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RESEARCH ARTICLE

Impact of stock market, renewable energy consumption and urbanization on environmental degradation: new evidence from BRICS countries

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Abstract

This study examines links between Morgan and Stanley capital Investment (MSCI), foreign direct investment (FDI), renewable energy, urbanization, and trade openness on environmental degradation in (Brazil, Russia, India, China, South Africa) BRICS countries. In this study, generalized method of moment (GMM) estimation is applied on a data set ranging from 1993 to 2018. Results illustrate that stock market index price (MSCI) has negative relationship on CO_2 emissions in India, China, Russia, and South Africa and has positive relationship in Brazil. One possible reason for this is strong environmental regulations and their enforcement by Brazilian government. The study also finds that trade openness, FDI, and urbanization have a significant positive relationship on environmental degradation. The impact of stock market development on environmental degradation varies among BRICS countries. Our outcomes have significant policy implications. For example, the policy makers have to initiate effective strategies to promote the renewable energy sources to meet the increasing demand for energy by replacing the use of conventional energy such as coal, gas, and oil. This will help to reduce the CO_2 emissions from fossil fuel and ensure sustainable stock market development in the BRICS nations. BRICS countries who have taken the initiative and formulated policies for businesses to conserve the environment play a positive role compared to those who do not.

Keywords Environmental degradation · Economic development · Renewable energy · GMM · BRICS countries

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Introduction

Over the last two decades, protecting natural environment has been one of the prominent global concerns. The increasing temperatures have become a significant threat to environmental degradation. The 1997 Kyoto protocol aims to reduce greenhouse gas (GHG) emissions which are major contributors to environmental degradation. Most of the GHG emissions come from fossils energy (Paramati et al. 2017b). Environment policymakers and energy economists urge to use renewable energy sources instead of fossil energy sources.

It is evident that renewable energy sources reduce carbon emissions (Hanif et al. 2019). Since renewable energies are harmless in environmental pollution as they decrease CO_2 and other greenhouse gasses, their consumption is not limited. The ever-increasing energy demand for the development and expansion of renewable energies is necessary for developing countries' sustainable development as an important factor. Although BRICS countries (Brazil, Russian, India, China, and South Africa) signed the Kyoto Protocol to control greenhouse gas emissions,

there are still major environmental concerns given the region's recent economic growth.

Other important factor that can be related to environmental improvement is stock market. Stock market is considered one of the leading economic indicators; its stock value determines future economic growth. The stock market is highly attractive for businesses (Sadorsky 2010), as it permits additional sources of funds and equity funding for entrepreneurs to expand their business. This enhanced activity helps businesses and investors diversify their risks, lower financing costs, optimize capital structure, and invest in new projects (Paramati et al. 2017b). This increased economic activity is anticipated with a high demand for energy.

A critical review of literature reveals that regardless of this theoretical link among economic activity, energy demand, and environmental degradation (Zhao and Yang 2020; Hanif et al. 2019; Paramati et al. 2017a, b; Tamazian et al. 2009), research related to MSCI, renewable energy conservation, and CO_2 emissions is still unexplored.

Financial development is another factor that degrades the environment. As financial development increases economic growth, this economic growth attracts more foreign direct investment (FDI) and R&D investments and hence requires more energy consumption resulting in more CO_2 emission (Tamazian et al. 2009). Additionally, literature illustrates that FDI boosts countries manufacturing production processes, expands its logistics and industrialization; requires more energy consumption, and leads to more CO_2 emissions (Hanif et al. 2019). These advanced technologies enhance energy efficiency and environment-friendly production and reduce carbon emissions (Doytch and Narayan 2016). The link between FDI and carbon emission is worth investigating as previous studies have certain conflicts (Dasgupta et al. 2001; Ozturk and Acaravci 2013; Sadorsky 2010; Shahbaz et al. 2013).

Moreover, the literature reveals that trade openness of a country also impacts its environment. Trade openness leads to environmental degradation (Nasir and Ur Rehman 2011). Many other studies also confirm this impact on environmental degradation. For instance, Haq et al. (2016) showed that trade openness may have detrimental effects on the environment. However, if these traded commodities or their products are environmental-friendly, this openness may save the environment from degradation. Trade openness may lead to environmental degradation in three ways: first based on traded technique, second based on scale, and third through composite effect (Grossman and Krueger 1991, b). Trade openness may also decrease carbon emission levels as technology transfer across countries and diffusion of environmentally friendly production technologies reduces carbon emission levels.

Additionally, foreign trade interjects domestic market thus increasing domestic competition and domestic traders shift toward efficient techniques for production. Thus, it helps lessen CO_2 emission. Also, trade openness increases a country's production levels using its scarce natural resources ultimately increasing carbon emissions. Furthermore, ratio of exports to imports is called composition effect. As trade openness of a country shifts toward cleaner industries, this will result in low carbon emissions levels and in turn low environmental degradation. If trade openness prefers dirty industries as compared to cleaner industries, then this will lead toward environmental degradation. Therefore, the role of trade in literature is ambiguous as it may improve or degrade environment (Nasir and Ur Rehman 2011).

Urbanization is a global phenomenon that is also considered as a prime determinant of economic growth. Half of the world's population lives in urban areas. Contrary to developing economies, this ratio is higher in developed countries (Seto et al. 2010; Sadorsky 2014). Usually, unemployed people from rural areas move toward urban areas for new learning and employment opportunities; this movement disrupts the environment and infrastructure in urban areas and cannot be controlled by law (Shahbaz et al. 2016). By providing employment opportunities, urbanization leads toward environmental degradation, poverty omissions, and disease spreads. Studies by Poumanyvong and Kaneko (2010), Zhang and Lin (2012), Al-Mulali et al. (2013), and Dogan and Turkekul (2016) show that urbanization increases demand for traditional fuel energy consumption and vehicles, among others (Katircioğlu and Katircioğlu 2018; Ali et al. 2019).

The impact of environmental degradation on urbanization can be positive and negative (Muhammad and Abdul 2014). Literature also reveals negative relationship between urbanization and carbon emissions (Fan et al. 2006; Sharma 2011; Muhammad and Abdul 2014), whereas urbanization also brings efficiency in scarce resources resulting in improvement of environmental quality (Capello and Camagni 2000; Gasimli et al. 2019). Additionally, urbanization can also help in improving environmental quality (Effiong 2016).

Hence, this study aims to examine the impact of annual stock market prices and renewable energy consumption on environmental degradation. The study also investigates the relationship between FDI, urbanization, and trade openness on environmental degradation. The study makes use of annual data from 1992 to 2018 in the BRICS countries by using econometric estimation. The study makes several contributions to the literature. First, this study investigates the relationship between annual stock market price, FDI, renewable energy, urbanization, and trade openness in BRICS countries. This study uses MSCI variable for stock market development that is missing in past studies. It also incorporates a variety of variables in single study like stock market development, FDI, urbanization, trade openness, renewable energy, and total energy consumption for a data set of 1993–2018.

To study the role of environmental degradation on stock markets in BRICS region in manifold, one major reason is the risks associated with its stock market development in terms of

energy consumption safety and environmental degradation. The BRICS countries might be a giant group then G6 in less than 40 years, and by 2025, they could account for over half the size of G6 (Sachs 2003). To maintain the pace of economic growth, BRICS countries' stock markets are under constant pressure by internal and external risks associated with environmental degradation.

Literature review

Environmental degradation and annual stock market price

Over the decades, studies have examined the link between financial development of stock markets, energy consumption, and environmental degradation around the globe. However, the results still are inconclusive. Either the financial development of a country increases energy consumption and hence environmental degradation (carbon emissions) or vice versa. Studies conducted on developed and developing markets showed that stock market indicators impact carbon emissions differently in developed and emerging markets. Stock market indicators of developed markets impacts carbon emissions significantly positive, whereas on emerging markets, their impacts are significantly negative, hence enhancing the support for environmental Kuznets curve (EKC) hypothesis, which says that stronger stock markets play a central role in minimizing carbon emissions. One reason for this phenomenon might be that developed stock markets have formulated effective policies against environmental degradation, and carbon emissions for listed firms, whereas emerging markets still lag.

Khan et al. (2020) studied the link between energy consumption, economic development, and CO_2 emissions in Pakistan. Data from 1965 to 2015 was used. Results indicated that energy consumption and economic growth increases the CO_2 emissions. One possible reason for these findings is the use of traditional energy sources such as coal, gas, and oil for increased demand of energy consumption instead of renewable energy sources. Işık et al. (2019) studied the impact of renewable energy, fossil energy, population, and real GDP on CO_2 emissions by taking a sample of ten US states from 1980 to 2015. Five states (Florida, Illinois, Michigan, New York, and Ohio) showed support of the EKC hypothesis, i.e., renewable energy resources help in lowering environmental degradation (carbon emission), whereas fossil energy has negative impacts on CO_2 emissions in Texas and other states.

Hanif (2018) examined the relationship between economic growth, urbanization, renewable energy consumption, fossil fuels, and solid fuels on CO_2 emission. A sample for this study was taken from 1995 to 2015 of Saharan Africa. The results from the GMM model illustrated that CO_2 emissions has positive relationship with fossil fuels and solid fuels. Bhat (2018) also examined the association between energy consumption and economic growth on CO_2 emission from 1992 to 2016. Findings showed that renewable energy resources negatively impact CO_2 emissions, whereas nonrenewable energy resources positively impact CO_2 emissions. One reason for high CO_2 emissions in developing countries as compared to developed markets is well illustrated by study conducted by Sinha and Shahbaz (2018). Shifting from traditional energy sources to renewable energy sources demands a high cost of the initial investment. Developing countries showed reluctance for this initial stage high cost to convert their traditional energy consumption to renewable energy sources, hence contributing more in environmental degradation to emitting more CO_2. Promoting renewable energy sources in underdeveloped countries might lead to economic distress in the short run.

Their study also supports the findings of Inglesi-Lotz and Dogan (2018), suggesting that varying technological and economic conditions impact the choice of varying energy structures among developing and developed countries. Due to the reason, shifting on renewable energy sources from ancient traditional energy sources is a far big challenge for developing countries.

Dasgupta et al. (2001) also studied the impact of developed stock markets on environmental degradation by selecting a US sample and Canadian markets. By implementing environmental-friendly policies and practices for listed companies, efficient capital markets play a role in improving environmental performance. Dasgupta et al. (2001) studied the same link in the developing markets of Argentina, Chile, Mexico, and Philippines. The results showed that several disclosure mechanisms elevated environmental performance. Some more noteworthy studies with their findings are listed in Table 1.

Environmental degradation and urbanization

A brief review of the literature showed that the effect of urbanization could be positive or negative on environmental degradation. Gasimli et al. (2019) study the relationship in Sri Lanka between energy, trade urbanization, and environmental degradation for a time series sample of 1971 to 2006. Findings illustrate that long-run and short-run energy consumption have significant positive relations with carbon emission. Trade openness also has a significant positive relation with carbon emission, as more and more trade leads toward carbon emission in atmosphere.

On the other hand, urbanization was found to be significantly negatively associated with carbon emissions. Shahbaz et al. (2014) study the relationship between urbanization and carbon emissions in UAE. Quarter frequency data for a period of 1975–2011 was taken and found a long-run relationship between economic growth, electricity consumption

Table 1 Studies on relationship between financial development of stock markets and environmental degradation

Author	Year of publication	Geographical location	Does financial development of Stock markets increases environmental degradation (carbon emission)?
Islam et al.	2013	Malaysia	Yes
Tang and Tan	2014	Malaysia	Yes
Çoban and Topcu	2013	European Union (EU) countries	Yes
Komal and Abbas	2015	Pakistan	Yes
Al-Mulali et al.	2015	Panel of 129 countries	Yes
Abbasi and Riaz	2016	Pakistan	Yes
Shahbaz et al.	2013	Indonesia	No
Ozturk and Acaravci	2013	Turkey	No
Omri et al.	2015	MENA countries	No
Le	2016	Sub-Saharan African countries	No

urbanization, and carbon emissions. Also, urbanization has a significantly positive effect on carbon emission.

The same findings of the link between urbanization and carbon emissions were reported by Katircioğlu and Katircioğlu (2018) on a Turkey economy sample. As rapid development in urbanization leads to the use of traditional sources of energy consumption, it positively affects carbon emissions. Al-Mulali and Ozturk (2015) examine the environmental degradation factors in MENA (Middle East and North African region). Data was taken from 14 MENA countries for a period of 1996–2012. The results showed that energy consumption, urbanization, trade openness, and industrial development lead to higher environmental degradations.

Whereas Wang et al. (2017) and Wang et al. (2019) studied the link within China, the results showed that in the western region, urbanization impacts significantly positive to carbon emissions, while in eastern regions where there is rapid urbanization development taking place, it did not affect carbon emissions.

Saidi and Mbarek (2017) study the impact of financial development, income trade openness, and urbanization on carbon emissions for 19 countries for a period of 1990–2013. An inverted U-shaped relationship was found between income and environmental degradation. Financial development was found to be abating environmental degradation as the link between financial development and carbon emissions was significantly negative. The rationale for this finding is the financial reforms for listed companies as they imply financial development. Urbanization was found to be reducing carbon emissions. Hence, a suggestion for these countries' policymakers is to impart the knowledge to slow the rapid urbanization increase.

Environmental degradation and foreign direct investment

FDI is another environmental degradation element (Grossman and Krueger 1991, b). To date, no consensus exists in the literature that either FDI helps in lowering environmental degradation or elevating the levels in the host country.

Two main streams of literature go parallel. Pollution haven hypothesis states that strict environmental policies countries prefer to invest in weak environmental policies countries to fulfill the need of investment projects which might lead toward higher environmental degradation in host countries (Sarkodie and Strezov 2019; Balsalobre-Lorente et al. 2019; Harris, 2008; Liu et al. 2017; Hanif et al. 2019; Gago-de-Santos and Abbas 2019). Whereas Azam et al. (2019), Sarkodie and Strezov (2019), Sarkodie et al. (2019), and Liobikienė and Butkus (2019) studies are in conjunction with pollution halo hypotheses which states that host countries overcome these environmental degradation activities through FDI by introducing smart/advanced technology transfer, better management, and environmental innovations.

Caglar 2020 examines nine countries identified as highest by Climate Change Performance Index 2018 (CCPI) to examine the link between renewable energy, non-renewable energy, foreign direct investment, economic growth, and carbon emissions. The results demonstrated a significant positive long-term relationship in some countries between foreign direct investment renewable energy and economic growth, whereas results were different for nine countries on short-term basis. The stated rationale for this was the difference in policy implications for all nine countries for CO_2 emissions. Some other studies are listed in Table 2.

Table 2 FDI and environmental degradation

Author	FDI leads toward environmental degradation in host country	FDI reduces environmental degradation in host country
Seker et al. 2015	✓	
Solarin et al. 2017	✓	
Koçak and Şarkgüneşi 2018	✓	
Terzi and Pata 2020	✓	
Gorus and Aslan 2019	✓	
Naz et al. 2019	✓	
Shahbaz et al. 2019a	✓	
Hao and Liu 2015		✓
Zhu et al. 2016		✓
Rafindadi et al. 2018		✓
Cheng et al. 2019		✓

Environmental degradation and trade openness

Boutabba (2020) investigates the role of financial development, economic growth, energy consumption, and trade openness in mitigating carbon emissions in India. The results showed that financial development reduces environmental degradation as financial development has long-run positive effect on carbon emissions.

Maji and Habibullaha (2015) study the link between trade openness and environmental quality in Nigeria through deforestation for a period from 1981 and 2011. Results showed that trade flow and economic growth were significantly associated but had an indirect relationship. For instance, both variables will help in the reduction of deforestation and turn will reduce environmental quality. The population was significantly positive in relation to deforestation, whereas the impact of energy was insignificant.

Ali et al. (2020) examine the relationship between trade openness, FDI, and institutional performance on environmental degradation in OIC countries. The results showed that trade openness, FDI, and urbanization have a significant positive relationship with environmental quality, but significant negative relationship between institutional performance and ecological footprints. The results suggest that OIC countries should incorporate green technologies, clean production, and improved institutions for sustainable and improved environmental quality.

Study conducted by (Alola 2019a) in the USA revealed that monetary policy, immigration, and trade are the hurdles to environmental sustainability. In another study, Alola (2019b) observed environmental degradation factors in the USA from 1990 to 2018. The short-run results showed a significant positive impact on CO_2 emissions, whereas positive relation was found between migration and CO_2 emissions.

Environmental degradation and renewable energy

Alola et al. (2019) study the relationship between renewable energy and environmental degradation in three European countries (France, the UK, and Germany). Robustness test also confirmed the reported relationship.

Sharif et al. (2020) study the link between renewable energy utilization and environmental degradation from 1990 to 2017 monthly. The sample was selected from the top 10 polluted countries of the world. The results revealed that renewable energy consumption is negatively associated with environmental degradation in China, the USA, Japan, Canada, Brazil, South Korea, and Germany, in contrast to India, Russia, and Indonesia. To lower ecological degradation, the government should implement policies of green energy as a substitute for old traditional energy sources.

Ben and Ben (2015) examine the relationship between trade openness and green and non-green energy under EKC hypothesis in Tunisia. Moreover, they found a unidirectional link between carbon emissions and green energy utilization. This link was unidirectional respectful of import and export-oriented variables.

Aggregate correlation

The trend of the correlational relationship of each variable with CO_2 emission is reported in Figs. 1, 2, 3, 4, 5, 6, and most of the relationship patterns are important here. The previous theoretical literature suggests that the positive/negative relationship between our explanatory variables and CO_2 emission could arise for several reasons, including policy and non-policy measures for economy-boosting's productivity effects.

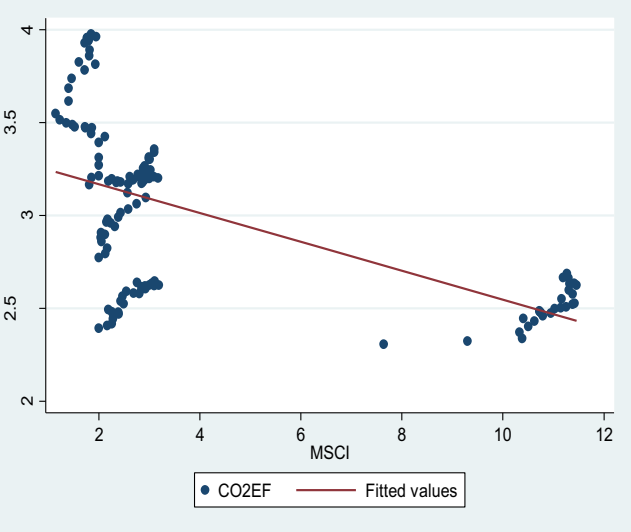

Fig. 1 CO_2 and MSCI emission across countries. Constant = 0.6544, Coef = − 0.2101, *t*-stat = 3.22, *p* value = 0.002, R^2 = 0.58, *N* = 134

Figure 1 is showing the relationship between MSCI and CO_2 emission for a cross section of 5 countries. The aggregate relationship suggests a negative relationship between MSCI and CO_2 emission since countries with a higher level of stock market performance have a significant lower CO_2 emission rate. We can say that each additional unit increase in MSCI is associated with − 0.21 points decrease in CO_2 emission. This estimated point is statistically significant at a 1% level, whereas the stock market performance level explains 58% of cross-country variance of CO_2 emission.

Figure 2 shows the relationship between trade openness and CO_2 emission for a cross section of 5 countries. The aggregate relationship suggests a positive relationship between trade openness and CO_2 emission since countries with a higher level of trade openness have a significantly higher

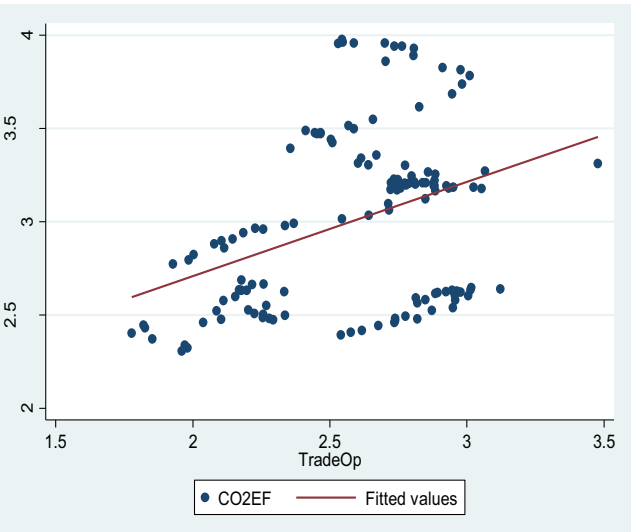

Fig. 2 CO_2 emission and trade openness across countries. Constant = 0.2390, Coef = 0.0956, *t*-stat = 4.67, *p* value = 0.000, R^2 = 0.34, *N* = 134

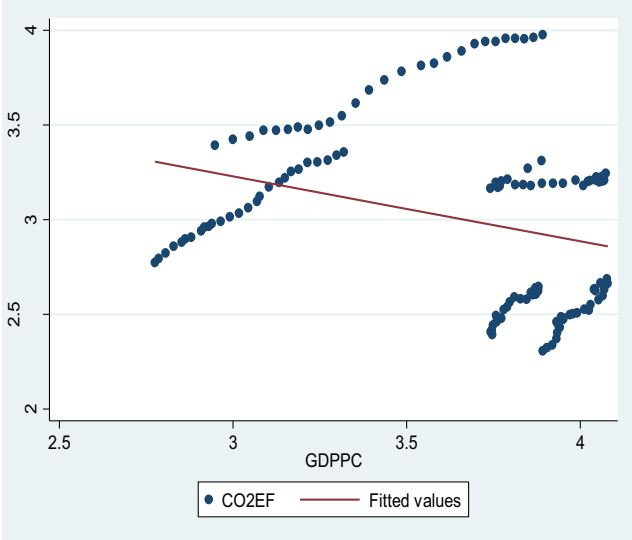

Fig. 3 CO_2 emission and real GDP across countries. Constant = 1.4471, Coef = − 0.1361, *t*-stat = 3.59, *p* value = 0.007, R^2 = 0.67, *N* = 134

CO_2 emission rate. We can say that each additional one percent increase in trade openness is associated with a 0.09-point increase in CO_2 emission. This estimated point is statistically significant at a 1% level, whereas the level of trade openness explains 58% of cross-country variance of CO_2 emission.

Figure 3 shows the relationship between GDP per capita growth and CO_2 emission for a cross section of 5 countries. The aggregate relationship suggests a negative relationship between economic development and CO_2 emission since countries with a higher economic development level have a significantly lower CO_2 emission rate. We can say that each additional one percent increase in GDP per capita growth is associated with a 0.13-point decrease in CO_2 emission. This estimated point is statistically significant at a 1% level,

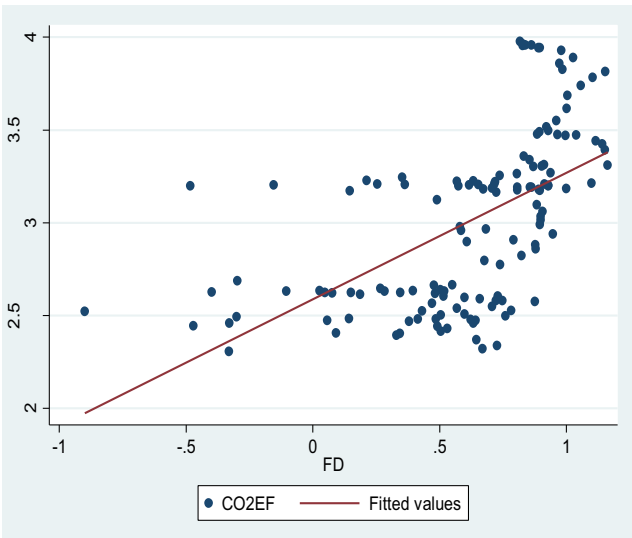

Fig. 4 CO_2 emission and FDI across countries. Constant = 0.6799, Coef = 0.2352, *t*-stat = 4.11, *p* value = 0.000, R^2 = 0.54, *N* = 134

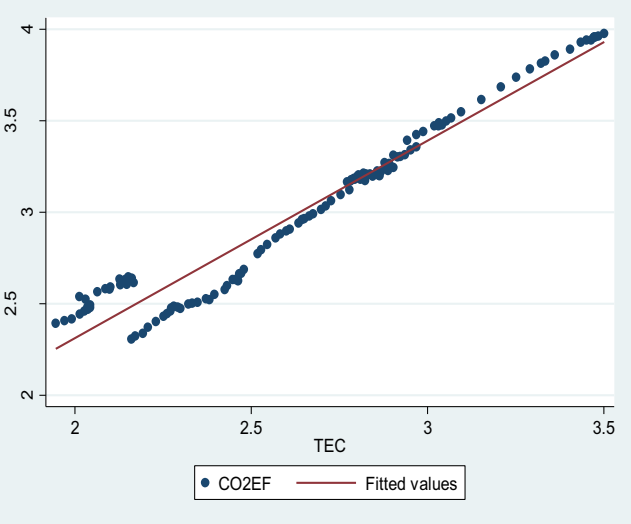

Fig. 5 CO_2 emission and total energy consumption across the countries. Constant = 0.6382, Coef = 0.3789, *t*-stat = 5.03, *p* value = 0.000, R^2 = 0.73, *N* = 134

whereas the economic development level explains 67% of cross-country variance of CO_2 emission.

Figure 4 shows the relationship between FDI growth and CO_2 emission for a cross-section of 5 countries. The aggregate relationship suggests a positive relationship between FDI and CO_2 emission since countries with a higher level of foreign direct investment have a significantly higher CO_2 emission rate. We can say that each additional one percent increase in FDI is associated with 0.23-point increase in CO_2 emission. This estimated point is statistically significant at 1% level, whereas the FDI level explains about 54% of cross-country variance of CO_2 emission.

Figure 5 is showing the relationship between technology growth and CO_2 emission for a cross section of 5 countries.

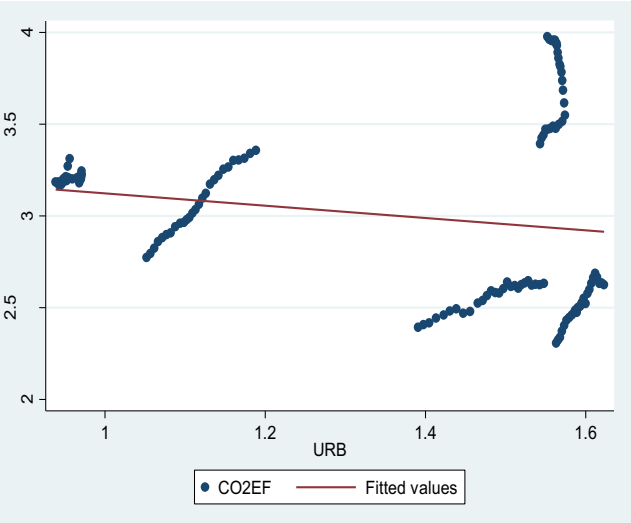

Fig. 6 CO_2 emission and urbanization across countries. Constant = 0.3122, Coef = -0.0781, *t*-stat = 3.69, *p* value = 0.002, R^2 = 0.62, *N* = 134

The aggregate relationship suggests a positive relationship between technology and CO_2 emission since countries with higher level of technological use have a significant higher CO_2 emission rate. We can say that each additional one percent increase in technology is associated with 0.37-point increase in CO_2 emission. This estimated point is statistically significant at 1% level, whereas the FDI level explains about 73% of cross-country variance of CO_2 emission.

Figure 6 is showing the relationship between urbanization growth and CO_2 emission for a cross section of 5 countries. The aggregate relationship suggests a negative relationship between urbanization and CO_2 emission since countries with higher level of urbanization have a significant lower CO_2 emission rate. We can say that each additional 1% increase in urbanization is associated with 0.07-point decrease in CO_2 emission. This estimated point is statistically significant at 1% level, whereas the FDI level explains about 62% of cross-country variance of CO_2 emission.

Materials and method

Data source and description of variables

To access the impact on environmental degradation of stock market, foreign direct investment, renewable energy consumption, and trade openness accompanied by urbanization, we use data for BRICS countries (Brazil, Russia, India, China, and South Africa) for a period of 1993 to 2018. This period is chosen based on data availability from data-stream. As data for China was available from 1993, all other countries variables are set to this year. For environmental degradation, data was collected from Enerdata. Burning of fossil fuels emits carbon dioxide in a process called "combustion"; this emission of CO_2 is taken as a proxy for environmental degradation ($MtCO_2$). Proxy for stock market development is named as MSCI, for which data was collected from DataStream. Data for GDP, foreign direct investment, renewable energy consumption, urbanization, and trade openness were collected from World Development Indicators available at the World Bank database (website www.wdi.com). GDP was measured as GDP (constant 2010 US$); renewable energy consumption was proxied by energy consumption, which is measured as total energy consumption (MTOE). Foreign direct investment is proxied by net of imports and exports (as a percent of GDP). Trade openness is measured as the sum of export and imports as a percent of GDP. Urbanization is measured as the urban population as a percent of total population. The relationship between the stock market prices and CO_2 emissions is depicted in Fig. 7. China showed inverse relationship between CO_2 emissions and stock price, i.e., as CO_2 emission increases the stock prices decrease. In this scenario, the CO_2 emissions affect the growth of stock

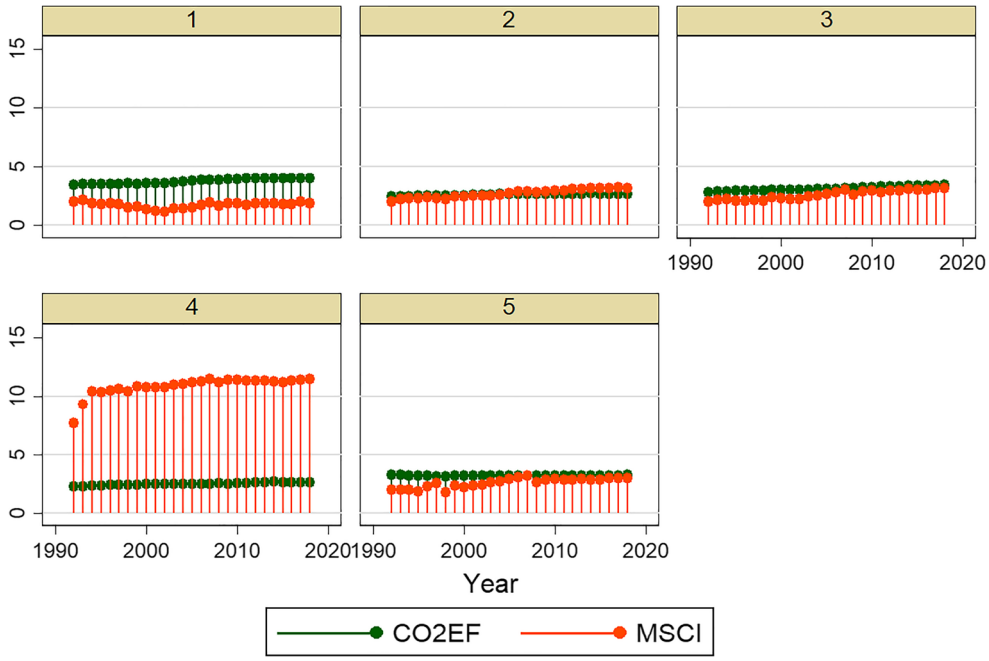

Fig. 7 Dynamic prices of MSCI and Dynamic emissions of CO_2 by countries. Country 1 = China, country 2 = South Africa, country 3 = India country 4 = Brazil, and country 5 = Russia

market due to traditional energy sources such as coal, gas, and oil for increased demand of energy consumption and affect the environment. The same behavior was observed for other countries except Brazil, where the stock prices increase as CO_2 emission decreases. Hence, Brazil stock market plays a significant role in minimizing carbon emissions. One possible reason for these findings might be effective government policies against environmental degradation, i.e., CO_2 emissions and renewable energy sources to fulfill the increasing demand of energy (Table 3).

Econometric methodology

Panel unit root test

To determine the stationarity of panel data variables, unit root tests were run for reliable estimates. Following Danish et al. (2018), the test was divided into two: first-generation panel unit root test and second-generation unit root test. As Levin Lin Chu (LLC) and Hadri, the Breitung tests comprise first-generation unit root tests but do not address cross-sectional dependence. As second-generation unit root tests are based on the assumption of homogeneity and cross-sectional dependence, second-generation panel root tests are suitable for this study. According to Danish (2019) and Wang et al. (2018), the problem of homogeneity is reduced by second-generation tests like the IM Pesaran Shin test, Fisher ADF test, and Fisher PP. Apart from these, Pesaran (2007) introduces tests like CIPS and CADF, which comprise the second generation unit root test. These tests address cross-sectional dependence as the CO_2 emission level varies significantly among BRICS countries.

Generalized method of moment model

This study investigates the link between stock exchange development, FDI, renewable energy, trade openness, urbanization, and environmental degradation. The study treats

Table 3 Description of variables

Variables	Description	Unit of measurement	Source
CO_2 emissions	Carbon Dioxide from fossil fuels	Metric tons	Enerdata
MSCI	Morgan Stanley capital investment	US dollar	DataStream
TEC	Renewable energy proxy for total energy consumption	Metric tons	Enerdata
GDP	Gross domestic products	Constant 2010 US$	www.wdi.com
FDI	Foreign direct investment	Net inflow of imports and exports	www.wdi.com
TO	Trade openness	Percent of GDP	www.wdi.com
UBR	Urbanization	Urban populations percent of total population	www.wdi.com

environmental degradation as outcome variable, while stock exchange development, FDI, renewable energy, trade openness, and urbanization are treated as predictor variables.

Endogeneity and simultaneity biases results in the presence of correlation among disturbance term and endogenous variables. So, in this situation, applying ordinary least squares regressions lead toward biased and unreliable estimates, resulting in a violation of one of the classical linear regression models' assumptions. Similarly, long-run panel data estimation methods are also unsuitable to use. To get reliable and precise analysis, we employ a generalized method of moment approach. Arellano and Bond (1991) introduce the GMM approach. In support of this approach, he argues that in the dynamic panel model, using the orthogonal condition between the lag value of the dependent variable and the error term, an additional instrument can be achieved. Hence, this new instrument eliminates the correlation between independent variable and the disturbances. Following Halkos (2003), Danish (2019), Ahmad et al. (2019), we use the GMM estimator in this study. Using orthogonal conditions between lag value of dependent variable and error term, the possibility of endogeneity of predictor variables can be controlled. Applying first-order differentiation through this approach helps counter cross-country effects. As a result, estimation is reliable and consistent.

Results analysis

Table 4 provides the statistics summary of all variables of the study. Urbanization was found to be the least volatile of all variables. There is not any considerable difference between MSCI and TO and FD and GDP. These 4 were less volatile than CO_2 and GDP_2. On the other hand, GDP_2 appears to have the highest volatility, approximately 2 times higher than all variables.

Table 4 shows the correlation matrix among variables. Tec shows highest positive correlation with a value of .9726, whereas GDP^2 positively correlates 0.7017, GDP = 0.6980, FD = 0.5700, and EOP =0.3736. On the other hand, MSCI and URB correlate negatively with a value of − .5750 and − .1854 respectively.

Preliminary analysis

Panel unit root tests

Among BRICS countries, as variable levels vary significantly, a group of second-generation panel unit roots test is suitable. The results showed that variables under consideration are not stationary at level but become stationary after taking the first difference. Hence, CO_2, MSCI, TO, GDP, FD, TEC, and URB are integrated at the first order I (1); we can go on to regression estimates (Table 5).

GMM estimation results

This study uses the GMM approach to get regression coefficients. The study takes environmental degradation (CO_2 emissions) as outcome variable, with MSCI, renewable energy, FDI, urbanization, and trade openness as predictor variables. As some variable shows strong positive correlation in the correlation table, which restricts the use of OLS regression, we use the GMM estimation for regression coefficients to

Table 4 Results of descriptive statistics

	CO_{2ef}	GDP^2	MSCI	GDP	TEC	TO	URB	FD
Mean	3.008	146.501	4.064	12.09740	2.645	2.594	1.341	0.616
Median	3.033	147.966	2.663	12.16413	2.711	2.716	1.487	0.716
Maximum	3.976	169.867	11.460	13.03331	3.500	3.478	1.622	1.162
Minimum	2.306	128.470	1.149	11.33449	1.946	1.777	0.938	− 0.900
Std. dev.	0.466	9.531	3.448	0.393822	0.419	0.344	0.259	0.390
Observations	134	134	134	134	134	134	134	134
Correlation matrix								
CO_{2ef}	1							
GDP^2	$0._{7017}$	1						
MSCI	− 0.5750	0.1499	1					
GDP	0.6980	0.9997	0.15690	1				
TEC	0.9726	0.8137	− 0.4094	0.8130	1			
TO	0.3736	− 0.1444	− 0.6356	− 0.1501	0.2049	1		
URB	− 0.1854	0.1642	0.4359	0.1556	− 0.1971	− 0.2805	1	
FD	0.5700	0.2997	− 0.4179	0.2996	0.5492	0.1976	− 0.1573	1

Table 5 Results of panel unit root tests

Variables	Level					First difference					Decision
	IPS	ADF	PP	CIPS	CADF	IPS	ADF	PP	CIPS	CADF	
CO_{2ef}	0.84 0.799	11.396 0.327	49.969*** 0	− 2.398	− 2.398*** 0.007	− 4.988*** 0	− 41.034*** 0	45.103*** 0	− 3.152*	− 3.152*** 0.001	I (1)
MSCI	− 6.513*** 0	82.088 0	84.044*** 0	− 3.17	− 4.014*** 0	− 11.333*** 0	93.475*** 0	592.764*** 0	− 4.868**	− 4.868*** 0	I (1)
TO	− 0.323 0.373	18.652 0.044	16.491* 0.086	− 3.052	− 3.052*** 0.001	− 6.714*** 0	53.431*** 0	76.599*** 0	− 4.02*	− 4.021*** 0	I (1)
GDP	2.82 0.997	6 0.815	5.401 0.862	− 3.074	− 3.074*** 0.001	− 3.041*** 0.001	26.344*** 0.003	28.836*** 0.001	− 3.454*	− 3.171*** 0.001	I (1)
FD	− 4.155*** 0	36.703*** 0	41.903*** 0	− 3.947	− 3.947*** 0	− 12.36*** 0	103.77*** 0	825.645*** 0	− 5.837**	− 5.387*** 0	I (1)
TEC	0.853 0.803	9.358 0.498	33.895*** 0	− 2.214	− 2.728*** 0.013	− 5.123*** 0	42.853*** 0	43.497*** 0	− 4.040*	− 3.729*** 0	I (1)
URB	0.023 1	10.714* 0.087	23.786*** 0.002	− 0.71	0.16 0.689	− 0.435*** 0.001	− 5.153*** 0	33.551*** 0	− 0.464*	− 0.464* 0.098	I (1)

* and ** are significance level at 1% and 5% respectively

IPS Im Pesaran, *ADF* augmented Ducky Fuller, *PP* Philips Pesaran, *CIPS* Cross Im Pesaran, *CADF* cross-augmented Ducky Fuller

avoid endogeneity biases. The results are reported in Table 6. Table 6 shows that the coefficient of MSCI is significant positive in 5 models and negative in 2 models, suggesting that the MSCI effect on carbon emissions from fossil fuels is not stable in all models. By adding FD, URB, and TEC, the stock market coefficient becomes negative in models 6 and 7. This may be due to encouragement through governmental policies toward economic development but less focus on conserving environment as there

Table 6 Results of regression

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Constant	2.395	1.658	− 4.627	19.440	19.066	− 6.207	23.326
	0.000	0.000	0.000	0.000	0.000	0.035	0.000
MSCI	.150	.093	.008	.0254	.025	− .008	− .006
	0.000	0.000	0.313	0.003	0.004	0.075	0.015
TO		.372	.157	.204	.202	.045	.066
		0.000	0.000	0.000	0.000	0.001	0.000
GDP			.594	− 3.304	− 3.245	1.019	− 3.937
			0.000	0.000	0.000	0.034	0.000
GDP^2				.156	.154	− .042	.158
				0.000	0.000	0.000	0.000
FD					.003	.009	.010
					0.764	0.083	0.034
TEC						1.143	.967
						0.000	0.000
URB							1.000
							0.000
R^2	0.69	0.52	0.50	0.63	0.63	0.68	0.67
F− test	299.68 0.000	478.25	103.34	109.57	100.91	108.42	30.09
		0.000	0.000	0.000	0.000	0.000	0.000
Rho	.99	.98	.98	.99	.99	.99	.99
Observation	134	134	134	134	134	134	134
No. of groups	5	5	5	5	5	5	5

are more emissions of CO_2 with respect to economic development. The relationship between trade openness and carbon emissions from fossil fuels is significantly positive, suggesting that opening the country boundaries for trade opens the roads for industrial pollution, hence raising carbon emissions levels. The environmental impact of GDP is significantly positive than significantly negative, and then again significantly positive.

In contrast, the effect of GDP^2 is significantly positive then significantly negative suggesting that GDP effect is not stable in all models. One possible reason may be that government policies are changing with respect to economic growth. FDI and urbanization impact the environment, suggesting that foreign direct investments and urbanization do not play a role in carbon emissions levels.

Robustness check

To check the robustness of GMM model, Table 7 shows the results. The corresponding model shows no autocorrelation, so we strongly reject the null hypothesis of second order Arellano and Bond autocorrelation tests (AR). The model does not report any heterogeneity, as instruments are not uncorrelated with disturbance term identified by Hansen overidentification restrictions (OIR). Overall, the results show that the model is well established. Furthermore, we also applied fixed effects regressions model for the 7 models as a robustness check. The results were similar to those of the GMM model.

Pool mean group (PMG) analysis

Following Danish (2019) and Sarkodie and Strezov (2018) to validate the estimation model from GMM, we use the pool mean group approach. The results in table showed that the coefficients of MSCI are found to be negative for all models. It showed that the impact of stock market on environmental degradation is negative. The coefficients for TO, TEC, and URB were positive, and it showed a positive relationship between TO, TEC, URB, and CO_2 emission. However, if we see the coefficients for GDP and GDP^2 were reverse in relation with CO_2 emission, first GDP is positive and then negative, but in case of GDP^2 coefficient, it has first negative and then positive association with CO_2 emission. The coefficient of FD was a positive relationship with CO_2 emission in model 5 and model 6 respectively, but a negative association in model 7. Additionally, the coefficients of MSCI, GDP, GDP2, FD, TEC, and URB are significant, whereas TO in one model was insignificant and then significant in all other models. Therefore, the findings of the pool mean group analysis are inconsistent with the GMM estimation results (Table 8).

Discussion

This study examines the relationship between stock market development, renewable energy, foreign direct investment,

Table 7 Result of robustness check

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Constant	.872 0.005	.748 0.012	− 1.146 0.000	2.948 0.000	1.486 0.000	− 4.343 0.043	3.594 0.000
CO_{2ef}	.964 0.000	.937 0.000	.768 0.000	.757 0.000	.761 0.000	.494 0.000	.447 0.000
MSCI	.778 0.000	.409 0.000	− .010 0.035	− .341 0.000	− .493 0.000	− .0547 0.002	− .013 0.007
TO		.041 0.000	.056 0.000	.0638 0.000	.057 0.000	.040 0.000	.044 0.000
GDP			.144 0.000	− .517 0.000	− .283 0.000	.696 0.045	− .635 0.418
GDP^2				.026 0.000	.017 0.000	− .027 0.053	.026 0.404
FD					.009 0.031	.009 0.003	.010 0.001
TEC						.523 0.000	.538 0.000
URB							.290 0.060
AR[2]	–0.54 (0.312)	− 1.44 (0.271)	− 0.77 (0.855)	− 0.61 (0.653)	− 1.31 (0.459)	− 1.53 (0.183)	− 1.08 (0.983)
Sargan OIR	6.41 (0.883)	4.55 (0.673)	7.89 (0.871)	3.45 (0.341)	4.53 (0.671)	2.89 (0.472)	1.96 (0.092)
Observation	134	134	134	134	134	134	134
No. of groups	5	5	5	5	5	5	5

Table 8 Results of pool mean group (PMG) analysis

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Constant	3.324	3.271	− 8.563	− 27.129	− 24.609	22.840	9.599
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MSCI	− .077	− .076	− .087	− .089	− .086	− .0185	− .019
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TO		.0184	.111	.119	.123	.122	.128
		0.883	0.000	0.000	0.000	0.000	0.000
GDP			.962	4.028	3.622	− 3.771	− 1.561
			0.000	0.000	0.000	0.000	0.000
GDP^2				− .126	− .110	.156	.061
				0.000	0.001	0.000	0.000
FD					.055	.009	− .007
					0.006	0.346	0.243
TEC						.970	1.078
						0.000	0.000
URB							.1668
							0.000
Observation	134	134	134	134	134	134	134
No. of groups	5	5	5	5	5	5	5

trade openness, and urbanization on environmental degradation. For this, we estimate the panel root test, which justifies the results of the macro panel. The panel root test deals with the non-stationarity and rejects the assumption of homogeneity. It also helps to identify the cross dependency of variables while dealing with panel data.

Empirical results illustrate that the relationship exists between the stock market and CO_2 emission across the panel in fixed effect, GMM, and pooled mean group. For instance, graph 1 shows a statistically significant negative relationship between stock market and environmental degradation in emerging economies, whereas Brazil shows a positive relationship. Empirical results advocate regulators and policymakers to ensure that listed firms of emerging and developed economies must develop their stock markets and follow low emission along with energy saving technologies. Our results are consistent with Paramati et al. (2017a, b) who investigated that stock market price per capita has positive impact on the CO_2 emissions in emerging economies while the negative effect in the developed market. Developed markets have effective policies against environmental degradation, especially for listed firms, and have advanced technologies that lag behind emerging markets. Khan et al. (2020) investigated that economic growth increases the CO_2 emissions by using traditional energy sources such as coal, gas, and oil. While Işık et al. (2019) connected the relationship between economic growth and CO_2 emissions, renewable energy resources help lower environmental degradation (carbon emission), whereas fossil energy has a negative impact on CO_2 emissions. Our results are also consistent with Shahbaz et al. (2020) study, who concluded that CO_2 levels increase financial development of an economy. Growth in economic sector of a country positively affects environemtal degradation wheras economic globalization negativly impacts CO_2 emissions. Whereas environmetal quality is improved by electricity consumption for industries, they recommend to maintain standards to implement environmentally friendly technologies and investment efficiency. For instituions, government, and banks, they suggest to initiate and engage in projects of code of good pracitces and highlighting and implementing the clean and green environmental issues and technologies.

Stock market development plays a prominent role in environmental degradation by emitting more CO_2. The foremost reason is through business expansion. As the stock market provides a platform for effortlessly exchanging funds across parties (both equity and debt financing), they are of prime importance to business activities. Growth in business activities also enhances the production process for exports and conserve more energy, leading to more carbon dioxide emissions. On the other hand, the availability of additional funds via stock markets helps businesses and customers diversify risks. This availability enhances business activities, which increases energy consumption and then environmental degradation (Sadorsky 2011; Paramati et al. 2017a, b; Kutan et al. 2018).

Stock market development also plays a prominent role in minimizing CO_2 emissions. As listed firms operate under stock market rules and regulations and stock markets especially in developed countries, stock markets have strong

regulations and strike actions on any violation. They use more efficient production processes, smarter technologies for industrial pollution, and sustainable energy sources (Lanoie et al. 1998). With respect to conserving the environment, listed firms also compete with each other in playing an environmentally friendly role for its consumers (Lanoie et al. 1998). In contrast, traditional technologies and energy sources that use fossil fuel burning contribute to environmental degradation. Their findings are inconsistent with those of Dogan and Inglesi-Lotz (2017), Shahbaz et al. (2017), Shahbaz et al. (2019b), and Solarin et al. (2018) They argue that the consumption of energy through fossil fuel increases environmental pollution.

Additionally, our study's findings support Onafowora and Owoye (2014) findings, who study the link between stock market growth and CO_2 emissions. Sample countries for this study were China, Egypt, Brazil, Mexico, Nigeria, and South Africa. The results showed that government policies are more favorable for economic development and less favorable for environmental protection, resulting in enhanced CO_2 levels and economic development. In 2018, Sarkodie and Adams claim that renewable energies and smarter technologies build a clean environment.

We also reveal that FDI, urbanization, and trade openness showed a positive relation with carbon dioxide emissions, which interprets that with the removal of trade barriers, inflow of FDI and growth of urbanization leads toward environmental degradation. The results were consistent in both fixed effects and GMM estimation. Hence, it proves that trade opening in BRICS countries leads toward environmental degradation due to weak regulations (Copeland and Taylor 1994; Talukdar and Meisner 2001; Xing and Kolstad 2002; Dinda 2004; Hoffmann et al. 2005; Baek and Koo 2009). FDI and CO_2 also showed positive relationship. With the increase in FDI, CO_2 also increases. These results were consistent with Chandran and Foon (2013), D'Agostino (2015), Sun et al. (2017), Solarin et al. (2017), and You and Lv (2018). The rationale for these findings is due to weak environmental and production regulations in host countries; developed countries shift their operation to host countries due to cheap processes.

Additionally, urbanization and CO_2 emissions from fossil fuels also showed a significant positive relationship. In BRICS countries, an increase in urbanization also increases CO_2 emissions and hence environmental degradation. In BRICS countries, trade openness is another factor which leads toward environmental degradation. One rationale for this is that as countries open their boundaries for trade activities, countries especially developing countries compromise on conserving the environment due to the affordability of unfriendly production machinery and reliance on cheap technologies, of which most of times outdated machinery and technologies which emit more pollutant and consume more energy. Additionally, opening trade also increases energy demand. Here again, production processes compromise on energy sources and prefer cheap conventional non-renewable energy sources like fossil fuels, which emits more CO_2 in the environment (Wang et al. 2017; Danish 2019; Akif and Asumadu 2019). Furthermore, due to slack environmental rules and regulations, trade agreement among BRICS and outside countries also leads to transferring old technologies, hence contributing to the degrading environment (Danish et al. 2017 ; Sarkodie and Strezov 2019b). Trade openness also leads toward environmental degradation. Enhanced trade needs enhanced energy demands; this energy demand requires more energy sources that are scarce and conventional like fossil fuels, and coal. The use of these unsustainable sources results in environmental degradation (Akif and Asumadu 2019).

Conclusion and policy implication

Keeping in view the nexus between environmental degradation, renewable energy, and stock market development, this study analyzes the impact of stock market, FDI, renewable energy consumption, trade openness, and urbanization on environmental degradation in BRICS countries. The analysis is conducted on data for years from 1993 to 2018. The results showed that there is a negative relationship between CO_2 emissions and stock market development in Russia, India, China, and South Africa. In Brazil, the relationship was found to be positive. One possible reason for this is strong environmental regulations and their enforcement by Brazilian government. Variables such as FDI, trade openness, and urbanization have significant positive relationship with CO_2 emissions; thus, it can be said that these variables contribute adversely to environmental degradation. As BRICS countries have weak regulations, developed countries shift their production to BRICS countries for availing cost-effective cheap production and energy sources. From the results, the study urges that BRICS countries should focus on formulating environment-friendly policies for business entities and ensure that policies are strictly enforced for conserving the environment. As urbanization also showed significant positive effect on the environment, the government of BRICS countries should take new initiatives and projects for remote and village areas so that migration from village to urban areas may be lessen. As this migration increases demand for energy, shelter, and transportation, this also lessens per acre environment levels. In this study, the analysis is conducted on the national data of BRICS countries and it does not go down to include various sectors within this economics. Hence, it is suggested that future studies may extend this analysis using big data and comparing BRICS, G20, and ASIAN countries. Also, future studies may incorporate other econometric techniques to further refine the results.

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Author contribution All authors have contributed to the study. Ijaz Younis developed the contextual framework of the study and prepared the original draft. Miss Aziza Naz assisted in the methodological formulation and data analysis. Mr. Muhammad Nadeem helped with the software analysis and result interpretation. Mr. Syed Ahsan Ali Shah reviewed and improved the initial draft. Mr. Cheng Longsheg provided valuable supervision and arranged funding's for the study.

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Declarations

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