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Research Article

The Impact of Human Capital and Biocapacity on Environment: Environmental Quality Measure through Ecological Footprint and Greenhouse Gases

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ABSTRACT

It is important to note in growth-energy-environment nexus, the use of other environmental proxies like ecological footprint and greenhouse gases are getting more attention in recent years. Though carbon emission (CO_2) has been mostly used to test the EKC hypothesis in the past years, it is irrational to capture the whole environmental degradation through CO_2 emission only; as it is one pollutant indicator. This paper includes four proxies such as; ecological footprint (EF), carbon emission (CO_2), Nitrous Oxide emission (N_2O) and methane emission (CH_4) to seizure the environmental quality. Thereby, this paper investigates the impact of human capital and biocapacity on the environment of BRICS economies by covering the period of 1991-2014. Empirical analysis of Kao, Westerlund, and Pedroni verify the presence of cointegration between the variables of the selected panel. Long run estimations of "Dynamic Seemingly Unrelated Regression (DSUR)" divulge the existence of an inverted U-shaped curve (EKC) for model 1, 2 and 4 while U-shaped association for model 3. Moreover, biocapacity (human capital) significantly contribute to environmental degradation in model 1 & 4 (3 & 4) while improve environmental quality significantly in model 2 & 3 (1 & 2). Energy consumption significantly enhancing the ecological footprint and GHGs emission. In addition, Granger causality tests confirm the bidirectional causal relationship between economic growth, biocapacity, human capital, and environmental degradation. Fascinatingly, long term estimations of individual country propose that China is the only country in which empirical analysis confirm the EKC hypothesis for all four models. Lastly, this paper provides some valuable policy inferences in the perspective of the sustainable environment in BRICS economies.

Keywords: Human capital; Biocapacity; Environmental degradation; Ecological footprint; GHGs, EKC; BRICS countries

INTRODUCTION

In accomplishments of a sustainable environment, global warming and Green House Gasses (GHGs) emissions are the key challenges for our ecosystem. Contest against climate change is one of the major issues of the United Nation's seventeen (17) points schema for sustainable development by 2030 (UNDP, 2015) [1-3]. According to two foremost challenges for humanity are (i) economic development and (ii) to preserve the environment of the planet. Due to emissions of Green House Gases (GHGs), global temperature is gradually rising with every passing day, which has become a severe threat not for developing countries but also for developed nations. In a competitive environment, all the countries are using their natural resources for high economic growth, irrespective its effect on environmental quality. Undoubtedly they are growing at the cost of substandard environmental changes which are due to land pollution, water pollution, and air pollution [4]. The equity theory of intergeneration proposes that it is ethical and moral vow toward future generations to preserve the environmental quality for them. According to, since several decades climate change and global warming are at the top in global environmental debates. The natural scientists state that the emission of Green House Gases (GHGs) is the main challenge for a sustainable environment [5-8]. That's why environmental hitches have been conquered great

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attention of the scholars and recently environmental economics has become one of the most popular subjects. In the literature of environmental economics, two core research aspects are: An inverted U-shaped association between per capita income and environmental degradation which is known as "the hypothesis of Environmental Kuznets Curve (EKC) [9-11]. According to EKC, initially, income upsurges the environmental degradation which gradually declines after the threshold point. The Pollution Haven Hypothesis (PHH) this hypothesis portrays that due to less stern environmental laws in less developed areas, production plants (especially high pollution generator) transfer toward developing countries through foreign direct investments or international trades which become the main cause of high environmental degradation [12]. To reduce global warming, the Kyoto Protocol executed the objectives of "United Nations Framework Convention on Climate Change". The targets apply to four main greenhouse gases (i.e. CO_2, CH_4, N_2O, and SF_6) and two other groups of gases (hydrofluorocarbons, perfluorocarbons). In Green House Gases (GHGs), carbon dioxide is at the top that's why most of the studies in environmental economics literature have investigated growth-energy-carbon emission nexus in EKC framework. In this context, many scholars have confirmed environmental curve between real output and carbon emission On the other side, uses an index (including CO_2) to determine the environmental quality and does not find evidence for the environmental Kuznets curve in the case of BRICS economies. Similarly, it also proposes mix results for BRICS countries. After carbon dioxide (CO_2), the second largest greenhouse gas is Methane (CH_4) [13]. According to the Intergovernmental Panel on Climate Change (IPCC, 2014), in short-term the potential of methane has 84 times greater on global warming than carbon dioxide. One-fifth of global warming is due to methane emission and after the industrial revolution its potential to catch is more than double. Using input-output models nexus between socioeconomic factors and methane (CH_4) emission, they postulate that with other greenhouse gases carbon dioxide (CO_2) and methane (CH_4) emissions are the major challenges to control global warming. Third most important GHG is a Nitrous oxide (N_2O), even its climate sensitivity poorly known but in global warming it has around 300 times greater potential that of CO_2 [14-16] Most of the scholars use CO_2 emission to determine the environmental quality in the EKC framework which is the major flaw in the environmental economics literature[17-19]. Carbon emission is one indicator which damages our environment; so, it is irrational to take into account only one aspect (or pollution type) to measure the whole environmental degradation. A most comprehensive proxy to measure environmental degradation is ecological footprint; because it accumulates six components (a) carbon footprints (b) forest land (c) fishing grounds (d) built-up land (e) grazing land and (f) cropland and it consider the degradation of mining, forestry, oil stocks and soil. Prior literature also demonstrates the importance of Ecological Footprint (EF) as a proxy to measure the quality of environment such as propose that EF highlights the impact (direct and indirect) of production consumption on the environment. In growth-environment nexus, EF measures the environment more comprehensively. They also propose that for high economic growth many countries utilize their natural resources irrespective its impact on the environment i.e., water pollution, air pollution, and land pollution, etc. In explicit processes, many pollutants (per unit) have waned through strict environmental protocols, innovations and technological change in many advanced economies. Even though policymakers are focusing on GHGs emission and other pollutant components but aggregate pollution per capita is still out of control. So, for more comprehensive findings we should determine the environmental quality through other environmental proxies in growth-environment nexus [20-28]

To achieve desired environmental and economic goals, investigators should give attention to human capital in environment-growth nexus. Because literature posits that it is a very important component. Development in human capital reduces the use of fossil fuel which eventually enhances the environmental quality by controlling high carbon emission without affecting economic growth [29] As demonstrate that in the production process the use of fossil fuel can be reduced through human capital improvement. Similarly, it can also reduce CO_2 by enhancing the efficiency of energy [30-32]. Many other studies do not investigate the direct effect of human capital on the environment but these studies accentuate that education (human capital) is very important to resolve the environmental hitches. Bio-capacity is an imperative gauge for environmental sustainability. For life sustenance and global climate change agriculture, land use and forestry playing a vital role, it contributes 24% global GHGs emissions (IPCC, 2018) [33-36]. Abolishing the foliage and growing population upsurge the demand of natural resources which in turn diminishes the natural bio-capacity (ecological deficit) and lead to environmental degradation. Ecological surplus (EF<BC) [37] is a prerequisite of sustainability while ecological deficit (EF > BC) is a gauge of unsustainability [38]. A report of 199 countries demonstrates that in 2008 only 60 countries have an ecological surplus (BC>EF). It means that other 139 countries either importing biological capacity or availing their own resources which are deteriorating the environment [39]. Biocapacity is very important in growth-environment nexus as it elucidates environmental degradation in EKC framework [40-42].

Five economies of G-20, Brazil, Russia, India, China and South Africa (BRICS) are outperforming as compared to other economies in the world or world trend (Figure 1) [43]. It is an international forum which encourages political, commercial, and cultural collaboration between five nations, was recognized at the end of 2010. Energy

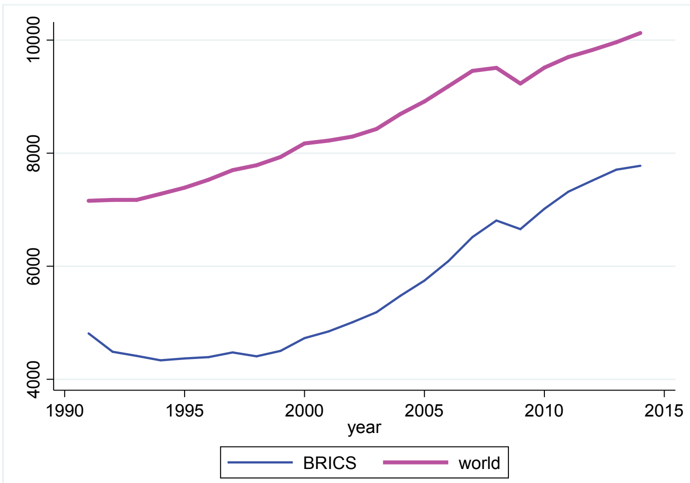

Figure 1: The trend in economic growth in BRICS countries vs the world trend (1991-2014) Source: by the author using data of World Bank (WDI, 2018)

security, economic stability, and environmental pollution were at the top in the agenda of the 6th summit. Because in 2013, these economies consumed more than 35% of the total world's energy and emitted more than 40% of the world's carbon emission [44-46]. To control global warming these counties have committed to reducing carbon emission i.e., up to 2020; 36-39% by Brazil, 34% by South Africa, 40-45% (2005 base year) by China, 34% (2005 base year) by India and 10-25% (1990 base year) by Russia. Today, more than half (50%) of the world's growth is depending on BRICS countries which are accommodating more than 40% population, globally [47]. propose that the growth of these 5 economies will be more than G-7 countries by 2050. Due to the high usage of fossil fuels, the panel of these economies is at number 3 (out of 5) of high carbon emitters [48,49]. To improve environmental quality, in 2017 BRICS economies have avowed to utensil the Paris agreement on climate change. It is the indication that these countries are trying to resolve their environmental hitches by controlling carbon emission [50]. So, in growth-energy-environment nexus, with CO_2 we should undertake other proxies also (as carbon is only one component of environmental degradation) to measure environmental quality [51]. It will give a clear picture for better policymaking related to sustainable development for BRICS economies [52].

MATERIALS AND METHODS

The motivation and contribution of the study

It is important to note in growth-energy-environment nexus, the use of other environmental proxies like ecological footprint and greenhouse gases are getting more attention in recent years [53]. Though carbon emission (CO_2) has been mostly used to test the EKC hypothesis in the past years, the most important thing is that we need appropriate proxy/proxies which can cover the environment broadly [54]. Because it is difficult to capture the whole environmental degradation through CO_2 emission only, as it is one pollutant indicator. All the prior scholars have used carbon emission to determine the deterioration of the environment in the case of BRICS countries [55]. Moreover, prior studies on BRICS countries did not take into account the impact of biocapacity and human capital on the environment in EKC framework. For better decision making, it is the present need to cover the environment broadly through other possible environmental indicators (i.e., ecological footprint and greenhouse gases) [56-58]. By measuring environmental quality comprehensively, we will be able to put the actual environmental condition of the BRICS economies in front of the policymakers for better decision making regarding environmental policies [57-59].

This paper tries to fill this gap and aims to contribute to existing energy-economics knowledge as follows: (i) There is a lack of consensus on growth-environment nexus in which scholars employ the other environmental proxies in the case of BRICS economies. The current study tests the EKC hypothesis by determining the environmental quality through greenhouse gases (CO_2, N_2O, CH_4) and ecological footprint in growth-energy-environment nexus [60-62]. With comprehensiveness in environmental degradation, we can get more reliable findings to explain the association between economic growth and environmental degradation in BRICS economies. (ii) For the first time, this study considers the dynamic impact of biocapacity and human capital on the environment in the case of BRICS countries. (iii) By employing second-generation econometric approaches the current study also conducts country-wise analysis for micro-level policymaking [63-65]. (iv)For long term estimation, this study used the latest econometric approach "Dynamic Seemingly Unrelated-cointegration Regression (DSUR)". (v) Lastly, we employed "Dumitrescu-Hurlin Panel Causality Test" to explore the causal relationship among the involving variables [66-71].

Literature review

In energy economics, there are many studies in which scholars have tested the EKC hypothesis during their growth-energy-environment nexus. However, that literature posits indecisive findings many studies confirm inverted U-shaped EKC between growth-environment nexus [72], while other studies do not find any piece of evidence of its existence. Even that some scholars show U-shaped, linear or N shaped association (or mix results) between interesting variables [73]. In the case of the panel of 5 BRICS countries do income-urbanization-CO_2 emission nexus by covering the period 1994-2013 and confirm the environmental curve for selected countries [74]. They also suggest that BRICS counties should focus on clean energy and they need to improve their energy efficiency [47] and investigate the role of capital investments as a mediator between consumption of electricity-carbon emission (CO_2) nexus. They confirm the EKC hypothesis and they infer that capital investment is very important for a sustainable environment in BRICS economies [75] also test the EKC hypothesis in growth-environment-trade liberalization nexus and validate it for all countries for the period of 1960-1996. Similarly [37] examine the influence of financial development, urbanization, energy consumption, globalization, and economic growth on CO_2 emission, [2] explores association between energy-growth-financial developments and [22-24] investigate the nexus between natural gas, renewable energy, GDP and CO_2 emission; all these studies confirm the environmental Kuznets Curve for BRICS countries. Contrary, investigates the influence of renewable energy on the environment (index), covering 1995-2015 they do not find evidence in support of the EKC hypothesis and they confirm the presence of pollution haven hypothesis in BRICS countries. Proper allocation of resources is necessary for a sustainable environment and food security in BRICS economies [3]. In addition, they confirm a U-shaped curve between economic growth and CO_2 emission in the selected panel countries. Unlike the above discussion, Tedino [76-78] finds mix evidence while testing the EKC hypothesis in the panel of these five economies. They validate this hypothesis for India, South Africa, and China but not for Brazil and Russia. Similarly, [50] use time series data (1990-2015) and test the environmental hypothesis in BRICS countries. One-fifth of the global warming is due to second largest greenhouse gas methane emission [48] and after the industrial revolution, its potential to catch is more than double [79,80]. The level of CH_4 is increasing gradually due to human activities such as extraction of fossil fuel and agricultural activities. The direct effect of CH_4 on the atmosphere can be controlled by mitigating of anthropogenic methane emission [52]. It is an unending quarrel and there is no consensus among scholars over the determinants of methane emission [81]. As propose methane emission is directly related to energy (extraction & supply), relate it to livestock farming and rice cultivation, and argue that waste management services are generating CH_4 [82]. Similarly, many other studies also suggest that agricultural activities in Asia, declines in hydroxyl radicals and feedback effects from tropical wetlands are key responsible factors for CH_4 emissions [83]. A review study posits that three primary GHGs (i.e., CO_2, CH_4, N_2O) are engendering by the agriculture sector, which is around 10-12% of total global GHGs emissions [18]. More precisely anthropogenic sources are responsible for more than 50% of methane and more than 60% nitrous oxide. N_2O has 269 times more potential for global warming as compared to CO_2. Use time series data for the period of 1970-2012 and validate the environmental hypothesis by confirming the quadratic association between economic growth and N_2O emission in Germany. Moreover, they find a significant positive association between N_2O emission and land area (agricultural) and negative relationship between exports and N_2O emission. Broucek (2017) [14] accumulate the knowledge of N_2O emission through review study and propose that soil is the largest donor to global GHGs emission. In addition, he says that soil nitrate, water-filled pore space, soil pH, soil carbon and temperature are the moderators of N_2O emission. Now growing body of research using alternative proxies (instead of CO_2 emission) to measure environmental degradation. So, a most comprehensive proxy to measure environmental degradation is ecological footprint [84-86]. In the latest studies, some scholars test the EKC hypothesis using Ecological Footprint (EF) for environmental deterioration. For example, Ulucak and Bilgili [79] use ecological footprint emission and advocate that EKC exists in three groups (high-income, middle-income, and low-income countries). Use EF for top ten tourist countries and validate an inverted U-shaped curve for a selected panel of counties [87]. Investigate the EKC hypothesis for fifteen (15) MENA countries and employ EF (a proxy for environmental quality) for the period of 1975-2007. Their empirical findings confirm the environmental hypothesis between GDP and EF. Similarly, and utilize EF as an environmental indicator and confirm inverted U-shaped association between economic growth and ecological footprint for Qatar, 144 and 116 countries respectively. Many other researchers do not find evidence in the support of EKC existence while using ecological footprint as a proxy for the environment. i.e. Destek et al. [19] test the environmental hypothesis in the nexus of growth-energy-trade for 15 EU countries covering the period of 1980-2013. They do not confirm it, instead, they confirm U-shaped between ecological footprint and GDP. Likewise, also do not find evidence to support the environmental hypothesis for selected 150 countries panel. On the other side, some researchers postulate mix results for EF, i.e., reinvestigate the EKC in growth-energy-finance-ecological footprint nexus for newly industrialized economies (1977-2011). They find evidence for the existence of EKC in Singapore, South Africa, Mexico, Philippine but do not for Thailand, India, Turkey, South Korea, and China. Likewise, test the EKC model one for developing and second for developed countries. Using data from 1990 to 2013, their empirical evidence confirms the EKC model for Japan and Korea but not for China.

To reduce carbon emission, improvement in human capital is necessary because it has the ability to decrease carbon emission without affecting the growth of the economy. Also, they find a two-way causal association between carbon emission and human capital and they confirm feedback effect between economic growth and human capital for the long run. They suggest that education is the main pillar of human capital to mitigate carbon emission. investigate on green return to education through a causal association between pro-environmental behavior and educational attainment. They conclude that more years of schooling increase the likelihood of taking environment-friendly actions. Traditional education leads to energy education and environmental awareness programs which is necessary for sustainable environment. Their results for selected countries (developed and developing) covering the period of 1980-2013 confirm one-way association from education to energy consumption. In the production process, human capital mitigates pollution through reducing fossil fuel utilization [88,89]. Similarly, proposes that carbon emission can reduce through improving human capital which enhances energy efficiency.

Check the association between agriculture and carbon emission in Ghana for the period of 1961-2012. They suggest that abolishing the foliage and growing population upsurge the demand of natural resources which in turn diminishes the natural bio capacity (ecological deficit) and lead to environmental degradation. An ecological surplus (EF<BC) is a prerequisite of sustainability while ecological deficit (EF>BC) is a gauge of unsustainability. A report of 199 countries demonstrates that in 2008 only 60 countries have an ecological surplus (BC>EF). It means that other 139 countries either importing biological capacity or availing their own resources which are deteriorating environmental. Bio capacity is very important in growth-environment nexus as it elucidates environmental degradation in EKC framework because it measures the nature's regenerative capacity and people's ecological budget. It includes productive land (biologically) and also sees areas which are the basic indicators in the calculation of ecological footprint [90]. In growth-openness-HC-Bio capacity nexus by dividing countries into high income, low income and middle income, postulate that bio capacity leads ecological footprint to decrease (increase) in high income (middle & low income) counties as expected.

Data sources, research model and methodology

Data: This paper investigates the role of human capital and bio capacity for environmental degradation using greenhouse gases (GHGs) and ecological footprint as proxies to measure environmental quality in EKC framework. From three different data sources, we collected data of BRICS countries for the interested variables i.e, Ecological Footprint (EF), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), Gross Domestic Production (GDP), Energy Utilization (EU), Human Capital (HC) and Bio capacity (BC) for the period of 1991-2014. The data of ecological footprint and bio capacity downloaded from "Global Footprint Network", the data of human capital is obtained from "Penn World Table the data of greenhouse gasses (GHGs), economic growth (GDP per capita, constant 2010 US$) and energy use (Kg of oil equivalent per capita) extracted from the "World Development Indicator. The graphical trend of all interesting variables (ecological footprint, carbon dioxide, nitrous oxide, methane, economic growth, energy use, human capital, and bio capacity) of the BRICS countries is provided in Figure 2.

Country wise summary statistics of all the variables of BRICS economies are presented in Table 1. Raw data reveals that Russia is at the top in ecological footprint, per capita carbon emission, human capital, and energy consumption in a panel of 5 BRICS countries with mean values 5.3323, 11.588, 3.1288 and 4647.35 respectively. India has highest mean value (11.179) of N_2O emission, China has highest mean value (500552.6) of methane emission

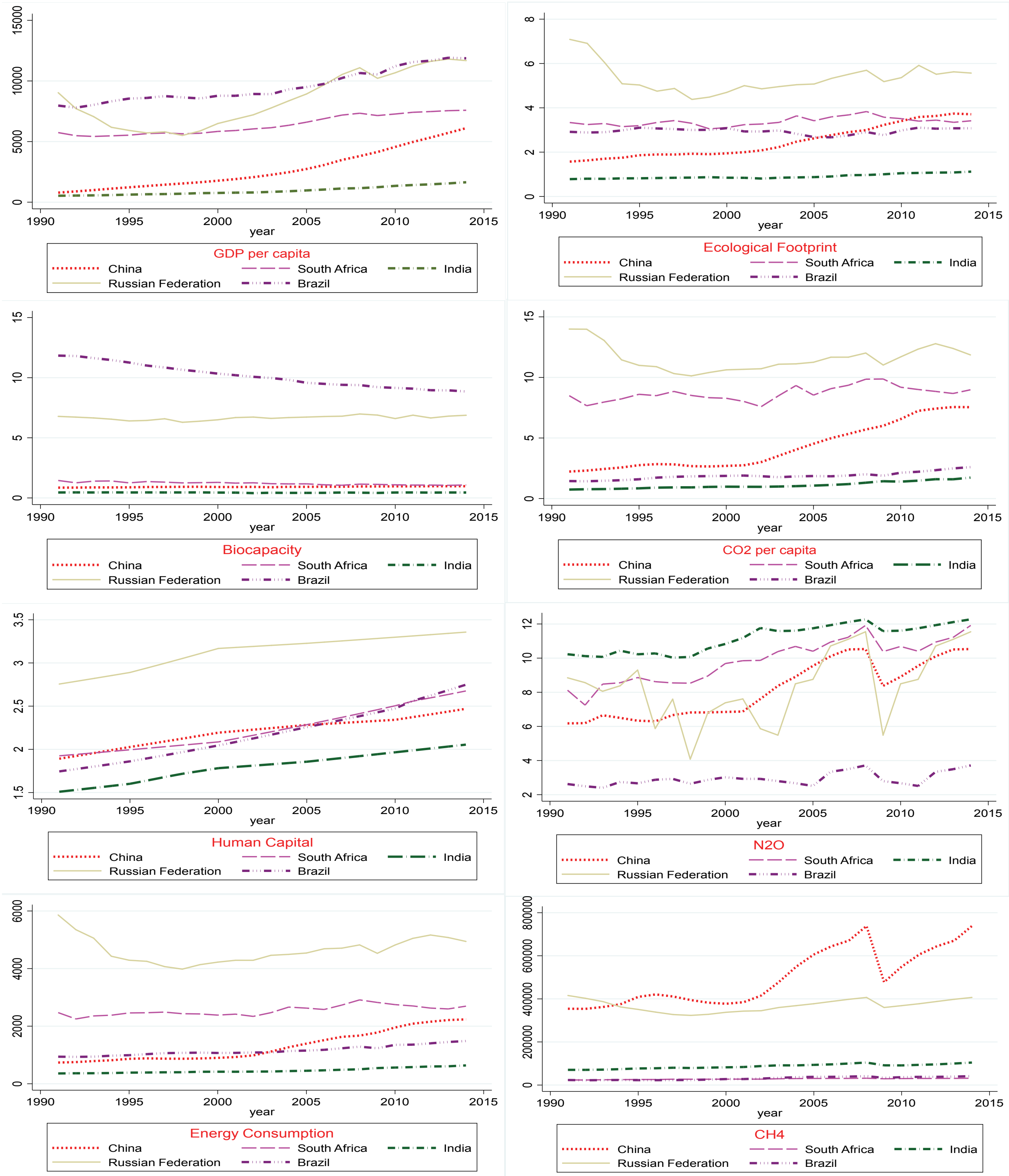

Figure 2: Graphical trend of variables in BRICS countries for the period of 1991-2014.

Table 1: Descriptive statistics.

Variables	Brazil		Russia		India		China		South Africa	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
EF	2.9475	0.1299	5.3323	0.6636	0.9047	0.1061	2.4778	0.7447	3.3815	0.1876
CO_2	1.8801	0.3036	11.588	1.0633	1.1047	0.2914	4.2575	1.9245	8.6761	0.5956
N_2O	2.925	0.3896	8.3573	2.0822	11.179	0.8216	8.1562	1.6692	9.851	1.2738
CH_4	31165.1	7241.1	369145.3	28144.2	87043.8	10596.6	500552.6	132199.1	28212.1	2603.7
GDP	9535.7	1332.8	8456.3	2218.4	946.02	345.65	2725.2	1653.5	6378.8	799.74
BC	10.145	0.9775	6.6667	0.1752	0.4442	0.017	0.9213	0.0366	1.2101	0.1208
HC	2.1773	0.3037	3.1288	0.1911	1.7988	0.1665	2.2053	0.1649	2.2336	0.2422
EU	1150.9	165.26	4647.35	456.66	459.24	85.847	1304.1	530.6	2544.1	169.06

and Brazil has highest mean values (953.7, 10.145) for per capita GDP and bio capacity. On the other side, India is at the bottom in a panel of 5 economies as the mean values of ecological footprint, carbon emission, per capita GDP, Bio capacity, human capital, and energy consumption are 0.9047, 1.1047, 946.02, 0.4442, 1.7988 and 459.24 respectively, which are the lowest values in the whole panel. Moreover, Brazil is at the bottom with respect to N_2O emissions and South Africa is at the bottom with respect to CH_4 emissions with mean values 2.9250 and 28212.1 respectively.

Econometric model

The current study deals with the empirical impact of human capital and biocapacity on environmental degradation in EKC framework for BRICS economies. For it we follow the theoretical framework and construct a model as follows

$$ED=f(y, y^2, BC, HC, EU) \quad (1)$$

Where ED=Environmental Degradation, (it is measured through i. ecological footprint ii. carbon emission iii. nitrous oxide emission iv. methane emission); y & y2 = per capita gross domestic production and its square; BC =biocapacity; HC=human capital; EU = energy consumption.

For empirical analysis, following we converted all our variables into the logarithmic form to attain reliable and efficient results. The empirical equations using the ecological footprint and GHGs (CO_2, N_2O, CH_4) for environmental degradation are presented as:

Model 1 (Ecological Footprint):

$$\log(\mathrm{EF}_i) = \beta_i + \beta_{1i}\log(\mathrm{GDP}_{it}) + \beta_{2i}\log(\mathrm{GDP}_{it})^2 + \beta_{3i}\log(\mathrm{BC}_{it}) + \beta_{4i}\log(\mathrm{HC}_{it}) + \beta_{5i}\log(\mathrm{EU}_{it}) + \varepsilon_{it} \ldots(2)$$

Model 2 (GHG-CO_2):

$$\log(\mathrm{CO}_{2i}) = \beta_i + \beta_{1i}\log(\mathrm{GDP}_{it}) + \beta_{2i}\log(\mathrm{GDP}_{it})^2 + \beta_{3i}\log(\mathrm{BC}_{it}) + \beta_{4i}\log(\mathrm{HC}_{it}) + \beta_{5i}\log(\mathrm{EU}_{it}) + \varepsilon_{it} \ldots(3)$$

Model 3 (GHG-N_2O):

$$\log(\mathrm{N_2O}_i) = \beta_i + \beta_{1i}\log(\mathrm{GDP}_{it}) + \beta_{2i}\log(\mathrm{GDP}_{it})^2 + \beta_{3i}\log(\mathrm{BC}_{it}) + \beta_{4i}\log(\mathrm{HC}_{it}) + \beta_{5i}\log(\mathrm{EU}_{it}) + \varepsilon_{it} \ldots(4)$$

Model 4 (GHG-CH_4):

$$\log(\mathrm{CH}_{4i}) = \beta_i + \beta_{1i}\log(\mathrm{GDP}_{it}) + \beta_{2i}\log(\mathrm{GDP}_{it})^2 + \beta_{3i}\log(\mathrm{BC}_{it}) + \beta_{4i}\log(\mathrm{HC}_{it}) + \beta_{5i}\log(\mathrm{EU}_{it}) + \varepsilon_{it} \ldots(5)$$

Where β_1, β_2, β_3, β_4, and β_5 are the coefficients of economic growth, the square of economic growth, biocapacity, human capital and energy use respectively; 'i' represents to countries (1, 2, 3 ...n); β_i/β_0 is the constant, 'ε_i' denotes to residuals and 't' stands for the periods (1991, 1992, ...n).

Methodological framework

Technically, the methodological procedure for estimations of the current study includes a family of latest econometric approaches. First of all, we confirmed cross-sectional dependency (characteristics of error term) in our variables by employing four tests (Breusch-Pagan LM, Pesaran Scaled LM, Bias-corrected Scaled LM, Pesaran CD). Second, we applied panel unit root tests (CIPS, CADF) to verify the stationarity property in the data. Third, this study used three famous and latest approaches (Kao, Westerlund ECM, Pedroni) to investigate the cointegration between the variables of interest. Fourth, after validation of cointegration, for long-run estimations, we applied Dynamic Seemingly Unrelated Regression (DSUR) for the panel of BRICS economies and Fully Modified Least Squares (FMOLS) for an individual country. Lastly, the current study applied a modified version of Granger causality (Dumitrescu and Hurlin Panel Causality) to check the casual association between variables.

Cross-sectional dependency: It is normal that heterogeneity or cross-sectional dependency may occur in panel data. While using panel data (as in the current study) to control these types of issues is necessary for reliable results. This is the main reason that advanced econometric approaches have the ability to auto control these types of issues. A famous test to check cross-sectional dependency is Breush-Pagan Lagrange Multiplier test Following the latest scholars the current study applied four tests; (i) LM test, which is effective for small 'N' and 'T' (ii) scaled LM test, which is valid for large 'N' and 'T' (iii) CD test, which is valid for large 'N' and fixed 'T' and (iv) Bias-corrected Scaled LM, which can be used for large 'N' and small 'T'.

Panel Unit Root: In the empirical investigation, the second step is to determine the level of integration or to check whether selected data is stationary or not. As we utilized panel data of five BRICS countries so, conventional unit root tests (i.e., IPS, LLC, ADF, etc.) [10] are not suitable for it hence, the current study employed second-generation unit root tests for reliable results. To address non-stationarity issues following and, we employed two-second generation unit root tests (i) CADF test (Cross-sectional Augmented Dickey-Fuller test) and (ii) CIPS test (Cross-sectional Im, Pesaran and Shin test). Both tests (CADF & CIPS) have been introduced by M. Hashem**.**

Panel Cointegration Test: Next is to identify the cointegration exist or not in the selected panel. Here, following and three different tests are employed to test the panel cointegration. (i) Kao t-statistic developed by Chihwa, it undertakes homogeneity in the panel and uses augmented Dickey-Fuller as a framework. The statistic of Kao is derived from "panel least square dummy variable" analysis. (ii) An advanced cointegration test proposed by Joakim. It undertakes two panel-specific autoregressive parameters for cross-sectional dependency. Using the error correction model, it analyzes whether cointegration exists in individual panels (Gt, Ga) or in the whole panel (Pt, Pa). The rejection of the null hypothesis of Gt & Ga infers that cointegration exists at least one of the cross sections. On the other side, the rejection of the null hypothesis of Pt & Pa conjectures that cointegration exists as a whole. (iii) A panel cointegration test based on the within-dimension (panel statistic) and between-dimension (group statistic), recognized by There are four components of panel statistic; the panel-v statistic (based on variances ratio; non-parametric), panel-rho (similar to Phillips-Perron ρ), panel PP (similar to Phillips-Peron t-statistics), panel ADF (similar to augmented Dickey-Fuller t-statistics). Group statistic includes three gears; group-rho (analogous to Phillips-Perron ρ), group-PP (analogous to Phillips-Peron t-statistics), and group-ADF (analogous to augmented Dickey-Fuller t-statistics).

Long-run estimation: After validation of the cointegration between variables, the current study employed a latest econometric approach "Dynamic Seemingly Unrelated Regression" proposed by for panel data, following the works of and. This econometric approach controls the cross-sectional dependency and heterogeneity issues which may arise in panel data and provide reliable results of long-run estimations. Following and, to check long run estimation of an individual country, the current study applied "Fully Modified Ordinary Least Square", proposed [90-93].

Table 2: Cross-sectional dependency tests.

Variables	Breusch-pagan LM		Pesaran scaled LM		Bias-corrected Scaled LM		Pesaran CD	
	Statistic	Prob.	Statistic	Prob.	Statistic	Prob.	Statistic	Prob.
LogEF	44.5253*	0	7.7201*	0	7.6114*	0	2.9627*	0.003
LogCO_2	87.7981*	0	17.3961*	0	17.2874*	0	7.1148*	0
LogCH_4	145.0585*	0	30.2000*	0	30.0913*	0	11.2391*	0
LogN_2O	115.3285*	0	23.5521*	0	23.4434*	0	10.3310*	0
LogGDP	205.9768*	0	43.8217*	0	43.7130*	0	14.3106*	0
LogGDP^2	207.9275*	0	44.2579*	0	44.1492*	0	14.3829*	0
LogBC	83.3588*	0	16.4035*	0	16.2948*	0	-2.1957**	0.028
LogHC	224.0977*	0	47.8737*	0	47.7650*	0	14.9627*	0
LogEU	119.9170*	0	24.5781*	0	24.4694*	0	9.7592*	0

Note: *, ** & *** show the level of significance at 1%, 5% and 10% respectively.

Causality test: propose that for heterogeneous panels test, which is the modified form of non-causality test, is appropriate for panel data. They advocate that this test has two key dimensions; this heterogeneous regression model can be applied to test causality (i) in Granger sense and (ii) heterogeneous causal relationship. So, to check the causal association between variables, we used test because it is flexible even with the unbalanced and heterogeneous panel; irrespective T>N or T<N.

EMPIRICAL ANALYSIS AND DISCUSSION

To check the error term characteristics among BRICS countries, the current study applied four cross-sectional independency tests for ecological footprint, GHGs (CO_2, CH_4, N_2O) emission, economic growth & its square, energy use, bio capacity, and human capital. (i) LM test, (ii) scaled LM test, (iii) CD test, and (iv) Bias-corrected Scaled LM. All the tests reject the null hypothesis which infers that the cross-sectional dependency is present, as shown in Table 2.

Next, we employed two second generation unit root tests (i) CADF test (Cross-sectional Augmented Dickey-Fuller test) and (ii) CIPS test (Cross-sectional Im, Pesaran and Shin test) in order to validate the stationarity properties in our variables (EF, CO_2, CH_4, N_2O, GDP, GDP, EU, BC, HC). The results of CIPS and CADF (Table 3) show that all the variables are stationary at '1st difference' and 'at level' respectively at 1%, 5% and 10% level of significance. Hence, both unit root tests confirm that all variables are integrated and allow us to use these variables to examine long term association. For confirmation of long-run equilibrium linkage between variables, this study applied three different tests for panel cointegration. Table 4 presents the outputs of Kao, Westerlund, and Pedroni tests [11] for Model 1, Model 2, Model 3 and Model 4 which have dependent variables ecological footprint, CO_2, N_2O, and CH_4 respectively. All three tests provide evidence to reject the null hypothesis of no cointegration among the variables 1%, 5% and 10% level of significance. It is the indication that for a long run the selected series tend to move together and their differences are stationary over the period of 1991-2014. So, a long-run association exists among the variables of all four models.

Keeping in mind the cross-sectional dependency and heterogeneity issues, this study applied "Dynamic Seemingly Unrelated Regression". A second-generation econometric approach which auto control these issues related to panel data even when T>N it works appropriately. The outputs of panel DSUR estimations are given in Table 5. These results reveal that all the coefficients in all

Table 3: Outcomes of panel unit root test.

Variables	CIPS		CADF
	At level	1st Difference	At level
LogEF	-1.841	-3.772*	-2.596**
LogCO_2	-2.077	-3.253*	-2.959*
LogCH_4	-1.729	-3.232*	-2.712*
LogN_2O	-1.77	-5.088*	-3.460*
LogGDP	-3.187*	-2.976*	-2.599**
LogGDP^2	-3.110*	-2.720*	-2.690**
LogBC	-2.270*	-5.781*	-3.409*
LogHC	-0.87	-2.261*	-2.609**
LogEU	-2.555**	-3.266*	-2.747**

Note: *, ** and *** denotes the statistical significance at 1%, 5% and 10% level, respectively. The critical values can be provided upon request.

Table 4: Panel cointegration tests.

Test	Cointegration test	Model 1	Model 2	Model 3	Model 4
		Statistics	Statistics	Statistics	Statistics
Kao	ADF	-4.8664*	-4.5718*	-5.4752*	-2.9118*
Westerlund ECM	Group-Ʈ	-3.039 **	-3.647*	-3.816*	-2.191
	Group-α	-3.041	-2.299	-1.367	-2.259
	Panel-Ʈ	-7.431*	-5.857***	-8.036*	-2.576
	Panel-α	-3.19	-2.537	-2.501	-0.966
Pedroni	**Within-dimension**				
	Panel v	-1.4744	-0.92	0.5785	-0.7694
	Panel-rho	0.9673	1.0309	-0.048	0.7896
	Panel-PP	-2.1050**	-2.3207*	-3.1835*	-1.6382**
	Panel-ADF	-2.0534**	-1.4641**	-3.9143*	-1.8203**
	Between-dimension				
	Group-rho	1.4945	1.2843	2.1027	1.9027
	Group-PP	-5.5664*	-7.9979*	-1.0869	-0.6852
	Group-ADF	-4.5772*	-5.0052*	-3.9682*	-0.877

Note: *, ** & *** show the rejection of null hypothesis at 1%, 5% and 10% level of significance respectively.

models are strongly significant at 1% level of significance, except energy use in case of model 4. The sign of the coefficients of GDP (GDP2) is positive (negative) in model 1, 2 & 3 while a negative (positive) in model 4. The sign of the coefficients of the human

Table 5: Long-term estimation of DSUR.

Regressors	Model 1 (LogEF)		Model 2 (LogCO2)		Model 3 (LogN2O)		Model 4 (LogCH4)	
	Coeff.	t-statistics	Coeff.	t-statistics	Coeff.	t-statistics	Coeff.	t-statistics
LogGDP	1.4986*	6.24	1.4487*	9.09	-2.6020*	-5.7	7.3345*	4.44
$LogGDP^2$	-0.2025*	-5.75	-0.2148*	-9.21	0.3628*	5.43	-1.3019*	-5.38
LogBC	0.1311*	8.95	-0.1906*	-19.63	-0.4601*	-16.5	0.4542*	4.51
LogHC	-0.2576*	-2.94	-0.2337*	-4.02	0.5295*	3.18	5.8151*	9.65
LogEU	0.5479*	19.73	1.3107*	71.18	0.4005*	7.59	0.1403	0.74

Note: * show the statistically significant at a level of 1%. () show to the dependent variable in each model.

capital (biocapacity) are negative in model 1 & 2 (model 2 & 3) but positive in model 3 & 4 (model 1 & 4). The coefficients of energy use are positive in all four models. These results ratify the existence of inverted U-shaped (EKC hypothesis) not only in model 1 but also in model 2 and 4. As, coefficients of economic growth (square of economic growth) are 1.4986, 1.4487 and 7.3345 (-0.2025, -0.2148 and -1.3019) and statistically significant in model 1, 2 and 4 respectively. More precisely, initially increase in economic growth leads to enhance the environmental degradation through increasing ecological footprint, carbon emission and methane emission in BRICS economies. Moreover, this marginal effect of economic growth will decline after crossing the threshold level and then finally turn to negative. In this way, it confirms that EKC hypothesis exists in model 1, 2 and 4 which is in the line with, As income level increases it enhance the environmental awareness which enforces the populace to follow laws, regulations, and policies related to the environment, resulting it control environmental degradation. It shows that BRICS economies enhancing environmental quality not only focusing on GHGs but also taking into account the ecological footprint. The results of model 3 reveal that there is a U-shaped relationship exist between economic growth and N_2O. This is consistent with [19,20], One possible reason is that in the case of nitrous oxide, BRICS economies have crossed the specific turning point, now 1% increase in economic growth will decrease the N_2O by 2.6020%. Another possible reason is that Technologies affect economic growth; when per capita energy intensity increases it reduces its efficiency, thus, U-shape association occur.

1% increase in biocapacity leads to ecological footprint by 0.1311% and methane emission by 0.4542% while decrease carbon emission by 0.1906% and nitrous oxide by 0.4601%. This effect of biocapacity on ecological footprint and GHGs is according to theoretical expectations. Ulucak and Bilgili (2018) [20] propose that biocapacity increases (decreases) EF for low & middle income (high income) countries. The policymakers of BRICS economies should focus on biocapacity to get sustainable environment because on one side it has the ability to produce biological material on the other side it also absorbs the GHGs emissions. High human development leads to low per capita ecological footprint, so it is expected that human capital has a negative impact on EF. The results reveal that 1% increase in human capital will decrease 0.2576% ecological footprint and 0.2337% carbon emission in panel BRICS countries. Human capital through education and awareness, playing a crucial role to enhance environmental quality [15]. The positive association of human capital with N_2O & CH_4 is the indication that policymakers are focusing only on carbon emission and ignoring other GHGs emission (i.e., N_2O & CH_4) in BRICS economies. Because carbon emission is only one component of pollutant, so to conquer a sustainable environment, the economists and policymakers should take into account all the GHGs emission.

Energy use leads to ecological footprint, carbon emission, nitrous oxide emission and methane emission (GHGs emission) in BRICS economies as it's coefficient values in four models are 0.5479, 1.3107, 0.4005 and 0.1403 respectively (Table 5). Many latest studies support these findings propose that use of energy playing a vital role in environmental degradation. Development in different sectors i.e., service sector, the manufacturing sector, raise the demand for energy. These results infer that economic activities raise energy use in BRICS countries which leads to ecological footprint, carbon emission, nitrous oxide, and methane emission. Hence, policymakers should keep energy use in first priority while making policies related to the environment. On the other side, they should also take into account the naturally replenished energy sources as these sources are clean, green, eco-friendly and affordable over fossil fuels. Fossil fuel energy technologies lead to environmental degradation while replenished energy technologies enhance environmental quality (Sarkodie and Adams, 2018) [5].

RESULT

Long run estimations of the individual country (Table 6) indicate that China is the only country in 5 BRICS countries in which four models validate the hypothesis of EKC. It shows that China is not only concentrating on carbon emission but also takes into account other GHGs (N_2O & CH_4) with ecological footprint. 1% increase in human capital in China significantly decrease ecological footprint by 0.5858%, carbon emission by 0.9595% and methane emission by 2.3860%. The regulatory authorities and policymakers need to concentrate on bio capacity and energy use in China. Because both are degrading the environment significantly. In BRICS economies, South Africa is the only country in which bio capacity is diminishing not only ecological footprint but also GHGs emission significantly. There is an inverted U-shaped association between economic growth and GHGs emission in South Africa and a U-shaped relationship between economic growth and ecological footprint. In addition, a significant negative (positive) association of human capital with ecological footprint and carbon emission (N_2O and CH_4) reveal that policymakers need to take into account other GHGs emission with carbon emission by policy reforms to get their environmental objectives. Russia is the only country in which human capital has a significant negative impact on ecological footprint and GHGs emission in all four models. The policymakers need to increase bio capacity by taking appropriate steps for a sustainable environment. Similarly, India and Brazil also show mix results, they need to increase their bio capacity and focus their human capital to control

Table 6: Country-wise estimations of Fully Modified Least Squares (FMOLS).

	Dep. Var.	LogGDP	LogGDP2	LogBC	LogHC	LogEU
China	EF	0.40849* [3.4419]	-0.0354** [-2.474]	0.4493* [4.5432]	-0.5858* [-3.103]	0.5418* [15.510]
	CO_2	0.5745** [2.1126]	-0.0839** [-2.557]	0.4277** [1.8873]	-0.9595** [-2.218]	1.2275* [15.335]
	$N2_O$	8.8704* [9.2384]	-1.4895* [-12.85]	2.3802* [2.9747]	1.0357 [0.6781]	2.0187* [7.1425]
	CH_4	12.811* [12.972]	-2.073* [-17.403]	4.0638* [4.9380]	-2.3860 [-1.518]	2.5223* [8.6768]
South Africa	EF	10.961 [1.1161]	-1.3633 [-1.059]	-0.1799 [-1.2037]	-0.8042** [-2.838]	0.5813* [3.7292]
	CO_2	-10.840***[-1.955]	1.379*** [1.900]	-0.2020** [-2.394]	-0.0831 [-0.5195]	1.4053* [15.968]
	$N2_O$	-9.727* [-4.688]	1.0149* [3.7350]	-1.519* [-48.102]	2.2072* [36.873]	0.5234* [15.893]
	CH_4	-20.405*[-59.052]	2.5611* [56.587]	-0.107* [-20.509]	1.0854* [108.87]	0.2512* [45.808]
India	EF	1.8950* [4.0455]	-0.3035* [-3.795]	0.5070* [11.285]	-0.525* [-4.4917]	0.7230* [8.0946]
	CO_2	1.5878 [1.2903]	-0.2875 [-1.368]	0.1210 [1.0254]	0.2301 [0.7493]	1.5386* [6.5573]
	$N2_O$	48.882* [73.543]	-8.154* [-71.854]	0.2533* [3.9736]	-6.760* [-40.752]	2.9554* [23.318]
	CH_4	-1.2202 [-0.584]	0.3727 [1.0460]	-0.1113 [-0.556]	0.6496 [1.2472]	-1.6832* [-4.230]
Russia	EF	0.7886*** [1.846]	-0.104*** [-1.944]	1.4094* [17.925]	-0.662* [-11.590]	0.9988* [24.861]
	CO_2	2.1355* [20.999]	-0.275* [-21.562]	-0.1460* [-7.801]	-0.278* [-20.502]	0.9740* [101.84]
	$N2_O$	-28.232* [-12.78]	3.5834* [12.898]	6.9678* [17.136]	-0.4591 [-1.5545]	0.8294* [3.9926]
	CH_4	1.7902* [2.9251]	-0.190** [-2.477]	0.3564* [3.1641]	-0.823* [-10.058]	0.0680 [1.1826]
Brazil	EF	-1.5358** [-2.817]	0.1550** [2.3201]	0.8580 [1.2563]	-0.2056 [-0.2771]	1.088*** [2.0516]
	CO_2	-2.7443* [-5.143]	0.1382** [2.1122]	0.1825 [0.2730]	-0.0955 [-0.1314]	2.8920* [5.5660]
	$N2_O$	154.15** [1.9088]	-19.583** [-1.929]	6.8554 [1.6504]	3.9561 [1.2709]	3.1599** [2.4380]
	CH_4	-54.98* [-51.032]	6.9869* [51.590]	-2.708* [-48.88]	-1.515* [-36.484]	-1.029* [-59.555]

Note: [] represents t-statistics. *, ** & *** represents 1%, 5% and 10% level of significance respectively.

environmental degradation. In all 5 BRICS countries energy sector is significantly degrading environment. If they want to achieve their environmental targets, there is a need to enhance their energy technologies and more depend upon naturally replenished energy sources instead of fossil fuel.

Lastly, the current study checked the causal relationship among variables using Granger causality test and findings are presented in Table 7. From the results, it is clear that bidirectional causality exists between environmental degradation (ecological footprint & GHGs emission) and economic growth (GDP, GDP2) in four models. In model 1; two-way association exists between ecological footprint and human capital, bio capacity and GDP (square of GDP), human capital and GDP (square of GDP), and bio capacity and human capital while one-way causality from energy use to ecological footprint and bio capacity exist, similarly, from human capital to energy use. In model 2; energy use and carbon emission, bio capacity and GDP (GDP2), human capital and GDP (GDP2) are cause to each other while from carbon emission to bio capacity, human capital to carbon emission, GDP (GDP2) to energy use, human capital to bio capacity, energy use to bio capacity, and human capital to energy use, unidirectional association exist. In model 3; there is bidirectional casualty between bio capacity and GDP (GDP2), human capital and GDP (GDP2), and unidirectional causality from energy use to bio capacity, human capital to bio capacity and human capital to energy use. Finally, in model 4; human capital and GDP (GDP2), bio capacity and GDP (GDP2) have a two-way causal relationship and there is one-way causality from human capital and energy use to bio capacity and from human capital to energy use. Overall these causal associations among variables validate the findings of the long-run analysis and suggest that economic growth significantly cause the through ecological footprint and GHGs (CO_2, N_2O, CH_4) emission in BRICS economies. Human capital has a significant impact on environmental degradation (overall) while bio capacity shows significant association only with an ecological footprint which is in support of over previous results. In a panel of BRICS countries, energy significantly causes ecological footprint, carbon emission, nitrous oxide, and methane emission which indicate that energy is the major factor of environmental degradation in these countries. So, it is the current need that regulatory authorizes should review their existing policies related to bio capacity and take measure to encourage biocapacity in BRICS countries. In addition, policymakers of BRICS countries should also pay attention to existing energy policies and reform them to enhance energy efficiency through technology changes or by using alternative energy sources for a sustainable environment in these economies.

CONCLUSION AND POLICY IMPLICATION

This study investigates the impact of human capital and bio capacity on environmental degradation by testing the hypothesis of EKC using ecological footprint, carbon emission, nitrous oxide, and methane emission proxies for environmental degradation in BRICS countries for the period of 1991-2014. Technically, we have adopted five steps methodological procedure which includes a family of latest econometric approaches. First of all, we confirmed cross-sectional dependency by employing Breusch-Pagan LM, Pesaran Scaled LM, Bias-corrected Scaled LM, Pesaran CD tests. Second, we applied panel unit root tests (CIPS, CADF) to verify the stationary property in the data. Third, this study used Kao, Westerlund ECM, and Pedroni approaches to investigate the cointegration between the variables of interest. Fourth, after validation of cointegration, we applied "Dynamic Seemingly Unrelated Regression (DSUR)" for long-run estimations in a panel of BRICS economies and "Fully Modified Least Squares (FMOLS)" for an individual country.

Table 7: Outcomes of Dumitrescu-hurlin panel causality test.

Variables	LogEF	LogGDP	LogGDP²	LogBC	LogHC	LogEU
			Model 1 (Ecological Footprint)			
LogEF	--	6.4422* [3.6021]	6.3884* [3.5557]	4.7430** [2.1362]	5.0963** [2.4410]	5.1105** [2.4410]
LogGDP	6.2701* [3.4536]	--	4.458***[1.8907]	4.324*** [1.7751]	6.1274* [3.3305]	3.4589 [1.0285]
LogGDP²	6.2226* [3.4127]	4.499*** [1.9258]	--	4.256*** [1.7164]	6.1508* [3.3507]	3.4754 [1.0427]
LogBC	3.7666 [1.2940]	9.7475* [6.4535]	9.642* [6.3625]	--	5.8982* [3.1328]	6.2185* [3.4091]
LogHC	4.2087*** [1.6753]	4.1274** [2.1663]	4.6289** [2.0378]	5.8982* [3.1328]	--	3.9547 [1.4563]
LogEU	1.8638 [-0.3475]	7.2216* [4.2745]	7.2900* [4.3334]	3.3900 [0.9691]	4.9319** [2.2992]	--
			Model 2 (CO_2)			
LogCO_2	--	8.6640* [5.5188]	9.0889* [5.8853]	3.0438 [0.6704]	4.8178** [2.2008]	11.008* [7.5411]
LogGDP	5.9967* [3.2178]	--	4.458*** [1.8907]	4.324*** [1.7751]	6.1274* [3.3305]	3.4589 [1.0285]
LogGDP²	5.8433* [3.0854]	4.499*** [1.9258]	--	4.2564** [1.7164]	6.1508* [3.3507]	3.4754 [1.0427]
LogBC	5.0944** [2.4394]	9.7475* [6.4535]	9.6421* [6.3625]	--	5.8982* [3.1328]	6.2185* [3.4091]
LogHC	4.0394 [1.5293]	4.7778** [2.1663]	4.6289** [2.0378]	1.7693 [-0.4289]	--	3.9547 [1.4563]
LogEU	13.220* [9.4497]	7.221* [4.2745]	7.2900* [4.3334]	3.3900 [0.9691]	4.9319** [2.2992]	--
			Model 3 (N_2O)			
LogN_2O	--	4.209*** [1.6758]	4.0626 [1.5493]	3.1754 [0.7839]	7.0721* [4.1455]	7.3240* [4.3628]
LogGDP	4.3264*** [1.7769]	--	4.458*** [1.8907]	4.324*** [1.7751]	6.1274* [3.3305]	3.4589 [1.0285]
LogGDP²	4.4860*** [1.9145]	4.499*** [1.9258]	--	4.256*** [1.7164]	6.1508* [3.3507]	3.4754 [1.0427]
LogBC	4.0708 [1.5564]	9.7475* [6.4535]	9.6421* [6.3625]	--	5.8982* [3.1328]	6.2185* [3.4091]
LogHC	2.4786 [0.1828]	4.7778** [2.1663]	4.6289** [2.0378]	1.7693 [-0.4289]	--	3.9547 [1.4563]
LogEU	2.3105 [0.0378]	7.2216* [4.2745]	7.2900* [4.3334]	3.3900 [0.9691]	4.9319* [2.2992]	--
			Model 4 (CH_4)			
LogCH_4	--	6.7594* [3.8758]	6.6280* [3.7624]	2.6338 [0.3167]	4.7860** [2.1734]	5.9540* [3.1810]
LogGDP	5.1115** [2.4541]	--	4.4583** [1.8907]	4.324*** [1.7751]	6.1274* [3.3305]	3.4589 [1.0285]
LogGDP²	5.1889** [2.5209]	4.499*** [1.9258]	--	4.256*** [1.7164]	6.1508* [3.3507]	3.4754 [1.0427]
LogBC	9.9421* [6.6213]	9.7475* [6.4535]	9.6421* [6.3625]	--	5.8982* [3.1328]	6.2185* [3.4091]
LogHC	3.7540 [1.2831]	4.7778** [2.1663]	4.6289** [2.0378]	1.7693 [-0.4289]	--	3.9547 [1.4563]
LogEU	3.6812 [1.2203]	7.2216 [4.2745]	7.2900* [4.3334]	3.3900 [0.9691]	4.9319** [2.2992]	--
			Note			
Null hypothesis: No causality				* represents 1% level of significance		
1st values represent w-stat				** represents 5% level of significance		
[] represents z-stats				*** represents 10% level of significance		

Lastly, the current study applied a modified version of Granger causality (Dumitrescu and Hurlin Panel Causality) to check the casual association between variables. Our empirical evidence corroborates the existence of cointegration and long-run association among variables. Fascinatingly, our results provide evidence for the presence of inverted U-shaped environmental curve between ecological footprint and economic growth, carbon emission and economic growth, and methane emission and economic growth while U-shaped association between nitrous oxide and economic growth of the panel of BRICS economies. Moreover, biocapacity influences environmental degradation positively through enhancing ecological footprint and methane emission while it enhances the environmental quality by decreasing carbon emission and nitrous oxide emission. Likewise, human capital enhances the environmental quality by lessening the ecological footprint and carbon emission, on the other side it boosts to environmental degradation by increasing nitrous oxide and methane emission in the panel BRICS countries. Lastly, energy consumption infers positive and significantly to environmental degradation (EF, CO_2, N_2O & CH_4) for the long term in the selected panel of countries. Granger causality reveals that bidirectional causality exists between environmental degradation (ecological footprint & GHGs emission) and economic growth (GDP, GDP2), bio capacity and economic growth, human capital and economic growth in four models. From the findings of the current study, we can propose some valuable policy implications to the policymakers. For a sustainable environment, the policymakers of the BRICS countries should pay more attention to human capital and bio capacity during the formulation of a new policy for the future. Because where human capital (*via* education) can enhance economic efficiency it can also decrease GHGs emissions by providing awareness of energy efficiency. Human capital is a very strong pillar of economic development because it decreases energy demand through innovations and technological changes in developing countries (i.e., BRICS). As energy consumption is enhancing the environmental pollution significantly in the selected penal of countries; so, regulatory authorities and policymakers should give attention to enhance the energy efficiency through application of technological changes, by utilizing alternative energy sources (i.e., naturally replenished sources of energy), by encouraging energy-saving projects, and through outsourcing, etc.

CONFLICTS OF INTEREST

None

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