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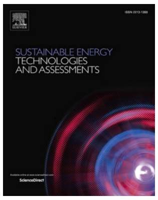

Original article

Environmental Kuznets Curve hypothesis from lens of economic complexity index for BRICS: Evidence from second generation panel analysis

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ABSTRACT

The present study contributes to the ongoing discussion on environmental sustainability, energy efficiency for the case of Brazil, Russia, India, China, and South Africa economies by investigating the dynamic connection regarding foreign direct investment, economic complexity index, renewable energy, natural resources, urbanization, and CO_2 emission for annual frequency data from 1990 to 2019. The present study employs robust econometric techniques including Augmented Mean Group with Fully Modified-Ordinary Least Squares estimators as estimation techniques. Empirical outcome shows both inverted U-Shaped and *N*-Shaped EKC relationship between ECI and CO_2 emission. The empirical findings also lend support to the Pollution Haven Hypothesis, which suggest that foreign direct investment influx is a contributing factor to environmental degradation in Brazil, Russia, India, China, and South Africa economies. Furthermore, renewable energy and the interaction between economic complexity index and urbanization is found to have adverse impact on emission while natural resources and urbanization have positive impact on the environment. Finally, the results from the Dumitrecu and Hurlin causality reveals a bi-directional causality between economic complexity and CO_2 emission. Similar causality is found between economic complexity index and urbanization and CO_2 emission while a one-way causality is seen running from foreign direct investment to CO_2 emission over study period. These findings encourage authorities of the investigated countries to offer a broader energy strategy on alternative energies i.e., renewables improve Brazil, Russia, India, China, and South Africa environmental quality. Furthermore, emphasis on economic strategies that foster a healthier manufacturing activity to engender environmental sustainability without compromise for economic prosperity should be pursued among the examined economies.

Introduction

Many policy inroads and structural changes have driven the shift from carbon-intensive energy sources toward more efficient energy sources thus, contributing meaningful reductions in CO_2 emissions in many countries. In lieu of this, advancements in technology, enforced regulations for the environment and environmental sustainability have altered pollution levels compared with economic expansions in many developed economies such as G-7, United states, OECD among others [61,42]. Owing to fast developments of urban populations and industrialization, many economies both developed and emerging have seen much economic growth in the last decade or so [33]. Particularly among BRICS nations (Brazil, Russia, India, China, and South Africa), economic expansion and transformations emanating from industrialization are revealed in terms of their GDP (Danish & Wang, 2019). These BRICS

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Nomenclature

Abbreviations

BRICS	Brazil, Russia, India, China, and South Africa countries
ECI	Economic complexity index
FDI	Foreign direct investment
AMG	Augmented Mean Group
PHH	pollution haven hypothesis
EKC	Environmental Kuznets Curve
SDG's	Sustainable Development Goals
UN	United Nations
EU	European nations
OEC	Observatory of Economic Complexity
CO_2	Carbon dioxide emission
ε_{it}	Disturbance term
ΔY_{it}	Change in output
$\beta_1 \cdots\cdots \beta_6$	coefficients of the regressors
$\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 > 0$	positive, negative, and positive coefficients respectively

economies have shown significant promise economically (Danish & Wang, 2019), especially with their GDP haven grown from $2187b to $16,266b between 1985 and 2016, averaging a 6.5 % growth rate annually (World Bank, 2017). Experts thus perceive that, at increased technology adoption, greater economic expansion, and transition from pollutant intensive (industrial engagements) to service economies will drive much reduction in pollution in the environment [29]. However, the rapid economic growth of BRICS economies can drive greater resource consumption, which subsequently poses significant environmental concerns [27,72]. Dong et al., [32] contends that the unsustainable utilization of natural resources also presents environmental consequences such as water pollution, deforestation, climate change and greenhouse gas emissions. Thus, the fast development rate of BRICS nations carries with it potential consequential effects like greater CO_2 emissions [31].

The economic expansion and pollution nexus has been scrutinized extensively, beginning with Grossman and Kruger (1991) who introduced the EKC framework, which has been commonly researched by many scholars. The EKC has been confirmed by several studies both recent and earlier ones (see, [60,29,74]; Solarin et al., 2017). As such, conclusions such as renewable energy utilization mitigating environmental problems such as carbon emissions, or urbanization driving energy consumption growth abound.

This current study pursues a similar examination, in which it draws on the EKC framework to discern the relationship between economic complexity, and other known but crucial antecedents of CO_2 emissions.

To begin with, an emergent but crucial issue is the concept of economic complexity, which describes the extent of economic expansion and defines the level of knowledge and skill acquisition for exporting products. Economic Complexity is assessed by the Economic Complexity Index (ECI) which measures an economy's capabilities to export [46]. The ECI explains the extent of sophistication in exports and the ability of an economy to produce several other products [68]. It assesses the interrelatedness of economies to produce items estimated to be technology-intensive outputs or the volume of viable awareness accrued to an economy (Charfeddine & Kahia, 2019; [68]. Considering this, it is perceived that modern economic complexity requires greater energy utilization, which subsequently results in greater pollutant emission into the environment. Studies have linked energy markets and carbon emissions reinforcing the direct association between expansion in energy sources and environmental pollution (Neagu, 2019). The extent of superiority and sophistication of export commodities of an economy tells the extent of diversity of its economic complexity. However, whereas an economy increases its complexity, there is greater diversification of production and output expansion, but expanded output levels consequently drive pollution, negative climate consequences and global warming. Despite this evidence, a strand of literature also finds economic complexity to have the potential to protect environmental quality. This is because it is highly driven by high innovation and research activity that promote the sustenance of eco-friendly technology and products [65]. Thus, as the economic complexity of a country increases environmental quality is more likely to increase [69,48]. This is tied to the logic that as the economic complexity index increases research and innovation activities increase and green innovation and pro-environmental production methods. Hence the need to understand the role of economic complexity index in mitigating environmental poor quality.

To this end, Grossmann, and Krueger [40] observed three distinct effects: scale, composition, and technological effects to describe the EKC relationship. The initial stage of real income generation is consistent with the scale effect, where at this stage there is greater damage done to the environment due to greater consumption of inputs (labour, natural resources, and capital) which inadvertently adversely impacts the environment. In the composition effect which depicts the second phase of economic expansion, there is the transition toward service sector. This in other words suggests that after attaining a maximum point of production, further increases in production exceeds a turning point beyond which pollution will begin to recede. This explains the inverted U-shaped curve. At the third phase, where the technological effect is felt, more eco-friendly production and equipment are employed to produce goods and services, hence lesser harmful effects on the environment which promotes environmental quality [69,56]. In conclusion, the EKC validation implies that at the beginning of economic expansion, there no modification to technology and structure, hence there is poor environmental quality; whiles the economy expands steadily modifications to technology and labour begin to occur, thus increasing the technological development and energy efficiency rates that mitigate environmental degradation.

Beyond considerations for the Environment Kuznets Curve framework, the need for realizing sustainable development goals has driven the need to examine the link between economic complexity and other factors such as urbanization, FDI, natural resource use, renewable energy sources and CO_2 emissions among others (Antonakakis, Chatziantoniou, & Filis, 2017; Neagu,& Teodoru, 2019). To this end, prior studies examining the energy-environment connection indicate that economic expansion and energy consumption are crucial to the situation of CO_2 emission [19,30]. Industrial expansion through the injection of foreign or domestic financial injection coupled with growing urban population increases demand for energy. These events will drive economic expansion, but at the expense of environmental safety and quality. The main issue common to these crucial determinants of economic expansion is the increased consumption of unclean energy like fossil sources among countries [22]. Furthermore, a series of varying reports exists from several findings to guide different economic and geographical settings.

For instance, in addition to renewable energy sources, and foreign direct Investments in some examinations is identified as a driver of ecological quality in line for its mitigating effects on CO_2 emission. However, some other scholars have reported otherwise [50,22]; (Balsalobre-Lorente et al., 2020), thus showing a grave lack of consensus on this issue. Further, in line with the pollution haven hypothesis, inflow of FDI into domestic pollution-intensive industries in developing economies is higher than among developed economies. Thus, FDIs facilitate economic expansion mainly among developing countries. In addition, urbanization is considered as a composite process, which includes a population, society, an economy, and some transition within space. Urbanization is globally considered as an issue of concern because it carries with it some negative consequences. For instance, the UN indicates that massive urbanization exerts pressure on natural and artificial resources. However, the impact of urbanization on the environment as studied in literature reveals inconsistent findings. For example, urbanization is found to largely expand CO_2 emission in nations while it also increases request for energy in all levels of income in economies (high-, middle- and low-income levels) [59], yet Al-Mulali et al., [7] observed a nonlinear relationship between urbanization and environmental pollution. Drawing on the discussion, this current research broadens the examination among these factors to cover economic complexity, urbanization, natural resource use, renewable energy, and foreign direct investments on environmental quality among BRICS member states.

This study extends the existing literature in the following ways: First, it is among the first to examine the effects of economic complexity at marginal levels which has the possibility to determine the scale effect, structure, and technological effects on CO_2 emission in the EKC. It stands among very few studies to have done this assessment, particularly for BRICS nations. Secondly, this research attempt also examines the dynamic relationships involving ECI, renewable energy, urbanization, natural resource use, FDI and carbon emissions. Here it bridges the gap in literature by shedding light on evidence from BRICS group of nations. It introduces the interaction term economic complexity and urban population growth. This is expected to help policy and BRICS countries emerging sustainable dimensions and if urban population growth mitigates the association between CO_2 emissions and economic complexity.

Review of previous studies

In seeking to discern the association between economic complexity and environmental quality, there is also the need to understand the role of other economic factors including economic expansion, urban population growth, and renewable energy in ensuring quality environment. In this current study economic complexity, renewable energy use, urbanization, natural resource use, and foreign direct investment. Based on this scope, the review of extant works is divided into sections discussing prior studies on each of these factors:

Economic complexity (ECI) and environmental quality

The framework of an inverted U-shaped curved proposed by Kuznets [47] has been used to explain the association between economic expansion and its effects on the environment, widely determined as the environmental Kuznets Curve (EKC). This framework has been applied and extended in many studies till date [42,23]. Drawing on the EKC's analogy, it asserts that in the early stages of attaining economic expansion there is increased automation and production activity, hence economic expansion increases damage to the environment at this stage, and as the economy steadily develops appropriately with required technology the initial environmental quality begins to be restored. This indicates a turning point in the relationship between environment quality and economic expansion.

A vast body of literature exists on the EKC hypothesis relative to unclean energy sources which contributes about 80 % of energy consumed globally and accounts for 75 % of the world's greenhouse gas emissions [18]. Many empirical examinations indicate that increased renewable energy contribute to reducing carbon emission and environmental quality [68,69]. This current examination similarly uses the EKC framework, to study the connection among CO_2 emission and ECI in BRICS (Brazil, Russia, India, China, and South Africa) countries, thus it substitutes income with economic complexity. The economic complexity indicator determines the extent to which an economy produces and exports wide variety of items [46]. In line with this view, it is as if modern economic complexity drives greater demand for energy, which eventually results in the emission of more pollutants into the environment. This is because the more diverse an economy becomes, the more it increases in sophistication and superiority in exports, hence greater economic complexity. This is evident in the conclusions of some prior studies. For instance, in Dogan et al., [31], who assessed the impact of ECI and manufacture structures on environmental quality, revealed the need to regulate existing economic growth strategies particularly in low- and middle-income European nations to drive safe economic expansion to control CO_2 emissions in the EU? Similarly, Trinh et al. [66] observed a U-shaped connection involving ECI and environmental pollution in the EU. While employing a fixed effect estimator, it was found the economic complexity facilitated the depletion of forest but mitigated waste generation in Brazil [65]. Hence, the study concluded that economic complexity is a source of shock on deforestation and atmospheric pollution.

Other studies have linked ecological deficit to economic complexity with an inverted U-shaped curve (e.g., [26]). The implication of the inverted U-shaped EKC is that, relative to economic expansion, environmental quality deteriorates until economic growth attains a appreciable level of development and income to drive positive impacts on the environment. More practically, this assertion relates to structural change which suggests that a productive system must first transition from a high pollution-intensive system toward low pollution-intensive one to reduce negative environmental consequences.

FDI and quality environment

Studies reveal that foreign and domestic capital inflows can present adverse environmental consequences, particularly in economies with high-pollution intensive systems. For instance, Murshed et al. [54] reveals that foreign direct capital inflows have positive environmental consequences. This is because it is perceived that foreign direct investments drive the use of modern technology and cleaner energy sources. Contrary, Solarin and Mulali, [63] found FDI inflows to increase adverse effects on the environment in Ghana. In a similar assessment, Elheded et al. [38] confirms the pollution Haven hypothesis among countries in the MENA region, by observing increased pollution due to FDI inflows.

Despite these negative effects being established by some prior studies, also established differing views on the unique association between direct investment inflows and environment quality. Like Adebayo [1], found no significant link between FDI and environmental degradation in twenty countries. Destek and Okumus [28] showed the existence of a nonlinear relationship between environmental pollution and foreign direct investment inflows among newly industrialized nations. Among OECD states, Alshubiri and Elheddad [9] examined the asymmetric association between CO_2 emission pollution and FDI between 1990 and 2015. As such they observed direct inflows increased pollution effects at the inception stages of FDI injections, thus confirming the EKC proposition. Among ASEAN countries the influence of FDI inflows, economic expansion and energy utilization on environmental pollution using the panel quantile regression, also confirmed the pollution Halo hypothesis in the region, between 1980 and 2010 [73].

From a comparative assessment view between developed and developing economies on the connection regarding FDI inflows as well as CO_2 emissions, Adeel-Farooq, Riaz, and Ali [4] found FDI inflows increased CO_2 emissions greater in developing economies, thus affirming pollution Halo hypothesis. Contrawise, FDI inflows in the developed economies rather increased environmental quality. In like manner, a few other studies have extended this conclusion to other regions. For example, Usman et al., [69] confirms the EKC and the pollution Halo hypothesis for the Asia and Americas, for MINT countries (Mexico, Indonesia, Nigeria, & Turkey) Balsalobre-Lorente et al., [12] and Baloch et al. [11] for BRICS.

Clean energy utilization and CO_2 emission

Further, this review investigates the interactions between renewable energy sources and pollutants. In this light, the argument has widely been to determine or discover how to sustain quality environments through the exploration of clean energy sources. A vast body of

Table 1
Description of variables, Symbols and unit of measurement utilized for the study.

Name of Indicator	Abbreviation	Proxy/Scale of Measurement	Source
Carbon Dioxide Emissions Per Capita	CO_2	Measured in metric tonnes	BP, 2020
Economic Complexity Index	ECI	Nations productive composition appearance by combining the information on their variety number of commodities it exports	OEC, Economic complexity rankings, 2020
Square of Economic Complexity Index	ECI^2	Measures the square of Economic Complexity Index	OEC, Economic complexity rankings, 2020
Cube of Economic Complexity Index	ECI^3	Measures the cube of Economic Complexity Index	OEC, Economic complexity rankings, 2020
Foreign Direct Investment	FDI	% of real GDP	WDI, 2020
Natural resources	NR	Total natural resource rent (% of GDP)	WDI, 2020
Urban population	UB	(% of total population)	WDI, 2020
Renewable Energy	REU	Renewable energy consumption (% of total final energy consumption)	BP, 2020
Interaction term	ECI*UP	Economic Complexity Index* Urban population	

Source: Authors compilation.

empirical studies, based on long run and short run macro and micro assessments of the interactions between renewable energy, economic expansion, and pollutant pollution in the environment. In Nguyen and Kakinaka [53] the assessment of the link between environmental quality and renewable energy revealed clean energy utilization in low-income states drives low emission levels, although this association was not consistent with the findings from the developed or high-income economies. Farhani and Shahbaz [39] earlier positioned that both clean and unclean energy sources augment environmental pollution. This evidence as drawn from MENA countries using an FMOLS and DOLS estimations indicate an inconsistency in the findings on the link between renewable energy and environmental pollution. Usman et al. [69] while performing an extended analysis on four continents, examined the interaction between FDI, economic expansion, trade, renewable and nonrenewable energy use on environment degradation confirmed that renewable energy utilization improved environmental degradation. This finding as established by Usman et al. is replicated in other studies such as Danish et al. (2020), in BRICS nations using the DOLS and FMOLS between 1992 and 2016. Further, Danish et al. (2020) determined that renewable energy and urban population growth increases environmental quality in BRICS countries. Thus, BRICS nations require a transition toward clean energy sources. Similar findings are reported in Alola et al. [8], who revealed a connection between economic expansion, trade policy, fertility renewable and nonrenewable energy, and ecological footprints in the EU.

Although these positive effects are reported on renewable energy and the environmental pollution nexus, there is evidence of consequential effects of renewable energy utilization on environmental pollution (see [1]; Danish et al., 2020; [8,58,70,24]. In conclusion, there many conclusions supporting the positive effects of renewable energy likewise its negative effects on environmental pollution. This raises the need for further examinations into this association to better discern the direction of this effect.

Urban population growth and emission

The migration from less developed locations to urban centers has steadily increased over time, and this has also increased pollution consequences on the environment [13]. Considering this, several studies have explored the actual role of urbanization in environmental pollution. In line with these studies like those of McGee and York [51] confirmed the assertion in a reverse observation. In that, a reduction in urban population rate contributed to a significant reduction in pollution levels using data from 1960 to 2010. Elahi et al. [37], Chien et al. [25], Bong et al. [20] all observed this same association between urbanization and environmental pollution. Thus, all these examinations establish a positive relationship between urbanization and environment pollution, thus confirming the EKC hypothesis in the long run.

Gap in the literature

Throughout this review, it is observed that not much exists on highlighting the effect of economic complexity and these other indicators in BRICS nations. Further, the interactions existing on many of these variables have revealed a litany of mixed results suggesting much inconsistency. This these findings do not provide many grounds for objective or conclusive focus for policy guidelines, hence a significant gap still existing needing to be addressed. Therefore, this current study pursues the goal of bridging this gap by focusing on economic complexity as a new consideration, FDI, clean/renewable energy natural resource use as means for improving environmental pollution through reduced CO_2 emissions.

Methodology

Data sources and variable description

The available study has established that radical transformation, the structure of energy mix (non-renewables, and renewable sources, among other things such as trade, product complexity, and economic complexity all have an impact on the environment (Neagu and Teodoru, 2019; Destek and Sinha, 2020; [61,13]). Specifically, as pertaining to the findings of the study, systemic modify and economic complexity may have a greater impact on environmental quality since they are deemed to be precise predictors of economic growth, skill- and knowledge-based advanced output, and therefore have a greater impact on environmental quality. An annual data from 1990 to 2019 is utilized for the BRICS economics for this study. The data for the economic complexity index (ECI), which measures the aspect of a country's industrial mix by integrating knowledge on the diversity of products it exports, is acquired from the OEC database. Furthermore, the ECI is a comprehensive assessment of the production capacity of significant economic categories, which are typically towns, nations, or territories. ECI is used to define the knowledge acquired by a populace and shown in the economic operations that take place in a town, a nation, or a territory, in specific. As a means of achieving this goal, the ECI describes material available at a site as median understanding of the activities existing in that site and understanding of an economic operation as the basic ability of the areas where that economic activity is carried out. The remaining coefficients, thus, FDI, natural resource, and urbanization are taken from the world development index (WDI) while CO_2 emission and renewable energy is taken from British Petroleum (BP). As seen in Table 1, a brief description of all variables is provided.Table 2..

Proposed framework

With the addition of natural resources, this analysis intends to assess the legitimacy of an environmental Kuznets Curve (EKC) assumption based on the study of Balsalobre-Lorente et al [13] which was conducted for PIIGS countries. In our study case the focus is on BRICS countries

Table 2

Cross-sectional dependency (CD) and Slope Homogeneity (SH) results.

Model	Pesaran CD Test	p-value	Pesaran LM Test	p-value	Breuch-Pagan LM	p-value
LCO_2	18.255*	(0.0000)	48.339*	(0.0000)	757.142*	(0.0000)
LECI	33.256*	(0.0000)	85.044*	(0.0000)	1252.315*	(0.0000)
FDI	13.245*	(0.0000)	45.378*	(0.0000)	634.105*	(0.0000)
LREU	14.385*	(0.0000)	50.617*	(0.0000)	787.868*	(0.0000)
LNR	15.3195*	(0.0001)	48.298*	(0.0000)	756.583*	(0.0000)
LUB	21.210*	(0.0000)	66.844*	(0.0000)	1006.787*	(0.0000)
LECI*LUP	28.334*	(0.0000)	77.116*	(0.0000)	1145.360*	(0.0000)
Slope Homogeneity (SH)						
	COEFFICIENT	p-value				
SH ($\tilde{\Delta}$ test)	5.723*	(0.0010)				
SH ($\tilde{\Delta}$ adj test)	4.123*	(0.0030)				

NOTE: * represents 1% level of significance.

while accounting for the pivotal role of economic complexity in an EKC environment for emerging blocs like BRICS. This analysis converted the dataset of all investigated coefficients, except for FDI, into a natural logarithm structure to minimize multicollinearity concerns, minimize the possibility of misfits from the dataset, and conquer the possibilities of data sharp and normalcy problems. As a result, the connection involving carbon emission, economic complexity, FDI, renewable energy usage, natural resources, as well as urbanization can be stated in eqn-1 as:

$$\mathrm{MODELI}: \mathrm{LCO2}_{it} = \beta_0 + \beta_1 LECI_{it} + \beta_2 ECI2_{it} + \beta_3 FDI_{it} + \beta_4 LREU_{it} + \beta_5 \mathrm{LNR}_{it} + \beta_6 LUB_{it} + \varepsilon_{it} \tag{1}$$

where CO_2 emission, ECI, ECI^2, FDI, REU, NR, UB are coefficients stated above. Moreover, $\beta_1 \cdots\cdots \beta_6$ stands for the coefficients of the regressors while I and t represent nations and timeframe respectively.

Model-2 investigates the connection involving urbanization and economic complexity, with the expectation that urbanization and economic complexity will have a mediating impact in the reduction of CO_2 output. This regulating role is formally represented as below in eqn-2 as:

$$\mathrm{MODELII}: \mathrm{LCO2}_{it} = \beta_0 + \beta_1 LECI_{it} + \beta_2 ECI2_{it} + \beta_3 FDI_{it} + \beta_4 LREU_{it} + \beta_5 \mathrm{LNR}_{it} + \beta_6 LUB_{it} + \beta_7 LECI{*}LUP_{it} + \varepsilon_{it} \tag{2}$$

Model-III analyzes the existence of a cubic link involving the ECI as well as CO_2 emission in the BRICS nations. The following is the purposeful pattern of the cubic-shaped EKC assumption, which can be represented in eqn-3 as:

$$\mathrm{MODELIII}: \mathrm{LCO2}_{it} = \beta_0 + \beta_1 LECI_{it} + \beta_2 ECI2_{it} + \beta_3 ECI3_{it} + \beta_4 FDI_{it} + \beta_5 LREU_{it} + \beta_6 \mathrm{LNR}_{it} + \beta_7 LUB_{it} + \varepsilon_{it} \tag{3}$$

Furthermore, Model-IV reflects on the *N*-shaped link involving economic complexity and CO_2 emission, as well as the moderating influence of urbanization that is incorporated with economic complexity. The following is the mathematical representation for Model-IV, which can be found in eqn-4 as:

$$\mathrm{MODELIV}: \mathrm{LCO2}_{it} = \beta_0 + \beta_1 LECI_{it} + \beta_2 ECI2_{it} + \beta_3 ECI3_{it} + \beta_4 FDI_{it} + \beta_5 LREU_{it} + \beta_6 \mathrm{LNR}_{it} + \beta_7 LUB_{it} + \beta_8 LECI{*}LUP_{it} + \varepsilon_{it} \tag{4}$$

Per the *N*-shaped EKC assumption, the connection linking CO_2 emission and economic complexity is expected to have positive, negative, and positive signs ($\beta_1 > 0, \beta_2 < 0$ and $\beta_3 > 0$) respectively. Moreover, FDI is expected to have positive impact on the environment base on the existing literatures since it involves dirty funding, conventional mechanism, pollution haven companies as well as the use of fossil fuel and other related energies. Again, renewable energy is expected to have negative impact with the environment whiles both urbanization and natural resources are expected to have positive connection with the environment.

Methodology

Cross-section dependence (CD)

To establish the suitable methodological approach(s) for this investigation, we used the cross-section dependency (CD) approach. The findings of the CD approach could help us decide whether to utilize first-generation or second-generation panel data estimate approaches. The research may be biased, inappropriate, and conflicting if the CD evaluation is not conducted [42]; Odugbesan et al. 2021). We utilised a robustness evaluation utilising three-CD tests: the Pesaran (2007) CD, Pesaran (2015) scaled LM and Breusch and Pagan [21] approaches, to ensure that the aforesaid difficulties do not emerge. The CD test is depicted as follows:

$$CD = \sqrt{\left(\frac{2T}{N(N-1)}\right)}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{p}_{ij}\right) \tag{5}$$

Whereas from Equation (3), $\hat{p}_{ij}$ identifies the indicators of the remaining evaluation of ADF regarding the pairwise cross-sectional interconnection. *N and T* are the panel range and model specifically for the e time and cross-section.

Stationarity approach

It is vital to identify stationarity attributes of indicators under investigation before moving to further analysis. Moreover, if there is an indication of CD, utilization of first-generation unit root test will produce outcomes that are misleading [2,44]. Based on this knowledge we utilize unit root tests that can identify variables stationarity feature amidst CD. Thus, we utilized 2nd generations stationarity test to identify variables of the investigation stationarity attribute. We utilized both CIPS and CADF to catch the order of the coefficients of integration. Equation presents the CADF as follows:

$$\Delta Y_{i,t} = \gamma_i + \gamma_i Y_{i,t-1} + \gamma_i \overline{X}_{t-1} + \sum_{l=0}^{p}\gamma_{il}\Delta\overline{Y_{t-l}} + \sum_{l=1}^{p}\gamma_{il}\Delta Y_{i,t-l} + \varepsilon_{it} \tag{6}$$

In Eq. (8), $\overline{Y}_{t-1}$ and $\Delta\overline{Y_{t-l}}$ shows the cross-section average. The value of CIPS is obtained as follow:

$$\widehat{\mathrm{CIPS}} = \frac{1}{\mathrm{N}}\sum_{\mathrm{i}=1}^{\mathrm{n}}\mathrm{CADF}_{\mathrm{i}} \tag{7}$$

The cross-section augmented Dickey-Fuller technique obtained from Equation (6) is represented by the term CADF in Equation (7).

Cointegration approach

If there is a presence of CD, utilisation of first-generation cointegration such as Pedroni and Kao cointegration tests will produce misleading outcomes since they do not consider CD. Based on this knowledge, we utilised Westerlund cointegration initiated by West-

Table 3
Panel CIPS unit root test.

VARIABLES	CIPS				
	I (0)		I (1)		
	C	C&T	C	C&T	Decision
LCO$_2$	−3.221*	−3.130*	–	–	I(0)
LECI	−1.324	−2.561	−3.713*	−3.930*	I(1)
FDI	−3.706*	−3.993*	–	–	I(0)
LREU	−0.509	−1.735	−4.008*	−4.643*	I(1)
LNR	−3.193*	−3.494*	–	–	I(0)
LUB	−3.217*	−3.305*			I(0)
LECI*LUP	−3.366*	−3.849*			I(0)

NOTE: * represents 1 % level of significance, while C = constant and C&T = constant and trend.

Table 4
Bootstrapped Westerlund [71] cointegration.

Statistics	Value	Z-value	p-value	Robust p-value
Gτ	−3.143*	−0.638	(0.080)	(0.000)
Gα	−5.369*	−1.235	(0.058)	(0.001)
Pτ	−5.478*	−1.356	(0.086)	(0.004)
Pα	−6.101*	−2.256	(0.010)	(0.005)

NOTE: *<0.01.

Table 5
Augmented Mean Group (AMG) analysis.

Variables	MODEL I	MODEL II	MODEL III	MODEL IV
LECI	0.138*	0.119**	0.089*	0.104**
p-value	(0.000)	(0.020)	(0.008)	(0.041)
LECI^2	−0.002*	−0.004*	−0.001*	−0.001*
p-value	(0.000)	(0.000)	(0.002)	(0.003)
LECI^3	–	–	0.003*	0.002*
p-value	–	–	(0.003)	(0.004)
FDI	0.010*	0.011*	0.009*	0.009*
p-value	(0.002)	(0.005)	(0.003)	(0.003)
LREU	−0.025*	−0.023*	−0.026*	−0.028*
p-value	(0.056)	(0.086)	(0.042)	(0.039)
LNR	0.604*	0.591*	0.580*	0.596*
p-value	(0.000)	(0.000)	(0.000)	(0.000)
LUP	0.073	0.032*	0.072*	0.118***
p-value	(0.000)	(0.004)	(0.000)	(0.062)
LECI*LUP	–	−0.048***	–	−0.050***
p-value	–	(0.088)	–	(0.066)
Shape of EKC	Inverted U-Shape	Inverted U-Shape	*N*-Shape	*N*-Shape
Wald test	16.62b	15.68b	10.75b	9.16a
P-value	(0.0121)	(0.0382)	(0.0456)	(0.0027)
No. regressors	6	7	7	8
No. of group	5	5	5	5

NOTE: * p < 0.01, ** p < 0.05, *** p < 0.1 respectively.

erlund [71] to catch the long-run association between energy intensity and the regressors. Unlike both Pedroni and Kao cointegration tests, Westerlund [71] considers CD. The Equation below presents Westerlund [71].

$$G_t = \frac{1}{N}\sum_{i-1}^{N}\frac{\hat{\text{Î}}\text{¬}_i}{SE(\hat{\text{Î}}\text{¬}_i)} \tag{8}$$

$$G_\alpha = \frac{1}{N}\sum_{i-1}^{N}\frac{\text{T}\hat{\text{Î}}\text{¬}_i}{\hat{\text{Î}}\text{¬}_i(1)} \tag{9}$$

$$P_T = \frac{\hat{\text{Î}}\text{¬}}{SE(\hat{\text{Î}}\text{¬})} \tag{10}$$

Table 6
FMOLS estimation for sensitivity check.

Variables	MODEL I	MODEL II	MODEL III	MODEL IV
LECI	0.0483*	0.297*	0.102*	0.308*
p-value	(0.003)	(0.001)	(0.001)	(0.000)
LECI^2	−0.001*	−2.89E-*	−9.85E**	−5.78E***
p-value	(0.000)	(0.003)	(0.031)	(0.088)
LECI^3	–	–	8.62E-*	5.03E-**
p-value	–	–	(0.041)	(0.011)
FDI	0.007*	0.009*	0.005*	0.008*
p-value	(0.008)	(0.000)	(0.033)	(0.025)
LREU	−0.138*	−0.081*	−0.139*	−0.085*
p-value	(0.000)	(0.001)	(0.000)	(0.000)
LNR	0.304*	0.411*	0.530*	0.366*
p-value	(0.000)	(0.000)	(0.000)	(0.000)
LUP	0.089*	0.5817*	0.0821*	0.505*
p-value	(0.001)	(0.000)	(0.003)	(0.006)
LECI*LUP	–	−0.080*	–	−0.071*
p-value	–	(0.004)	–	(0.001)
Shape obtain	Inverted U-Shape	Inverted U-Shape	*N*-Shape	*N*-Shape
R_sq	0.973	0.974	0.973	0.974
Adj R_sq	0.971	0.972	0.971	0.972
No. regressors	6	7	7	8
No. of group	5	5	5	5

NOTE: * p < 0.01, ** p < 0.05, *** p < 0.1 respectively.

Table 7
Dumitrescu and Hurlin [34] causality analysis.

	W-stat.	Z-Stat	p-value	CAUSALITY FLOW
LECI → LCO$_2$	3.566***	1.747	(0.080)	LECI ↔ LCO$_2$
LCO$_2$ → LECI	3.842**	2.130	(0.033)	
FDI → LCO$_2$	1.756	−0.765	(0.444)	LCO$_2$ → FDI
LCO$_2$ → FDI	4.717*	3.345	(0.000)	
LREU → LCO$_2$	2.529	0.307	(0.758)	LCO$_2$ → LREU
LCO$_2$ → LREU	5.329*	4.195	(3.E-05)	
LNR → LCO$_2$	3.259***	1.321	(0.086)	LCO$_2$ ↔ LNR
LCO$_2$ → LNR	6.146*	5.330	(1.E-07)	
LUP → LCO$_2$	6.296*	5.538	(3.E-08)	LCO$_2$ ↔ LUP
LCO$_2$ → LUP	4.021**	2.379	(0.017)	
LECI*UP → LCO$_2$	5.620*	4.599	(4.E-06)	LECI*UP ↔ LCO$_2$
LCO$_2$ → LECI*UP	3.682***	1.908	(0.056)	

NOTE: * p < 0.01, ** p < 0.05, *** p < 0.1 respectively.

$$P_\alpha = \text{TÎ¬} \tag{11}$$

The test alternative and null hypotheses are “there is cointegration” and “no cointegration” accordingly.

Augmented Mean Group (AMG) and Fully Modified-Ordinary Least Squares (FMOLS) Techniques

Therefore, the authors utilized two robust method that are considered to lodge the latter anxiety of this analysis The Augmented Mean Group (AMG) as the main technique for the analysis while the Fully Modified-Ordinary Least Squares (FMOLS) is use as sensitivity check. The AMG method offers the unusual capacity to account for cross-sectional dependence as well as slope heterogeneity. It can sustain a unique path because of the way commonly affected impacts are handled. For the AMG these impacts represent a single continuous change that can be compensated for by deducting it from the dependent factor. The Augmented Mean Group (AMG) heterogenous panel estimator of Eberhardt and Bond [35] as well as Eberhardt and Teal [36] were utilized in the study following the expression in eqn-12:

$$\Delta Y_{it} = \alpha_i + \beta_i \Delta X_{it} + \sum\nolimits_{t=1}^{T}\pi_t D_t + \varphi_i UCF_t + \mu_{it} \tag{12}$$

The OLS method of the difference is applied to the AMG technique.

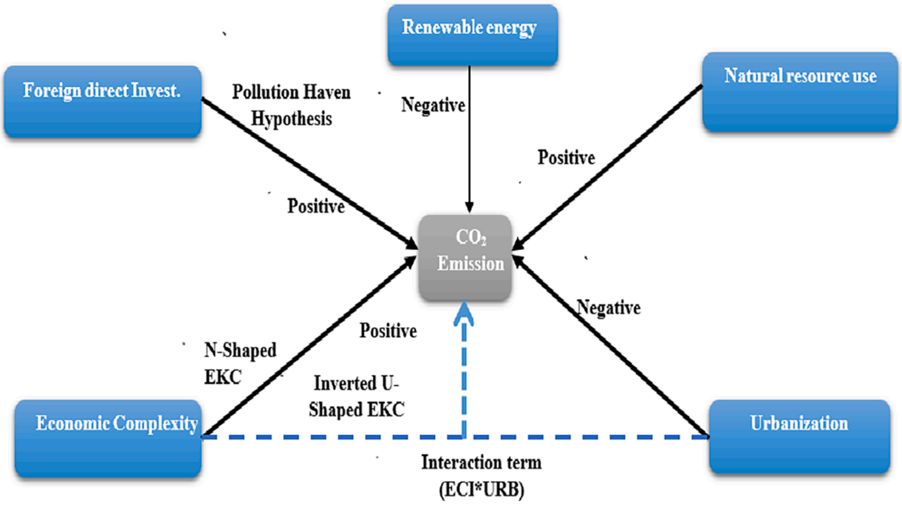

Fig. 1. Graphical presentation of empirical analysis. Source: Authors compilation.

This is shown in eqn-13 whereas φ_i symbolises the projected slope parameters of X_{it} coefficient in eqn-12.

$$\text{AMG} = \frac{1}{N}\sum\nolimits_{i=1}^{N}\varphi_i \tag{13}$$

Panel causality

To identify the causal interrelationship regarding renewable energy as well as CO_2 emission and the regressors (NR, Y, FDI and UB), this research utilizes [34] panel causal technique. We choose the first difference of all non-stationary indicators because the test is still not relevant to non-stationary data. The cross-sectional knowledge is included in this test, which is an extension of the existing Granger causality formula. Because of its adaptability to varied mixtures of time periods and cross-sections, this test has much more strength. In addition, the test is applicable to both heterogeneous and balanced panels. In the context of CD, the test yields beneficial results.

$$z_{\mathrm{i,t}} = \alpha_{\mathrm{i}} + \sum\nolimits_{j=1}^{p}\beta_i^j z_{\mathrm{i,t-j}} + \sum\nolimits_{j=1}^{p}\gamma_i^j T_{\mathrm{i,t-j}} \tag{14}$$

The alternative and null hypotheses are “there is causality” and “no causality” accordingly.

Empirical outcomes and interpretation

Based on the findings of the empirical research, individual time series are first analyzed to determine whether or not there is cross-sectional dependence (CSD). This is done by applying the Breusch-Pagan LM test, the Pesaran scaled LM test, and the Pesaran CD techniques, all of which can be found in table 2. The cross-sectional link demonstrates that the null hypothesis CSD outcome can be rejected at the one percent level of significance for all the techniques utilized in this study. This implies that the panel unit root analysis must consider the connection among cross-sectional individuals. However, the Pesaran & Yamagata, (2008) SH techniques on the other hand produced a 1 % siginficat level. This indicates that a shock appears to be transmitted to other nations within the panel in each of the oil-producing countries in sub-Saharan Africa. The findings proceed to demonstrate that neither multicollinearity nor serial autocorrelation can be found among the datasets under consideration. The results of the CIPS unit root technique by Pesaran (2007) presented in Table 3 provide evidence in favor of this assumption for the coefficients that were investigated, and Table 4 contains the outcomes of the panel cointegration investigation. The CIPS outcomes validate that all variables are stationary after difference.

Subsequently, outcome of the Westerlund [71] Cointegration test shown in Table 4 traces a long run equilibrium relationship between the highlighted variables in the panel analysis. The conclusion was supported by the evidence of rejecting the null hypothesis.

Panel estimation techniques

Furthermore, this research analyzes the long-run flexibility of the explanatory variables that could impact environmental deterioration, either negatively or positively. We used the AMG technique (table 5) for all four models to derive long-run elastic in the contexts of the EKC as well as PHH frameworks, while FMOLS (table 6) is used as a sensitivity or robustness check for this analysis. However, both outcomes show relatively close outcomes, with slight variations mainly noted in relation to the scales of the assessed variables and their equivalent level of statistical significance. All the models confirm the present of EKC and PHH by adding renewable energy, natural resources, and urbanization to affirm if the economic-FDI-environs relationship fits an *N*-shaped or not. Form model I and II, the analysis aims to check for the existence of inverted U-Shaped EKC connection for economic complexity ($\beta_1 > 0$, $\beta_2 < 0$). From both models, the outcomes prove positively and negatively significant coefficients confirming the presence of inverted U-Shaped EKC for the BRICS countries. However, from model III and IV the outcome shows$\beta_1 > 0$, $\beta_2 < 0$ and$\beta_3 > 0$ which affirms the presence of *N*-Shape EKC connection involving economic complexity and CO_2 emission. As a result of this scenario, carbon emission habit is classified according to ECI, where the first phase of economic expansion generating a high amount of ecological degradation ($\beta_1 > 0$). At this point, the economy will be affected by the scale effect, as previously demonstrated by Adebayo et al. [2] and Sinha and Shahbaz [62]. Upon attaining a specific income scale where carbon emissions show a declining trend ($\beta_2 < 0$, a rise in economic complexity will result in a reduction in ecological harm. This verifies the composition and technical effect in the BRICS economies,which is like previous outcomes of [42,43,17,13]. Furthermore, after obtaining the lowest possible degree of emissions, economies tend to place less emphasis on ecological protection, and the scale technological obsolescence effect ($\beta_3 > 0$) begins to manifest itself as a result [16,13,57,3,41]. This proofs that, all the four models affirm the existence of inverted U-Shaped whiles model III and IV affirms the existence of *N*-Shaped EKC of ECI and carbon emission for the BRICS economics.

Moreover, FDI was seen to also have positive impact on the ecology for the BRICS economics. There are other elements that contribute to the appeal of FDI, such as availability to cheaper labour, proximity to the sector, and less stringent policies in terms of controlling the abuses of overseas investors, that make this outcome more likely. This serves as a reminder that economies in the BRICS are continuing developing in their economic operations and growth while paying little attention to the health of their ecology. This supported the position of some critics of foreign direct investment, particularly those concerned with the long-term viability of underdeveloped nations. This observation lends credibility to the notion of a pollution haven (PHH). This validates the results of Sarkodie and Strezov [60],Udemba [67]; Gyamfi et al. [45] and Steve et al [64].

The relationship between renewable energy and the environment is determined to be negative and statistically significant. In recent years, it has been proven that transitioning to more environmentally friendly (renewable) energy sources result in improved environmental outcomes regardless of where the economy is located. This is line with the observations of Dong et al. [32], Gyamfi et al. [42] Bamidele et al [14], Ohajionu et al [55] and Agboola et al [5].

The outcome acquired from natural resources, on the other hand, is found to have a positive and statistically significant link with ecological degradation. This verifies the findings of Amed et al. (2020) and Gyamfi et al. [45] who found that natural resources promote pollutants in BRICS economics. These nations have a substantial quantity of revenue that can be utilized for both export and inland intake. This discovery, however, lends weight to the impression that, obtained from natural resources from these economics has never been lucrative. Extreme dependence on natural resources contributes to the loss of biocapacity, which is the capacity of living organisms to reproduce [15]. Furthermore, considering the vital consequence of the BRICS economics, the usage and growth of agricultural resources encourage deforestation, which increases emission. Aside that, several countries make use of their natural resources (coal, petroleum, and natural gas) to acquire their energy requirements. It has been claimed that the profusion of resources would enable a nation to become more self-sufficient by dropping energy importation and depending on inland energy generation with less emission levels [6].

Furthermore, we discovered that urbanization exacerbates ecological damage in the BRICS economies. Several previous analysis have determined that urbanization has an adverse impact on ecological deterioration, and this study adds to that body of knowledge [52,45,10]. It is beneficial to the economy to increase the density of towns with limited resources, just as it is beneficial to increase the density of towns with abundant resources. As a result, among other things, it increases the demand for transportation, housing, and household appliances [49].

It is noteworthy to consider the ecological consequences of these shifts in economic models in nations where the major task is shifting from the core to the tertiary sector. According to the indicator LECI*LUB (ECI interrelated with urbanization) given in Tables 5 and 6, this concept is supported by the fact that there is an adverse association involving urban growth as well as economic complexity and environmental emission ($\beta_8 > 0$). From the analysis, the moderation effect will decrease pollution in the environment by 0.04 and 0.05 in models II and IV respectively. In light of this viewpoint, Balsalobre-Lorente et al [13] shown that the environmental harms caused by an economy are highly connected with the combination of products that it exports and manufactures. It is therefore critical to analyze which areas of the economy are dominant in a country order to gain a better understanding of the country's environmental efficiency. As economic activity accelerates and countries' economies become more prosperous, the financial systems of these nations shift in the path of the tertiary sector, thereby lowering the degree of ecological degradation in the process. Within this time frame, there is a greater desire for protection, knowledge, health, and comfort, which enhances concern about the surroundings.Table 7..

Causality analysis

Form the Dumitrescu and Hurlin [34] Granger causal technique presented in Table 6, it was observed that there is bidirectional causality between ECI and CO_2 emission, natural resources and CO_2 emission, urbanization, and CO_2 emission as well as the interaction between ECI and urbanization with CO2 emission. However, a uni-directional causality is obtained between CO_2 emission and renewable energy as well as FDI and CO_2 emission. All these findings are similar with the early findings from table 5 which indicates that, ECI, natural resources unionization and FDI all have positive impact on the environment while renewable energy has negative impact on the environment which the findings are in line with Gyamfi et al [42], Bekun et al [17] and Balsalobre-Lorente et al [13]. Therefore, to attain a decrease in CO_2 emission from enterprises in the BRICS economies and to aid efforts toward green development and healthy economy, stricter laws will be required. As a result, strategy and decision-makers should investigate additional techniques for raising renewable energy production, thereby boosting green intake, and ensuring that environmental damage is kept to the bare minimum through the adoption of modern innovations for reducing carbon emissions. Fig. 1 outlines the causality scheme over the sampled period and chosen variables.

Conclusion and policy direction

Conclusion

To achieve numerous Sustainable Development Goals (17-SDG) objectives, a cleaner and healthier environment is essential. With only a little less than decade left before the final deadline of 2030, the world's economies must pick up the tempo and invest more resources in the finding of better explanations for rising temperatures, pollutants, habitat destruction, and climate change to revitalize cultures and economies. Following this viewpoint, this study investigated the dynamic connection between ECI, FDI, renewable energy usage, natural resources, urbanization, and CO_2 emission for the BRICS countries. The research makes use of datasets spanning the years 1990 and 2018, as well as 2nd generational methods like CIPS, Westerlund cointegration, slope heterogeneity (SH), CSD, AMG, FMOLS, and causality proposed by Dumitrescu and Hurlin [34]. The outcome of the CSD as well as SH provide evidence in favor of the adoption of approaches from the second generation. The results of the Westerlund cointegration analysis revealed the existence of a long-run interconnectivity involving the dependent coefficient of CO_2 emissions and the regressors. The outcome from the methods (i.e., AMG, and FMOLS) show relatively close outcomes, with slight variations mainly noted in relation to the scales of the assessed variables and their equivalent level of statistical significance. From the outcomes, the inverted U-Shaped and the *N*-Shaped EKC was confirmed showing a positive, negative and positive connection between ECI, ECI^2 and ECI^3 with CO_2 emission respectively. Moreover, the connection between FDI and CO_2 emission was positively significant which affirms the existence of PHH for the BRICS economics. Again, both natural resources and urbanization increases emission whiles renewable energy and the interaction involving ECI, and urbanization have negative impact on the environment of BRICS economics. Furthermore, from the causality analysis, a bidirectional causality between economic complexity, natural resources, urbanization as well as the interaction between economic complexity and urbanization and the dependent variable, thus, CO_2 emission while a uni-directional causality is obtained involving FDI as well as renewable energy and the dependent variable CO_2 emission.

Policy directions

Following the outcomes of the current study, we will create numerous policy recommendations that will be considered.

- The results of the EKC theory, which is associated with economic complexity, suggest that authorities in the BRICS countries should encourage the exporting of skill-intensive, knowledge-based, and energy-efficient products to ensure a greener livelihood. Within this spectrum, greater incentives should be provided to enterprises that adopt more environmentally acceptable technologies and use greener forms of energy, and a Pigovian tax must be levied against traditional businesses. As a result, the BRICS economies may increase the exporting of sophisticated goods and products with substantial value while simultaneously protecting the environment. It has been noted that several emerging markets (notably the BRICS) have turned to relax laws and restrictions to draw higher levels of investment. Nevertheless, the regulatory agencies of these nations should now strive to enact severe ecological regulations to reverse the cumulative environmental destruction. There is a scarcity of economic means, institutional abilities (particularly following the 2008 financial crisis), and in numerous instances, political enthusiasm, which is exacerbated by the campaigning of proficient investors, which is impeding substantial progress toward an ecologically responsible environmental framework. To achieve this goal, the authorities, regulators, and the central supervisory board of these nations should regulate cleaner inflows of foreign direct investment (FDI) to promote greener and healthier advanced technologies and support alternative energy supplies throughout the area.
- The goal of increasing renewable energy usage must be achieved in place to bolster and execute the new financing in hygienic and cleaner energy infrastructure. As a result, more funds must be allocated to R&D to investigate newer and more dependable renewable energy financial advice. The investment in innovative technologies and the avocation of the usage of renewable energy would, generally, enhance the green healthiness of BRICS economies in general. To achieve stable economic expansion and the usage of sustainable power along with the BRICS countries, strategies must be implemented in the areas of monetary flow, technological improvement, and long-term economic plans in the BRICS countries. In a similar vein, rules for discovering newly upgraded renewable resources would significantly boost economics, and technological improvements would aid in the production of renewable energy. Besides, carbon emission plans are also important to encourage investment in renewable energy resources.
- Taking into consideration urbanization, which is favourably connected with carbon emission, on the other hand, the safeguarding character of the ecology of urbanization is linked with the complexity of economic systems. As a result, healthy urbanization should be the foundation of healthy economic growth, because the positive impact of urbanization will help to reduce carbon emission. Authorities and state agencies should take this viewpoint into consideration when planning for sustainable development in all elements of urbanization, such as urban housing, sewage, and mobility. Policies aimed at dissuading personal vehicle ownership, increasing non-motorized (oil-free) mobility, and promoting mass transit should be maintained and expanded. Furthermore, strategies for consolidated lodgings should be developed to limit the amount of time spent traveling. The urbanization of the BRICS countries has resulted in the increased usage of energy supplies in both firms and homes, as well as in transportation. Environmental protection should be shifted away from traditional to sustainable energy usage, and renewable energy should be made available to companies and families at appropriate and affordable costs.
- The outcomes of this study should be taken into consideration by authorities. With less than a decade remaining to fulfil UN goals, more serious attempts in discovering more effective ways to accelerate the tempo of ecological deterioration are urgently required to reach these goals. It will be necessary for the globe to make even greater attempts in discovering answers to urbanization problems, making considerable public funding in green energy resources, and implementing comprehensive pollution control regulations.

Limitation and future studies

The present study is clearly not without flaws since it is the subject of several different limitations. Economic complexity, foreign direct investment, renewable energy utilization, natural resource, and urbanization are not the only variables that influence carbon emission. Another disadvantage of this study is the inaccessibility of the data. Moreover, variables like, non-renewable energy, technological innovation etc. can be added to further obtain it impact on the environment. Lastly, the study can be extended to other areas like Sub-Sahara Africa, emerging seven (E7), G7 etc.

CRediT authorship contribution statement

Divine Q. Agozie: Validation, Visualization, Data curation, Writing – original draft, Investigation. **Bright Akwasi Gyamfi:** Conceptualization, Formal analysis, Methodology. **Festus Victor Bekun:** Writing – original draft, Supervision. **Ilhan Ozturk:** Writing – original draft, Investigation. **Amjad Taha:** Validation, Visualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix

Table A1
List of countries.

LIST OF COUNTRIES: Brazil, Russia, India, China and South Africa

Table A2
Descriptive statistics and correlation matrix analysis.

	LCO$_2$	LECI	FDI	LREU	LNR	LUB	LECI*LUP
Mean	−0.896	9.193	0.688	2.233	4.416	3.893	36.358
Median	−0.975	9.301	0.738	2.472	4.476	4.001	34.915
Maximum	0.320	10.648	5.635	4.024	4.604	5.542	56.700
Minimum	−2.240	6.768	−12.942	−3.802	3.724	1.180	8.895
Std. Dev.	0.591	1.100	1.657	1.190	0.194	0.823	10.610
Skewness	0.045	−0.148	−2.244	−2.003	−1.589	−1.006	−0.278
Kurtosis	2.261	1.422	21.376	8.254	4.742	4.510	2.565
Jarque-Bera	7.098	33.061	4592.171	560.312	168.667	81.253	6.405
LCO$_2$	1						
LECI	−0.845	1					
FDI	0.012	−0.034	1				
LREU	−0.163	−0.063	0.207	1			
LNR	0.495	−0.113	−0.095	−0.486	1		
LUB	−0.465	0.626	0.263	0.175	0.074	1	
LECI*LUP	−0.684	0.849	0.179	0.088	−0.012	0.939	1

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