Do health expenditure and human development index matter in the carbon emission function for ensuring sustainable development? Evidence from the heterogeneous panel

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Abstract

This study is an attempt to explain the nexus between health expenditures, GDP, human development index (HDI), CO₂ emissions (COEM), renewable energy (RENE), financial development (FD) and electricity consumption (EC) using data from 2000Q₁ to 2014Q₄ for Brazil, India, China and South Africa. The study applies CIPS and CADF to determine the integration order. The tests confirmed the unique order of integration. The study further uses the Westerlund panel cointegration, which suggests the existence of a long-run relationship. Moreover, the panels dynamic ordinary least squares (DOLS) and fully modified ordinary least squares (FMOLS) are applied to ascertain the long-run elasticity. The health expenditure and electricity consumption affect the COEM positively. Moreover, HDI and RE affect COEM negatively. The study further confirms the existence of an N-shaped EKC in the long run. The pairwise Dumitrescu and Hurlin, Econ Model 29:1450–1460, (2012) test is used to uncover the direction of the association between the variables. The findings obtained from DH confirm a bidirectional causality between HDI and FD. Likewise, another bidirectional causal relationship has also been found between FD and EC. The findings of our study advocate policies in the direction of HDI and health expenditure by adopting RENE. This study highlights the importance of RENE, which can facilitate a reduction in carbon emissions and decreasing health expenditures. Moreover, the financial sector needs to be improved to create entrepreneurship opportunities for the public in improving the HDI in ensuring sustainable development.

Keywords N-shaped EKC · Health expenditure · HDI · Heterogeneous panel · Financial development

Introduction

In the current era, the significant rise in the emissions of various GHGs poses significant threats to human health. These GHG emissions deteriorate the environment, thus damaging human health. On one hand, the industries are producing domestic output to increase the domestic production at the local

level, but on other hand, the increased output at the initial level upsurges the level of CO₂ emission (COEM), thus causing environmental pollution at the cost of production. Furthermore, it has been reported that 18% of global CO₂ is emitted from the residential sector, causing serious risk to humans and animals (WHO 2015).

The most threatening risk to life is environmental degradation, which is mainly caused by greenhouse gases (GHG). The concentration of GHGs is increasing and this is primarily responsible for global warming and climate change (Zhang et al. 2017). Global warming agents such as CO₂ lead to chemical and climate changes, which affects health adversely and increases annual air pollution deaths. Climate change has a severe influence on human health, and among many factors, carbon dioxide is the most dominant GHG that deteriorates the environment and damages human health (Danish et al. 2018). Moreover, the increased GHG emissions eradicate the ozone layer, thus exposing the environment to carcinogenic gases and increasing accumulation of particulate matter in the air, which in turns increases hospitalisation and death rates

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(Allen et al. 2016). Jacobson (2008) argued in his study that COEM are increasing the harmful substance which gradually eliminates the ozone layer, thus exposing the environment to dangerous emissions. This not only damages the environment but also human health resulting in an increase in casualties and deaths. This further impacts the productivity of labour, industrial production and economic growth in a country (Allen et al. 2016; Borhan et al. 2018). Further to this, environmental degradation and economic growth are positively related to health expenditure (Bedir 2016; Siti Khalijah 2015). It has been quite evident from the previous studies that fossil fuels (coal, oil and gas) are dominating the global energy consumption that upsurges the GHG emissions, thus raising the global temperature. This motivates the researchers to search for alternative energy sources with more efficiency and less emissions. This will not only lessen the environmental pollution but at the same time upsurge the production, thereby maintaining good health under a hygiene environment. Thus far, previous studies have focused on the importance of renewable energy (RENE), which can provide a wide range of social, economic and environmental benefits if implemented properly (Sarihi and Cherni 2018; Sinha et al. 2017). Moreover, the adoption of new technologies to produce RENE (solar, wind, biogas etc.) can undoubtedly minimise the level of COEM (Apergis et al. 2018). It has been quite evident that health care facilities play a vital role in combatting global climate change (WHO 2011). Further to this, Jerret et al. (2003) argued that countries with higher pollution experience high healthcare expenses, while countries that allocate spending to improving their environment have lower healthcare expenditures. Efficient management of the resources is essential. The countries can prosper if they manage their resources well. In this connection, Gielen et al. (2019) further highlighted that it is technically possible to identify alternative energy sources, which can be explored without damaging the environment. Land, water and energy are the most precious resources that can be used to generate electricity without damaging the environment.

Resource management is important in this case and can have a favourable impact on our long-term usage. Efficient resource management is extremely significant. Further to this, COEM represents two-thirds of all GHGs, thus innovation in the field of RENE is of utmost importance.

Shahbaz and Sinha (2018) explained that at the initial growth stage, the country damages the environment as a result of GHG emissions, deforestation and soil and water contamination. The country progress and the income increase with environmental pollution simultaneously. After reaching the threshold point, the income increases and at the same time, the quality of the environment improves. At this point, the environmental degradation slows down, thus hypothesising a relationship between income and CO₂ that is defined as an inverted U-shaped or environmental Kuznets curve (EKC), as suggested by Kuznets (1955) and Grossman and Krueger (1991).

This shows that in the initial phases of development, the countries always strive for more production at the cost of environmental pollution. At the same time, it also damages human health, which upsurges the health expenditure incurred by the country (Wang et al. 2019). In the last decades, it has been noticed that a rise in mortality rates and diseases is associated with air pollution (Yazdi and Khanalizadeh 2017). Since economic activities lead to more energy consumption that ultimately elevates air pollution, this upsurges healthcare expenditure. There are many economic and non-economic factors such as population, ageing, income, number of doctors, government health care facilities and care finance, and urbanisation (Yahaya et al. 2016). Developing countries are in the initial phases of development in which more industries are established to enhance their domestic production. This may be due to the cheap and abundant supply of labour, low regulations and cheap supply of inputs. These inputs are not focussed on quality, thus emitting various gases and raw materials that are damaging to the environment and air (USEPA 2010). Yahaya et al. (2016) argued that clean air is not only important for humans, but also for animals, water, vegetation and soil. The GHG emissions pollute the environment, thus making it difficult for people to breathe in clean environment, resultantly increasing healthcare expenditure.

In order to enhance the energy efficiency of the world, it is necessary to evaluate the use of RENE and CO₂ reduction in the potential countries, based on their economic growth. The outcomes of the study will help in policymaking regarding the use of RENE, environmental sustainability and reduction of human healthcare expenditure and contribute towards human development in the countries that have a major impact on the global economy. This research study attempts to investigate the nexus among renewable energy, human development index (HDI), health expenditure (HEXP) and COEM in the presence of an N-shaped EKC for Brazil, China, South Africa and India (BRICS countries except Russia). The selection of the BRICS countries (except Russia) in the study is because of their major contribution and influence on the world economy. Amorim (2010) highlighted the importance of the BRICS countries due to their rapid economic growth, their large landmass, abundant natural resources and high technological improvement. Further to this, Faisal et al. (2020) has identified Brazil, India, China and South Africa as fast-emerging economies (FEC) due to their strong infrastructure foundation and their dependence on fossil fuel energy consumption, which leads to increased emissions of GHG and affects human health.

This study makes several contributions to the literature. This study investigates the effects of HDI and health expenditure on COEM in the presence of RENE and electricity usage. Moreover, the second-generation panel techniques are applied using the Westerlund (2007) panel cointegration and second-generation panel unit root test (SPURT) and. In

addition, the robust cross-sectional technique is applied to the variables of the study for causal inferences. Additionally, this is the first in the context of the health-carbon emission nexus to include GDP³ for the validation of the N-shaped EKC.

The rest of the study has been organised as follows. The “Literature review” section reviews the relevant literature. The “Model estimation and methodology” section highlights the relevant methodology. The “Results and discussion” section sheds light on the results and discussion and the “Conclusion and policy implications” section presents the policy implications and conclusion of the study.

Literature review

Renewable energy and carbon dioxide emissions

Environmental pollution is a serious threat to global society. This is a considerable challenge that researchers have attempted to confront to ensure sustainable economic development. The change in the environment is highly associated with the threat of greenhouse gases (GHG) emissions. CO₂, CH₄ and N₂O are the main types of GHG. Consumption of fossil fuel is a major source of CO₂ which is a key source of GHGs. Therefore, to reduce the use of non-renewable resources such as fossil fuels, it is important to search for an alternate resource of RENE. Some of the recent studies have explored the nexus between RENE and COEM. Several studies have reported a positive connection between RENE and COEM, while other researchers have highlighted a negative relationship.

Ben Jebli and Youssef (2015) attempted to explore the nexus among GDP, international trade, RENE and non-RENE and COEM for the case of Tunisia from 1980 to 2009 by applying the autoregressive distributive lag (ARDL) model. The study findings identified a positive association between the trade, COEM and the use of non-RENE in the long run. Moreover, evidence of an inverted U-shaped EKC was not supported in their long-run results. Narayan and Singh (2007) stated that the intense pressure on large economies of the world to enhance energy efficiencies has forced them to reduce the consumption of energy and search for new sources of energy in order to reduce energy wastage and environmental pollution. The decrease in the use of fossil energy will contribute to sustainable development. Jaforullah and King (2015) employed Granger causality and the Johansen cointegration procedure to test the role of RENE consumption in mitigating carbon emissions in the USA. The study considered energy prices as one of the significant factors in energy consumption. No evidence was detected in their study proving the effectiveness of using nuclear energy in reducing emissions. However, the empirical analysis supported the existence of a negative association between

carbon emissions and RENE consumption. Waheed et al. (2018) analysed the nexus among RENE consumption, agricultural production, forest and COEM in Pakistan using the ARDL approach for the period 1990–2014. The study confirmed a negative relationship in the long run among RENE and COEM. Further to this, the use of RENE could reduce the COEM. In another study by Danish et al. (2018) Granger causality was utilised to investigate the EKC hypothesis using the data from 1970 to 2012 for Pakistan. The findings provided strong evidence for the existence of the EKC in the selected period. Further to this, the use of RENE can curb COEM. On the other hand, the consumption of non-RENE could increase COEM. Another study by Sinha and Shahbaz (2018) attempted to explore the possible existence of the EKC hypothesis for India using the ARDL for the period 1971–2015. The evidence suggested a negative and significant linkage between RENE and COEM.

Apergis et al. (2018) examined the relationship between RE and COEM in 42 sub-Saharan African countries for the period 1995–2015. The causal nexus was investigated using the Granger causality framework. The study identified a bidirectional causality between RE and COEM. Further to this, the study argued that countries should invest in RENE sources and health expenditure. Likewise, Dong et al. (2018) empirically tested the association among COEM, RENE and economic and population growth in 128 countries by applying the common correlated effects mean group. The research findings showed that in all six regions, the RENE performs a substantial role in the reduction of COEM. However, the coefficient of the RENE for the case of Eurasia, Europe and America is relatively strong. Recently, Chen et al. (2019) investigated the presence of an inverted U-shaped EKC among the COEM, economic growth, trade and energy (renewable and non-renewable) using ARDL and the vector error correction model (VECM). The empirical analysis identified that foreign trade and RE negatively affect COEM.

On the other hand, Apergis et al. (2010) explored the relation between COEM, nuclear energy RENE and GDP for a group of 19 countries. The study provided confirmation of a negative linkage between the consumption of nuclear energy and COEM, but a positive significant long-run association was identified between RENE and COEM. However, nuclear energy was found to lower COEM, but RENE does not play a vital role in lessening COEMs in the short run.

Menyah and Wolde-Rufael (2010) examined the nexus among COEM, nuclear energy, RENE and GDP for the USA using the modified version of the Granger causality test. The study identified a unidirectional causality relationship from nuclear energy to the emission of COEM. However, no causality was found from RENE to COEM. A weak causal relationship was identified between RENE and COEM using the panel autoregressive model for the Middle East and North

African (MENA) countries. The study concluded that the use of nuclear energy does have a negative impact on mitigating COEM.

Health expenditure and CO₂ emissions

Recently, air pollution has been a major cause of health problems around the world. Environmental pollution and health issues have gained serious attention around the world. It is known that in recent decades, millions of people in China died due to air pollution (Zhang et al. 2018).

Boachie et al. (2014) identified different indicators of healthcare expenditures in Ghana using the FMOLS approach for the period 1970–2008. The results indicated that COEM and healthcare expenditure are positively linked. Further to this, the study suggested policies for the reduction of COEM in order to reduce the healthcare expenditure in Ghana. Yazdi and Khanalizadeh (2017) conducted a study to demonstrate the role of environmental quality and GDP in ensuring healthcare. The study found that COEM and health expenditure are positively associated using the ARDL approach for MENA countries.

Moosa and Pham (2019) empirically examined the nexus between environmental degradation (using COEM as a proxy) and healthcare spending via ARDL for the possible existence of EKC. The study findings highlighted the positive effect of environmental degradation on healthcare spending.

In another study, Wang et al. (2019) investigated the association among COEM, health expenditures and economic growth in Pakistan using the ARDL technique for the period 1995 to 2017. The study findings concluded that a significant association among all three variables exists in both the short and long run. Moreover, a bidirectional causality between COEM and total health spending was identified under the causal framework.

In another study by Haseeb et al. (2019), a significant positive association was revealed among COEM, EC, GDP and HE by utilising the ARDL for ASEAN countries. The study confirmed that environmental degradation affects health expenditure positively.

Several research studies have found contradictory results to the positive relationship in many countries. Chaabouni and Saidi (2017) examined the dynamic linkage between COEM, health expenditures and GDP in a group of 51 countries by using dynamic simultaneous equations and generalised method of moments for the period 1995–2003. These selected countries were further categorised into low-income countries, lower- and upper-middle-income countries and middle-income countries. The results revealed a unidirectional causality between COEM and health spending and middle- and lower-upper-middle countries. However, the study did not find any significant evidence in lower-income countries.

HDI and CO₂ emission nexus

HDI has been consistently used by the UNDP for comparing social and economic development within or across countries. The Millennium Ecosystem Assessment (2001) determined that HDI is composed of three basic indicators: education ratio of adults and overall enrolment rate, life expectancy and gross domestic per capita income that shows the index of the overall living standard. Brooks et al. (2005) determined that deaths due to climate change are correlated with changes in the natural environment. The study found that the two indicators of HDI, life expectancy and literacy rate, are significantly correlated with climatic disasters.

Pirlogea (2012) investigated the role of energy development in the HDI in EU countries. The research study considered both renewable and non-RENE sources. The study argued that energy consumption is associated with COEM. Thus, countries focus on alternative sources of energy that reduce the COEM and the greenhouse effect. Viewing the association between the use of energy and HDI via a regression model, it was noted that the consumption of fossil fuel (sources of COEM) adversely affected the HDI index in Romania and Bulgaria, which have high HDI. The research findings strongly argued that the effectiveness of energy consumption should be enhanced to mitigate the effect of climatic change.

According to Bedir and Yilmaz (2016), COEM is the major source of the greenhouse effect and is emitted as a result of fossil energy consumption. Further to this, the study analysed the nexus between COEM and HDI in 33 OECD countries for the period 1992–2011. The study confirmed the growth hypothesis for Japan, Ireland, Denmark, Slovakia, Italy, Korea, Luxemburg, Poland, Spain, Israel, Turkey and the USA using panel causality analysis. The energy conservation policy has a negative impact on GDP and HDI. In another study by Sinha and Sen (2016), the association between COEM, economic growth and HDI was assessed for the BRIC countries using data from 1980 to 2013 by applying GMM. The study findings supported the feedback hypothesis between COEM and HDI. The COEM increase air pollution, which adversely affects the hygienic conditions for the labour force and impacts their productivity.

Recently, Wang et al. (2019) attempted to examine the dynamic association between COEM, HDI, FD and globalisation in OECD countries for the period 1990–2015. They used Dickey–Fuller, unit root test to identify the series integration order. The Westerlund (2007) test was further employed to confirm the long-run relationship. Further to this, the dynamic ordinary least squares (DOLS) and fully modified ordinary least squares (FMOLS) techniques were applied to determine the long-run coefficients. The results confirmed a negative relationship between HDI and COEM in the OECD countries. Moreover, the study highlighted that energy

consumption and economic growth are the major sources of COEM in the OECD countries.

Model estimation and methodology

This study investigates the effects of health expenditure (HEXP), HDI, financial development (FD) and RENE on COEM. This study selects a group of emerging countries that includes Brazil, India, China and South Africa. Because the data for some parameters were not available for Russia, it was excluded from the sample. The GDP is further used in the form of $(\text{GDP})^2$ and $(\text{GDP})^3$ for the validation of the N-shaped EKC under the framework of the health emission nexus model. Moreover, the health emission nexus is investigated in a multivariate regression to avoid any omitted variable biasness. Based on the discussion in the previous sections, the proposed empirical model has been formed following Apergis et al. (2018) that included renewable energy, GDP, health expenditure and COEM. However, this study differs by further adding electricity consumption, human development index and financial development in the model as proposed by Apergis et al. (2018) in the carbon emission model. Additionally, the N-shaped EKC is investigated using $(\text{GDP})^2$ and $(\text{GDP})^3$ and can be written as follows:

$$\begin{aligned} \ln \text{COEM}_{it} = & \beta_{11} \ln \text{GDP}_{it} + \beta_{12} (\ln \text{GDP})^2_{it} \\ & + \beta_{13} (\ln \text{GDP})^3_{it} + \beta_{14} \ln \text{EC}_{it} \\ & + \beta_{15} \ln \text{HEXP}_{it} + \beta_{16} \ln \text{RENE}_{it} \\ & + \beta_{17} \ln \text{HDI}_{it} + \beta_{17} \ln \text{FD}_{it} + \varepsilon_{it} \end{aligned} \quad (1)$$

where COEM stands for carbon dioxide emission; GDP, GDP^2 and GDP^3 are the linear, square and cubic polynomial form of GDP per capita to validate the N-shape EKC, respectively; EC is the electric power consumption; HEXP represents the health expenditure; RENE denotes renewable energy; HDI represents the human development index; and FD represents a proxy for financial development. Moreover, the data in our study spans the period 2000–2014. “ i ” shows the cross-section and “ t ” represents the time. Further to this, the quadratic match sum method (QSM) is used to change the frequency of the annual data to quarterly. This method is preferable as it eliminates the point-to-point differences in changing the frequency of the data from low to high (Sbia et al. 2014; Cheng et al. 2012). Further to this, this method also takes into account adjustment for seasonal variations. The QSM method is more flexible and convenient as compared to the interpolation. Further to this, the QSM divides the low-frequency data by the number of observations to perform local quadratic interpolation (Shahbaz et al. 2017; Sbia et al. 2017). Using Eviews 10, this study converts the yearly data into

quarterly data using QSM. The data used in this study are from 2000Q1 to 2014Q4 (Rafindadi and Ozturk 2017). The list of the variables used in the study has been shown in Table 1.

CD and CIPS unit root test

Pesaran’s (2004) cross-sectional dependence test (CD) is used to determine whether the gathered data contains the CD or independence. Before approaching the second-generation panel unit root test (SGPUT), it is important that the series of the study needs to be tested for cross-sectional dependency (CD). The 1st generation unit root test is not effective when it is applied to a panel series that has CD issues (Paramati et al. 2016). Consequently, in the existing study, Pesaran’s (2007) CIPS and CADF unit root tests have been employed. These tests are based on the hypothesis of CD. The Westerlund (2007) panel cointegration, which is an error correction-based model, requires the integration order to be identified by CIPS and CADF unit root test. If all the variables in the series are identified to be of unique order at first difference, then this indicates that the entire variables of the study have no unit root problem and are stationary at first difference.

Panel cointegration technique

To identify the indication of a long-run connection between variables, the current study applies the bootstrap panel cointegration (PCI) technique as proposed by Westerlund (2007). This method is more beneficial provided that each cross-section consists of reduced time series. Traditional techniques accept the null hypothesis of no cointegration even in the presence of CD as they do not take the CD into the account. This allows us to apply the Westerlund (2007) PCI, as proposed in the studies by Westerlund (2007) and Persyn and Westerlund (2008). The Westerlund (2007) panel cointegration test focuses on structural dynamics instead of residual dynamics.

The null hypothesis of no cointegration has been tested by using two different tests based on the normal distribution (a) group mean test and (b) panel test. Four test statistics, namely, Pa, Pt, Ga, and Gt, are based on the error correction model and were developed by Westerlund (2007). Further to this, these tests are based on the normal distribution and takes autocorrelation and heteroscedasticity into the account. Gt and Pt can be calculated by using the standard error parameters of the error correlation model. Ga and Pa are adjusted for autocorrelation and heteroscedasticity and are based on standard errors given by Newey and West (1994).

To apply this test, it is assumed that none of the variable contains unit root problem at 1st difference. Further to this, this test also calculates the bootstrapped critical p -values in addition to the normal p -values. The decision of the long-term

Table 1 Variables

No.	Variable	Specification	
1	Financial development (ln FD)	Domestic credit to the private sector (percentage of GDP)	The data has been taken from the World Bank for these variables. https://data.worldbank.org/country
2	Renewable energy use (ln RENE)	Percentage of total final energy consumption	
3	Carbon dioxide emission (ln COEM _j)	COEM (metric tons per capita)	
4	Economic growth (ln GDP)	GDP per capita (constant 2010 US\$)	
5	Health expenditures (ln HEXP)	Health per capita in current expenditures US dollars.	
6	Electricity consumption (ln EC)	Electric power consumption (kWh per capita)	
7	Human development index (ln HDI)	Index (UNDP, COVID-19 and Human Development - Exploring Global Preparedness and Vulnerability)	

¹ The data for the variables ln FD, ln COEM, ln GDP and ln EC has been used in Faisal et al. (2020) study on a yearly basis. This study converts the same yearly data used in Faisal et al. (2020) into quarterly data and used them for further analysis.

association is considered based on the *p*-values for each test (Sharif et al. 2020).

Long-run elasticities

Use of OLS on panel data set is considered to be biased and its distribution focuses on an annoyance constraint. These annoyance constraints can cause serial correlation and endogeneity between the regressors (Pedroni 2001a, 2001b). The FMOLS and DOLS cointegrating equations have been used in this study to solve the endogeneity problem that arises during the estimations to determine the long-run elasticities.

Heterogeneous panel causality test

Appropriate method and technique are important in empirical studies to investigate the causal nexus under the panel causality framework. The traditional Granger causality test is not effective for panel data that does not consider the heterogeneity across the CS. To determine the causal outcome among the variables, this study used Dumitrescu and Hurlin (2012), which is applicable in CS studies containing heterogeneity. Moreover, the null hypothesis of no causal relationship is examined between the variables across each cross-section. Finally, the Wald statistics are calculated for each of the cross-sections with Z bar stat and corresponding *p*-values at various levels of alphas at 1, 5 and 10%.

Results and discussion

Results of Pesaran (2004) CD test

As stated in the earlier section, identifying CD is mandatory before conducting any CS study. In this connection, the cross-

sectional dependency (CD) among RENE, HEXP, HDI and COEM is investigated. In this regard, the Breusch and Pagan (1980) and the Pesaran (2004) tests are applied to investigate the CD among renewable energy, human development index and COEM. The results of the CD have shown in Table 2.

Table 2 illustrates the findings of the Pesaran (2004) CD tests and indicates the existence of CD among the variables based on statistically significant *p*-values at 1%. Therefore, the study rejects the null hypothesis and considers that CD exists among the variables. This further implies that it is essential to investigate the integration order using the second PURT, which is robust to CD. The Pesaran CADF and CIPS are applied to evaluate the stationary properties of the variables. The results of the CADF and CIPS are shown in Table 3.

Table 3 highlights the findings of the second PURT. The results show that renewable energy, health expenditure, financial development, human development index, GDP, electricity consumption and COEM contain a unit root at level. However, upon 1st differencing, these variables become stationary with no unit root problems. This suggests that renewable energy, health expenditure and human development index, health expenditure, electricity consumption and COEM are stationary at their first difference. Therefore, based on sufficient evidence as shown in the results of the CADF and CIPS tests, this study suggests that all the variables in the series are stationary at first difference. Therefore, this further concludes that renewable energy, GDP, health expenditure, financial development, human development index, health expenditure, electricity consumption and COEM are integrated of order 1 or $I(1)$. Therefore, this unique order of the variables of our study allows us to apply the Westerlund (2007) panel cointegration (PC) and Kao test for cointegration tests are applied for possible existence of the long-run relationship. Westerlund (2007) suggests four types of cointegration for panel data, which are G_t , G_a , P_t and P_a . The tests consider G_t

Table 2 Results of Pesaran (2004) CD test

CS test	Parameters						
	ln COEM	ln EC	ln FD	ln GDP	ln HDI	ln HEXP	ln RENE
Pesaran (2004) CD Test	12.172*	7.636*	9.770*	18.566*	17.507*	6.509*	3.864*
Breusch and Pagan (1980)	174.201*	17.75*	123.533*	344.814*	307.642*	118.987*	133.471*

Note: * represents the rejection of null hypothesis of CD at 1%

and G_a for the rejection of H_0 for at least one cross-sectional unit, while P_t and P_a consider for all cross-sections. Further to this, the technique uses the bootstrap mechanism to reduce the effect of cross-sectional dependency on the tests. Table 4 outlines the outcomes of the Westerlund (2007) ECM panel cointegration tests.

Table 4 shows the robust p -values determined by the bootstrap simulations. The results suggest that G_t , G_a , P_t and P_a reject the null hypothesis of cointegration at 1% as shown by the robust p -values. This suggests that in all the four cases as identified by G_t , G_a , P_t and P_a , considering the robust p -value, the null hypothesis of no-integration is strongly rejected based on the evidence of the long-run linkage among the variables. This test further concludes that renewable energy, health expenditure, human development index, health expenditure, electricity consumption and COEM are in a long-run relationship. The results of the Westerlund (2007) test are further verified using the Kao test for cointegration. The results for the Kao test have been shown in Table 5.

In Table 5, the ADF value is -3.2671 with a corresponding p -value of (0.0005), which suggests evidence of a strong long-run relationship. It further confirms the results of the Westerlund (2007) test for cointegration.

Results of DOLS and FMOLS

After the confirmation of a long-run relationship among the variables, this study further applies the FMOLS and DOLS

Table 3 Pesaran's CADF unit root test panel unit root test and CIPS unit root test

Pesaran's CADF unit root test			CIPS unit root test	
Variable	L	1st Dif.	L	1st Dif.
ln COEM	-1.665	-3.113*	-0.819	-3.752*
ln EC	-2.605	-3.447*	-2.605	-4.191*
ln FD	-2.662	-3.662*	-2.662	-4.162*
ln GDP	-1.867	-2.779*	-0.607	-3.567*
ln HDI	-2.532	-3.295*	-1.985	-3.791*
ln HEXP	-1.451	-2.767*	0.456	-2.721*
ln RENE	-1.598	-2.852*	-0.176	-3.466*

Note: * represents significance at 1%

techniques to find the long-run nexus among the variables using the COEM as the regressed. Since the log has been taken for all the variables, the coefficients are interpreted as elasticity. The results of the DOLS and FMOLS are shown in Table 6. The results of both DOLS and FMOLS are similar in their coefficients with the same sign. This adds robustness to our estimations in this study.

The coefficient of electricity consumption is positive and statistically significant at 1%. This shows that a 1% rise in electricity consumption will increase carbon emissions by 0.4070%. This means that more electricity consumption induces more emissions as more electricity is generated by fossil fuels. Fossil fuels are the primary source of emissions. Financial development has a positive and insignificant effect on carbon emissions. Moreover, our estimations for the long-run results confirmed the validity of the N-shaped relationship between income and CO_2 . It can be noted in Table 5 that the coefficients of $\ln GDP$, $(\ln GDP)^2$ and $(\ln GDP)^3$ are 18.6470, -2.9045 and 0.1485 . This shows that the signs of coefficients are positive, negative and positive implying the validity of N-shaped EKC in the carbon emission function. This suggests that in the initial stages, the economic growth starts to rise; however, there is no focus on the quality of the environment; thus, damage is caused to the environment and the health of the people. This confirms the existence of the scale effect in the economy. Moreover, it has been found that the negative coefficient of $(\ln GDP)^2$ implies that environmental pollution is decreasing as economic growth is maintained. This further suggests the benefits of adopting clean and green technology that decreases emissions and converts the EKC into an

Table 4 ECM Westerlund panel cointegration tests

Statistic	Value	z-value	Robust p -value
G_t	-2.953	-1.033	0.010
G_a	-9.574	1.027	0.000
P_t	-5.515	-1.059	0.050
P_a	-8.726	0.293	0.020

Note: In the above table, the group statistics are shown using the G_t and G_a values, while the panel statistics are represented by P_t and P_a respectively. Robust p -values are considered in confirming the long-run relationship that has been generated using 100 bootstrapped replications

Table 5 Kao test for cointegration

	t-statistic	Prob
ADF	−3.2671	0.0005
Residual v.	0.0003	
HAC v.	0.0005	

Note: This test is conducted with the absence of the deterministic trend at lag 1, where Newey-West is used in selecting the lag

inverted U shape curve. The efficiency of the technology also improves with low carbon emissions. Moreover, the industries are producing output by adopting low carbon emission policies. Additionally, old and obsolete technology is replaced with modern and green technology. This can be observed by the fact that the coefficient of RENE has a negative sign, which implies the lessening of carbon emissions. Thus, all these activities contribute to low carbon emissions. This further confirms the composition and technical effects on the economy. However, as the technical advances bring no improvement in lessening the environmental pollution, these decreasing technical returns further induce the COEM, thus damaging the environment as represented by the coefficient of $(\ln \text{GDP})^3$. This further confirms the validity of the N-shaped EKC curve. These findings are aligned with the study of Sinha et al. (2017) for N-11 countries. Further to this, a 1% rise in HDI lessens the COEM by 0.3763%. This further highlights that an increase in the education rate and real income enables to lessen the carbon emission. This further confirms that with lower carbon emissions the rate of diseases decreases, which increases the life expectancy of the individuals. The negative sign of HDI further reinforces the results obtained in validating the N-shape. Additionally, health

expenditures have a positive impact on carbon emissions. This has been quite evident as these emerging economies are in a developing stage and do not focus on improvement in the environment by lessening COEM to overcome the abrupt climate changes. Danish and Wang (2019) argued that the BRICS economies are characterised by the continuous production due to the promotion of industrialisation in these transition economies that have been the utmost reason for causing more COEM. The average annual growth has risen to 6.5% from 1985 to 2016. Additionally, the BRICS economies consist of 40% of the world population that consumes 40% of the world energy by contributing 21% to the world GDP. This further confirms the BRICS economies are one of the leading global producers of the COEM. This indicates that environmental pollution rises after technical obsolescence, which brings no progress in lessening the pollution. This causes more pressure on the hospitals. Moreover, funds are allocated to the health sector to treat the patients. A similar study was conducted by Jerrett et al. (2003) for Canada for 49 districts. The study argued that the districts with a higher level of COEM must incurred more on health expenditures. This further suggests that pollution damages human health. This indicates that health expenditures are rising in line with the increase in environmental pollution. These results of our study are in concordance with the study of Zaidi and Saidi (2018) for sub-Saharan countries. The findings of Bedir (2016) supported the argument that an increase in health care expenditures can cause a reduction in the productivity of the human capital due to poor health conditions as a result of the prevailing air pollution. This causes a decrease in aggregate productivity in the national economy. Further to this, the coefficient of RENE (−0.9178) is negative and statistically significant as well. This implies that a 1% rise in RENE usage can decrease carbon emissions by 0.9178%. This highlights the importance of

Table 6 Results of DOLS and FMOLS. Dependent variable: $\ln \text{COEM}$

Vari.	DOLS			FMOLS		
	Cof.	SE	t-value	Cof.	SE	t-value
$\ln \text{EC}$	0.4070***	0.0647	6.2893	0.4197***	0.0655	6.4025
$\ln \text{FD}$	0.0417	0.0604	0.6911	0.0379	0.0578	0.6567
$\ln \text{GDP}$	18.6470***	5.5884	3.3367	19.3106***	5.4590	3.5373
$(\ln \text{GDP})^2$	−2.9045***	0.8548	−3.3976	−3.0056***	0.8328	−3.6087
$(\ln \text{GDP})^3$	0.1485***	0.0435	3.4125	0.1536***	0.0423	3.6238
$\ln \text{HDI}$	−0.3763***	0.3793	−0.9922	−0.4319***	0.3906	−1.1057
$\ln \text{HEXP}$	0.2606***	0.1158	2.2498	0.2641***	0.1126	2.3446
$\ln \text{RENE}$	−0.9178***	0.0768	−11.9413	−0.9295***	0.0734	−12.6506
R^2	0.998			0.998		
Adj. R^2	0.998			0.998		
SE of reg	0.0280			0.0279		

Note: *** represents significance level at 1%

Table 7 D-H causality test

Variables	ln COEM	ln EC	ln FD	ln GDP	ln HDI	ln HEXP	ln RENE
ln COEM	--	2.9351 (−0.79263) [0.4280]	2.27052*** (0.17772) [0.8589]	4.23538** (1.99569) [0.046]	0.88009 (−1.10875) [0.2675]	3.07619 (0.92317) [0.3559]	5.73662* (3.38471) [0.0007]
ln EC	5.52226* (−3.18636) [0.00141]	--	2.07227*** (−0.0057) [0.9955]	1.5848 (−0.45673) [0.6479]	2.68114 0.55765 [0.5771]	3.61686 (1.42342) [0.1546]	3.93258*** (1.71553) [0.0862]
ln FD	3.80332 (−1.59593) [0.1105]	2.18664*** (0.10012) [0.9202]	--	2.91357 (0.77270) [0.4397]	4.76122** (2.48223) [0.0131]	4.85284 −2.56699 [0.0103]	3.12024 (0.9639) [0.3351]
ln GDP	5.35541* (3.03199) [0.0024]	1.58480*** (−0.45673) [0.6479]	6.34135* (3.94422) [0.00008]	--	2.87168 (0.73394) [0.463]	4.02811*** (1.80392) [0.0712]	5.30274* (2.98326) [0.0029]
ln HDI	4.83856** (−2.55378) [0.0107]	5.61189* (3.26930) [0.0011]	4.76122*** (2.48223) [0.0131]	5.52889* (3.19250) [0.0014]	--	6.54898* (4.13633) [0.00004]	4.70605** (2.43) [0.0150]
ln HEXP	1.73266 (−0.3199) [0.7490]	2.7555 (0.62645) 0.531 [0.0011]	1.01290 (−0.98587) [0.3242]	0.46780 (−1.49022) [0.1362]	3.16673 (1.00694) [0.314]	--	1.58839 (−0.45341) [0.6503]
ln RENE	4.05747*** (−1.83108) [0.0671]	2.06242 (−0.01482) [0.9882]	5.27596* (2.95848) [0.0031]	4.38434** (2.13352) [0.0329]	1.27222 (−0.74594) [0.4557]	6.25287* (3.8624) [0.0001]	--

The test considered a null hypothesis of no causality

Top value represents w-stats; values in parenthesis represents z-stats; brackets “[]” show *p*-value

*1% level of significance

**5% level of significance

***10% level of significance

RENE in lessening carbon emission. This energy source has been of vital importance as it is used as alternative energy to fossil fuels. However, the coefficient is small indicating that an increase in the use and adoption of RENE is important. The governments of China, Brazil, South Africa and India need to invest more in the RENE sector to lessen pollution and decrease health expenditure by providing a clean and green environment to the general public. Both DOLS and FMOLS estimations show the highly adjusted value of R^2 , which is 99.8% each confirming the regressors have explicitly explained the change in the COEM by 99%. This further confirms the relevancy of the estimated variables in the model. Additionally, the regressors are added in order to avoid omitted variable bias.

Causality test

The long-run results under the framework of the DOLS and FMOLS methods provide interesting significant inferences. However, the cointegrating equations do not provide any information about the causal inferences among the variable of our study that can be useful in framing policies. Using this motivation, it is important to identify the causal direction that can predict the causal movements of the variables and their behaviour. Moreover, the causal inferences need to be captured in the presence of CD individually. This study applies the Dumitrescu and Hurlin (2012) test, which can determine the causal inferences of each variable in each cross-section separately. Further to this, the causal results of the Dumitrescu and Hurlin (2012) test are based on W -bar-statistics and Z -bar-statistics, which take the average statistics of the tests and a standard normal distribution, respectively. The results of the Dumitrescu and Hurlin (2012) test are shown in Table 7.

From Table 7, a bidirectional causality exists between HDI and financial development. This suggests that improving the financial performance in the emerging economies can improve the human development index. Further to this, the role of banking sector is important in enhancing the HDI by giving loans to the deficit economic units. This can further improve the living styles of the individuals at one hand by acquiring better health conditions thus increasing the average life expectancy of the individuals. At the same time improvement in financial status can thus enable the individual to acquire education thus can contribute to economic growth. The aforementioned causal relationship is new to the literature yet to the knowledge it has not been investigated so far in the causal nexus framework. Likewise, another bidirectional causal relationship has also been found between electricity consumption and FD. This further confirms the validity of the feedback hypothesis between electricity usage and financial development. This confirms that both financial development and electricity consumption have been of vital impor-

tance for the emerging economies which are in a transition stage. These findings are similar to the study of Sbia et al. (2014). Additionally, a unidirectional causal nexus has been identified from RENE to COEM, GDP and health expenditures to renewable energy. This further demonstrates the importance of RENE with regard to HDI and health expenditure. Additionally, the use of renewable energy not only lessens COEM but also causes improvement in financial development and decreasing health expenditures. Since renewable energy promotes environmental quality by lessening the COEM. These findings are supported by the study of Apergis et al. (2018) confirming the uni-direction relation from RENE to COEM.

Conclusion and policy implications

The study examined the nexus between renewable energy, human development index, health expenditures and COEM in emerging economies. The study confirmed the CD among the variables by applying the Pesaran (2004) and Breusch and Pagan (1980) techniques. After the confirmation of CD among the variables, Pesaran CADF and CIPS techniques were used to investigate the unit root causality and integration order. Further to this, the study validated the long-run linkage among the variables in the presence of CD by applying the Westerlund panel cointegration test. To verify the long-run linkage, the study further used FMOLS and DOLS tests. The main findings of the study pertaining to the long run are as follows.

Both electricity consumption and health expenditure affect COEM positively. Moreover, HDI and RE have a negative impact on COEM. The study further confirmed the existence of the N-shaped EKC in the long run.

The pairwise Dumitrescu and Hurlin (2012) causality test was used to find the direction of the association among the variables. The main results indicated a bidirectional causality between HDI and financial development. Likewise, another bidirectional causal relationship has also been found between electricity consumption and FD.

The empirical findings of our study suggest policies in the direction of HDI and health expenditure by adopting renewable energy. This study highlights the importance of the RENE sources, which can facilitate a reduction in carbon emissions. The study provides evidence indicating that electricity consumption from fossil fuels induces carbon emissions. This further implies that the government must promote the use and adoption of RENE to decrease emissions. Additionally, it can also improve the health of humans and animals. The government must encourage public-private partnerships in managing environmental pollution by encouraging and promoting clean and green technologies. Heavy penalties must be imposed by the government on the firms adopting

fossil fuel emission technology. Additionally, the role of financial development in our study is negligible. The government must advance credits on low-interest rates and should encourage the firms to adopt renewable energy projects to lessen the adverse effects of fossil fuels. The government must also encourage the firms to adopt renewable energy by giving various tax rebates. Special incentives must be ensured to promote the use of renewable energy, not only in the short run but also in the long run for sustainable development. The hospitals must be sufficiently equipped to use cheap and clean energy.

Moreover, the financial sector needs to be improved to create entrepreneurship opportunities for the general public in improving the HDI. More forestation must be encouraged, not only in rural areas but also in urban environments. Strict actions must be taken by the government to prevent deforestation as trees provide fresh oxygen and absorb the emissions. Moreover, they also add beauty to the environment. In addition, the government must create awareness among the general public about the use of fossil fuels (gas, oil coal, etc.) and should encourage them to adopt RENE sources like wind, hydropower and solar sources to obtain clean energy.

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