853	1.495	0.135	FDI_NEG → REM_POS	3.853	1.495	0.135
REM_NEG → FDI_NEG	2.724	0.467	0.640	REM_NEG → FDI_NEG	2.724	0.467	0.640
FDI_NEG → REM_NEG	3.858	1.499	0.134	FDI_NEG → REM_NEG	3.858	1.499	0.134
GDP → FDI_NEG	3.814	1.459	0.145	GDP → FDI_NEG	3.814	1.459	0.145
FDI_NEG → GDP	2.707	0.452	0.652	FDI_NEG → GDP	2.707	0.452	0.652
TRADE → FDI_NEG	4.385	1.979	0.048	TRADE → FDI_NEG	4.385	1.979	0.048
FDI_NEG → TRADE	3.556	1.224	0.221	FDI_NEG → TRADE	3.556	1.224	0.221
REM_NEG → REM_POS	8.409	5.642	0.000	REM_NEG → REM_POS	8.409	5.642	0.000
REM_POS → REM_NEG	57.55	50.47	0.000	REM_POS → REM_NEG	57.59	50.40	0.000
GDP → REM_POS	1.988	−0.203	0.839	GDP → REM_POS	1.988	−0.203	0.839
REM_POS → GDP	0.985	−1.115	0.265	REM_POS → GDP	0.985	−1.115	0.265
TRADE → REM_POS	7.796	5.083	0.000	TRADE → REM_POS	7.796	5.083	0.000
REM_POS → TRADE	4.632	2.204	0.028	REM_POS → TRADE	4.632	2.204	0.028
GDP → REM_NEG	1.695	−0.469	0.639	GDP → REM_NEG	1.695	−0.469	0.639
REM_NEG → GDP	2.171	−0.036	0.971	REM_NEG → GDP	2.171	−0.036	0.971
TRADE → REM_NEG	7.344	4.672	0.000	TRADE → REM_NEG	7.344	4.672	0.000
REM_NEG → TRADE	5.932	3.387	0.001	REM_NEG → TRADE	5.932	3.387	0.001
TRADE → GDP	5.462	2.999	0.003	TRADE → GDP	5.462	2.999	0.003
GDP → TRADE	5.149	2.711	0.007	GDP → TRADE	5.149	2.711	0.007

Note: ***$p < 0.01$; **$p < 0.05$; and *$p < 0.1$

such lending mechanisms that finance only environment-friendly activities. Environmentally sustainable energy benefits of FDI and remittances can also be attained by giving incentives to green innovations or technology transfer from advanced economies. From an environmental policy perspective, BRICS governments should more focus on receiving higher inflows of finance to execute their environmental quality improvement program in the long run. The governments can utilize foreign finance more towards the consumption of clean/smart energies (i.e., wind, solar, and biomass) than spending foreign finance on dirty-oriented energy consumption (i.e., coal, oil, and natural gas). The government can also restrain the spending behavior of foreign investors by FDI inflows via offering economic incentives. This study cannot add foreign aid in renewable energy consumption and CO2 emission models. Future studies can also explore the impact of total foreign aid and foreign energy aid inflows on renewable energy consumption and environmental quality.

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Availability of data and materials The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical approval Not applicable.

Consent to participate We are free to contact any of the people involved in the research to seek further clarification and information.

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