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RESEARCH ARTICLE

Testing EKC hypothesis with energy and sustainable development challenges: a fresh evidence from belt and road initiative economies

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Abstract

Diverse impact of greenhouse gasses (GHGs) over the landscape of environment is generally believed in literature. As CO2 emission acutely leads to GHGs is a major contributor for global warming, it creates a serious pressure on natural resources and ecological settings. Similarly, low-carbon (CO2) economy, plenty of energy resources, and sustainable growth are a big ask for worldwide economies in this era of mechanization. This paper analyzes the Environmental Kuznets Curve (EKC) hypothesis, for Belt and Road Initiative (BRI) economies, to contend the role of mega projects in BRI as an attribute for ecological detriments. The on-hand study engages fresh data information ranging from 1981 to 2016 holding with heterogeneity and cross-sectional dependence as a special deliberation. The calculated outcomes expose that, mean group estimator provides strong evidence and favor the existence of EKC approximately in every region. The long-run influence is measured by pooled mean group estimators, which shows significant outcomes in every region; additionally, the EKC hypothesis affirmed in the long run especially for developed economies. Mega projects, i.e., BRI requisite immense energy sources to accomplishing the enclosed projects efficiently and effectively. The positive association between carbon emission and energy consumption troubled the governments to make policies for restraining the magnitude of carbon emission and controls energy usage for enduring environment to its original position. Next, the valuations depicted the dense recommendations for state administrations in capacity of rigorous level supremacy, trash managing campaigns, renewable energy reliance, and advance for desirable judgments to sterilize the atmosphere.

Keywords Sustainable development · Climate change · Environmental Kuznets Curve · Environment policy · Mega projects · Belt and road initiative

JEL classification P28 · Q56 · R11

Introduction

Recently, the world school of thoughts is revolving around the core "EEE" notion: energy, environment, and economy. Energy is deemed to be a prime necessity for nurturing all developmental operations. It is also experienced that more energy usage in developmental projects may destruct the environment in either way. The detrimental gasses like carbon

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and sulfur emission can degrade the original quality of nature and demolish it severely.

The climate degradation is mostly alleged by greenhouse gasses (GHGs) like sulfur dioxide (SO2), nitrous oxide (NO2), Methane (CH4), and carbon emission (CO2). The participants of the United Nations Framework Convention on Climate Change (UNFCCC) in December 2015 embraced the Paris Agreement (PA) to deal with climate change impression in the participant's territories (United Nations 2015). According to (UNFCCC), 75% of greenhouse gasses are caused by carbon emission (CO2), where CO2 emission is a main promoter of global warming and climate change in the world (IPCC 2014). Similarly, the UNFCCC treaty objectively working (from 1994) in diminishing the effect of (GHGs) on antagonistic zones of ecosystem. Moreover, the subjected parties of UNFCCC has been contracted to retain the rise in worldwide average temperature to well under 2 °C over pre-industrial magnitudes, and to track the endeavors hanging on around under 1.5 °C. The striving intention of the Paris Agreement entails that countries should think wider and extend the time span than what they have been proposed in 5 years Nationally Determined Contributions (NDC). In compliance, economies may treasure its rewards for rebounding from isolated NDCs and visualize where they aspire to be in ecologic and economic sustainability in extended tenure, i.e., in 2050 (Comstock and Hackmann 2018).

Alternatively, several scholars have inspected the linkages between energy consumption and economic growth, which postulates that spill out in energy consumption leads to economic development (Jahangir Alam et al. 2012; Ozcan 2013; Robalino-López et al. 2015). In spite of that, in the studies of (GHGs), frequently investigators are used to focus on carbon emission (i.e., 75% of worldwide GHGs are caused by CO2) as a proxy for environmental degradation and links it with economic growth (Beg et al. 2002; Hossain 2012). However, the rise in economic growth could lead to an increase in energy use, which could then adversely affect environmental settings. In general, emerging, developing, and lower developing countries are the main victims of this disadvantage owing to the lack of clean energy and the low reliance on green investment and trade imbalances. That phenomenon must be addressed and environmental degradation should be controlled through the use of economic growth as a basis.

The Chinese president visited Kazakhstan in 2013, where he contends a world-changing plan that was termed as "One Belt One Road" (OBOR), henceforth altered in 2016 "Belt and Road Initiative" (BRI). This plan put together more than 65 nations to distribute technological changes, optical fiber, energy resource sharing, and modernized infrastructural development within the border and outside the jurisdiction for achieving the goal line of "sustainable development goals" (SDGs) vision 2030. BRI unified the "Silk Road and 21st century Maritime Silk Road" with a shared illustration, where developed, emerging, developing, and lower developing economies are formulated goal posts at mutual-based cooperation under the supervision of China. The primary intent of the Chinese government is to propagate BRI over the globe, and reconfigure distant sectors to prevail manifest economic conclusions and share experiences with other countries on mutual bonding (Du and Zhang 2017; Yu 2017). As per BRI economies, due to big ask for accomplishment of projects the level of energy utilization is augmenting, and consequently directs for growing tendency in carbon emissions depicted in Fig. 1. It entails that there is lack of revival in energy mix (wind energy, hydropower, waste-based energy, biomass energy, solar energy, etc.) and operational effectiveness. Despite the fore stated phenomenon, CO2 emission in BRI economies is still majorly blamed form fossil fuels energy sources. Hence, it is one of the paramount evils for the advancement of entire BRI countries and their feat. Moreover, it is problematic for economies to endure their ecological and economic sustainability much rationally. Being Asia as the most prominent continent which significantly interjects into the world's GDP at a considerable scale. Likewise, China is a country recently labeled as having the second highest GDP growth in the world (The World Bank Group 2017). Indeed, China commenced wave of "Going Global strategy" under the heading of BRI in the Asian, European, and African regions, but it would have massive challenges for their sustainability, environmental worsening, and energy projection in full panel or regional bases.

The view of shifting economic growth with CO2 emission is primarily presented in the 1990s by Kuznets (1955). The idea is trademarked as Environmental Kuznets Curve (EKC), which hypothesized the elemental linkages of income per capita with (CO2) environmental degradation. The EKC postulates that weak economies have massive ecological degradation, but with the passage of time if these weak economies become developed, the environment deprivation also sharply curtailed. This sharp U-turn association between income level and environmental degradation pursues the EKC hypothesis. Thus, for testing EKC hypothesis, an inverted U-shape is formed from income level of an economy and its ecology-degrading indicators. Specifically, the income level of an economy is low when it has an inverse relation with environment indicators (Hafeez et al. 2018). However, when income level of that state turns to be higher, the connection becomes favorable.

According to the EKC hypothesis, economic growth at an early stage can exhaust the natural resources and breed a different kind of harmful waste. So, in the primary stage of economic development the pollution and growth are directly proportional to each other. With the passage of time, modern techniques and technologies are introduced in developed economies; consequently, the industrial waste seems to diminish which also lessens the notion of environmental degradation. Past specialists have proclaimed the connection between economic development and carbon outflow (Ayeche et al.

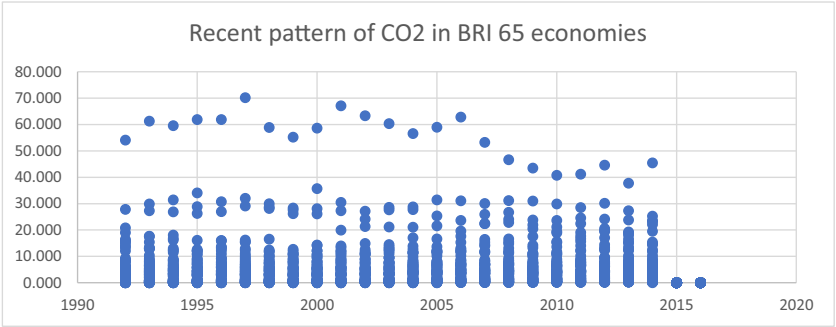

Fig. 1 The BRI 65 economies environmental degradation in a glimpse

2016; Hafeez et al. 2018; Khan et al. 2017; Sarwar et al. 2017; Shahbaz et al. 2017). Hence, it implies that economic growth is guaranteeing a healthy and entirely hygienic environment instead of harming and degrading it.

As energy is a primary determinant for economic development of any frontier-based economy (Armeanu et al. 2017), it also recovers the production and effectiveness in operations of that community. The arrival of a large machinery in industrial sector, a robust increase in the size of population, and an advancement in business operations alarmingly demand of additional energy consumption. Especially in developing countries, the relationship between energy consumption and economic growth is analyzed by variant models like EKC hypothesis. The idea is still vague across the world as researcher put variant postulation in their research outcomes.

The topical investigation is an innovative effort from the past literature in three outlooks: initially, we utilize the example of 65 economies who are taking an interest in the Belt and Road Initiative distributed in full and regional-based panels. To be sure, a few ventures of BRI have finished like; Maldives keen small-scale network by Trina BESS energy stockpiling; Karot Hydropower Station in Pakistan operationalized in 2016; Chinese cargo arrived through the land course at the Gwadar Port; and manufacturing development zones in Kazakhstan, other projects are still moving forward. Aside, we endeavor to pinpoint the significant support of CO2 emissions because of energy utilization, and other subjected factors in BRI may lead for future complications and projections, furthermore suitable measures proposing now and after the perpetuation of such undertakings. Therefore, testing the EKC hypothesis in 65 BRI countries in full and continental regional panel is a supplementary innovation. Subsequently, the outcomes through analysis may lead some policy implications and recommendations to encounter environmental degradation and energy challenges for candidature countries in future.

The central objective of on-hand investigation is to testify the EKC hypothesis for 65 BRI economies to cope the role of mega projects of (BRI) as an attribute to environmental degradation and energy-related challenges and prospects. The on-hand study engages fresh data information ranging from 1981 to 2016, holding with heterogeneity and cross-sectional dependence as a special deliberation. Mean group (MG), common correlated error mean group (CCEMG), augmented mean group (AMG), and pooled mean group (PMG) estimators are applied to account for the slope heterogeneity and cross-sectional dependency issues which provide robust results. The long-run influence is measured by pooled mean group estimators which show significance outcomes in every region; additionally, EKC hypothesis affirmed in the long run especially for developed economies. Hence, the contemporary paper reported some strategical guiding principle for energy, sustainable development, and environmental capacities and combats in approaching time. Moreover, the study would impart policy inferences for 65 states full and regional-based panels. Next, the valuations depict the dense recommendations for country administrations and experts in the capacity of rigorous level supremacy, trash-managing campaigns, renewable energy reliance, and advance for desirable judgments to sterilize the atmosphere.

The rest of the paper is as follows: Section 2 presents literature review, Section 3 provides methodology, Section 4 postulates the empirical outcomes and their interpretations, and Section 5 contends the conclusion, recommendations, and policy implications.

Literature review

Numerous studies validated various environment-degrading indicators especially for testing EKC curve, which is primarily proposed by Grossman and Krueger (1991). Mostly, researchers who have engaged the local indicators for ecological degradation are successful in proving the EKC hypothesis, e.g., Culas (2007), Jayanthakumaran and Liu (2012), Managi and Jena (2008), Orubu and Omotor (2011), and Stern and Common (2001) analyzed the local environmental-degrading indicators; such as deforestation, water pollution, sulfur dioxide, etc. Some researchers also examined the international indicators like Apergis and Ozturk (2015) for Asian countries; Chandran and Tang (2013), Lau et al. (2014), Tan et al. (2014), and Zanin and Marra (2012) analyzed the carbon emission internationally as an environmental-degrading indicator for testing EKC hypothesis.

Principally, the EKC hypothesis is claimed by Grossman and Krueger (1991) for testing air quality and economic development in 42 emerging economies. They proved that level of SO2 augmented with income per capita, but after the particular level of income per capita, it turns down. Next, this study is followed by Selden and Song (1994) for 30 emerging economies and used four proxies for air pollution. Thus, they verified the EKC hypothesis and treasure-inverted U-shaped curve between air pollution and economic growth.

Technological shocks are also analyzed by the researchers to have a role in environmental degradation. Dinda et al. (2000), Kaika and Zervas (2013), Lee and Brahmasrene (2014), Stern (2005), and Stern and Hansen (2016) revealed that technological factors have a significant impact on the level of CO2 emission. They postulated that technological advancement detains CO2 level after the developmental stage. Similarly, List and Gallet (1999) examined panel data with the help of cross-sectional dependence (CD), and test the heterogeneity issue for US states, considering the level of income and CO2 emission from 1929 to 1994. They tested and verified the EKC hypothesis in all states with the assumption that the inverted U-shape ties differ in each state for significance and curved level.

On the other hand, most of the studies also criticize EKC as it only proves testimony for specific environmental-degradation pointers. It is also recorded that most economies do not maintain the data information regarding pollution and environmental degradation, thus due to that reason, these cannot be taken for testing the EKC hypothesis. Liu (2012) postulates that due to redundancy, noise, or lack of completeness in the data, it is not possible to verify the inverse nexus between human health and pollution from industries. Furthermore, the omitted variables partiality and model tolerability is also not specified under consideration of the EKC hypothesis. Aslanidi (2011) and Müller-Fürstenberger and Wagner (2007) intensely disapprove the estimation techniques and methodology of EKC hypothesis.

The criticism on EKC is also supported by Dasgupta et al. (2001), Frankel and Romer (1999), Sadorsky (2010), and Zhang (2011). Researchers argued that industrialization enlarges the machinery operation works that enrich the consumption level of fossil fuels, and resultantly supporting CO2 emission in the atmospheric surroundings. Furthermore, foreign investors are attracted toward developing economies, those who also support CO2 extension. Additionally, Ozturk and Acaravci (2010) and Zhang (2011) postulate that prosperous government citizens prefer to use luxurious lifestyle, which consists of heavy domestic machinery, appliances, and their utilization in routine may also enrich magnitude of energy consumption.

Most of the literature postulates income at the level as well as in quadratic form as an independent variable to verify the environmental degradation and economic growth connection (Grossman and Krueger 1991; Holtz-Eakin and Selden 1995; Panayotou 1993; Roberts and Grimes 1997; Selden and Song 1994; Shafik 1994; Shafik and Bandyopadhyay 1992). These fore stated researchers challenged major econometric complications like multicollinearity, cross-section dependence, non-stationarity, or endogeneity during their work.

By studying the prevailing text, it is located that the prior literature text missing the influences of BRI schemes on sustainable development, outline of energy consumption, and their destructive drifts on atmospheric settings. Today's economies are on a quest to develop an optimum strategy which balances the energy demand with economic growth without affecting the environment. To test such optimum strategy, we use EKC hypothesis and verify the real-time progress. The present study is conducted to corroborate the EKC hypothesis in BRI-listed nations keeping in view the environmental and energy demand challenges to complete the BRI mega projects on time and effectually. The causality of pollutant proxies is tested on six continental region-wide supported by the major economic indicator of Asia, Europe, and African countries respectively.

Methodology and data

All BRI-listed countries (65 economies) are population, as a full panel, and furthermore in Appendix Table 12 characterized into six regions by their corresponding continental data diffusion (The World Bank Group 2017). The dataset information for variables as mentioned in Table 1, is taken from World Development Indicators (WDI) from 1981 to 2016. The study inculcates all 65 BRI economies ranging in Asia, Africa, and Europe. The study employs CO2 emission as dependent variable while GDPPC, EC, and POP are independent variables as mentioned in Table 1.

From the literature, it is concluded that EKC can be tested by using the below equation:

$$\mathrm{ED} = \alpha_{\mathrm{o}} + \alpha_1 \mathrm{IPC} + \alpha_2 \mathrm{IPC}^2 + \alpha_4 X + \mathscr{E}_{\mathrm{it}} \quad (1)$$

where ED is a proxy for environmental-degradation measures (deforestation, water quality, air pollution); X is a vector of variables consisting of population growth and energy consumption, while IPC and IPC2 are the income per capita (GDP) in its level and quadratic form respectively. For normality issues, IPC should be taken in its natural logarithm form. It is generally experienced from the literature that if outcomes of IPC at level shows positive and IPC in its quadratic form is showing negative, it means EKC is being verified. The following equation measures the turning point of per capita income at income level:

$$Y = -\frac{\alpha_1}{2\alpha_2} \quad (2)$$

Table 1 Data elaboration and sources

Variables	Elaboration	WDI codes	Data source
CO2	Carbon emission	Metric tons of CO2 equivalent per capita	WDI
GDP	Economic growth	GDP current US$	WDI
EC	Energy consumption	(Kg of oil equivalent per capita)	WDI
POP	Population growth	Growth rate	WDI

Note: author's tabulation

Furthermore, income per capita in its logarithm form can be calculated by the following equation:

$$Y = e^{-\frac{\alpha_1}{2\alpha_2}} \tag{3}$$

Results and discussion

Descriptive statistics

Table 2 propagates the descriptive statistics of a whole population that is signifying the clear picture of dataset; maximum, minimum, standard deviation, skewness, and kurtosis with normality position of variables under the Jerqa-Bera test.

Cross-sectional dependence (CD) tests

It is a prerequisite for performing CD test to identify the cross-sectional dependence in panel data analysis. Cross-sectional dependence test eliminates the means during computation of correlations. Outcomes of CD test, the data detected non-zero cross-sections with 2080 degrees of freedom.

Null hypothesis for CD Test: No cross-section dependence (correlation) in residuals.

The Pesaran (2004) CD test is calculated as below:

$$\mathrm{CD} = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right) \sim N(0,1) i,j$$
$$= 1,2,3\ldots 65\ldots N \tag{4}$$

$$M = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right)\frac{(T-k)\hat{\rho}_{ij}^2 - E(T-k)\hat{\rho}_{ij}^2}{\mathrm{Var}(T-k)\hat{\rho}_{ij}^2} \tag{5}$$

$\hat{\rho}_{ij}^2$ means residual pairwise correlation sample estimate taken by the simple linear regression equation. The outcomes of the above two equations have contended in the below Table 3 respectively. As per H0 already mentioned above, we cannot reject the absence of cross-section dependence at 1% level.

Residuals cross-sectional dependence

We also applied residuals cross-sections dependence tests to take into cross-dependence in fixed effects or random effects models. One parametric test and two semi-parameter tests are proposed by Frees (2004, 1995), Friedman (1937), Pesaran (2004) respectively with a small time and a large number of cross-sections panel models to estimate residuals cross-sections dependence. Since having 65 BRI economies and 25 years' time span in our analysis. Therefore, we also have applied residuals cross-section dependence tests. The results displayed in Table 4 indicates that cross-section independence hypothesis is rejected by Pesaran and Frees' tests respectively.

Panel unit root tests

Since the existence of cross-section dependence in the data, thus both parametric and non-parametric panel unit root tests have utilized to diagnose the order of integration in BRI economies as full and region-wide respectively. Table 5 illustrates the panel unit root outcomes both BRI-listed countries and region-wide panels.

Panel unit root tests indicate that variables are non-stationary at level while stationary at first difference in mostly all the cases. Whether time trend is inculcated or not, variables are stationary at first difference. Traditional panel unit root tests cannot consider the cross-sectional dependence. Thus, we also applied Panel Unit Root Test in the Presence of Cross-section Dependence (CIPS) test proposed by Pesaran (2007) to counter the cross-sectional dependence. CIPS test results are displayed in Table 6. The outcome of CIPS test validate that all variables are stationary at first difference in BRI-listed economies.

Cointegration tests

The Padroni Cointegration test is employed to know the association between data series. According to Pedroni (2004), test is the better fit for data having a large set of T and N. The test calculates in Table 7, where the seven H0 hypothesis with the assumption of having no cointegration exhibited. If more hypothesis is rejecting the null hypothesis, it means that data has the cointegration and vice versa.

Consulting to the above Table 7, it is clear that four tests are rejecting the null hypothesis. Which means that the on-hand study's variables are cointegrated in the long run, since it was clear from previous diagnostics tests, where the data is stationary at level and cointegrated in the long run also. By keeping

Table 2 Descriptive statistics

Variables	Obs.	Mean	Std. dev.	Min	Max	Skew.	Kurt.	JB
CO2	1538	5.878	8.725	0.000	70.135	3.531	19.574	20,803[a]
LNCO	1538	0.979	1.386	−3.244	4.250	−0.317	2.702	31.566[a]
GDP	1538	7099.397	10,963.71	117.409	88,564.82	3.221	16.835	14,926[a]
LNGDP	1538	7.959	1.392	4.765	11.391	0.118	2.192	45.447[a]
GDP2	1538	1.71E + 08	6.11E + 08	13,785.04	7.8E + 09	7.721	79.169	387,080[a]
LNGDP2	1538	15.919	2.785	9.531	22.782	0.118	2.192	45.447[a]
EC	1538	2266.190	3092.586	0.000	21,959.44	2.911	13.546	9299.6[a]
LNEC	1538	6.235	2.817	0.000	9.996	−1.457	3.831	588.67[a]
POP	1538	5.121	6.737	−5.814	18.344	0.994	2.233	291.23[a]

[a] Represents 1% level of significance

[b] Represents 5% level of significance

[c] Represents 10% level of significance

in view, the fore-stated assumption; the study now implies the long run econometric tests to dig out the EKC phenomenon in the BRI-listed nations. To counter cross-sectional dependence, we have applied panel cointegration developed by Westerlund (2007) and Persyn and Westerlund (2008). Table 8 demonstrates the Westerlund ECM panel cointegration tests and also validates the results from Pedroni residual cointegration test.

Model estimations

Next to CD test, unit root, cointegration, and slop homogeneity tests, we concluded that the study data contains some serious issue of stationarity, cross-sectional dependence, unit root, and cointegration. To grasp over such issue, we employ robust estimators to cope with the fore-stated issues and depict the reliable outcomes.

Common correlated effects mean group (CCEMG) estimator

The study experience heterogeneously splattered and cross-sectionally dependent the on-hand data. Therefore, we employ the method which is introduced by Pesaran (2006) named Common Correlated Effects (CCE). This method is robust to structural breaks and nonstationary unobserved common factors. The econometric equation of CCE model is as follows:

$$Y_{it} = \alpha_{1i} + \beta_i x_{it} + \varphi_i f_t + \varepsilon_{it} \quad (6)$$

Where Y_{it} is dependent, and x_{it} is independent observations. α_{1i} is fixed effect cope the time-invariant heterogeneity across group, and β_i is the slope to country specific within the regression equation, f_t is the unnoticed general aspect with variant factor stuffing φ_i, and ε_{it} is the error term. The above Eq. (6) is amplified with an average of dependent and independent variables as follows:

$$Y_{it} = \alpha_{1i} + \beta_i x_{it} + \delta_i \bar{y}_{it} + \theta_i \bar{x}_{it} + \varphi_i f_t + \varepsilon_{it} \quad (7)$$

Though the regression equation is still facing issues of autocorrelation and heteroscedasticity, thus to address these issues, we use Newey West (Newey et al. 1987) test. When there is the issue of heterogeneity slope coefficient, literature recommends to use MG estimators. The MG estimators for common correlated effect is acquired by computing coefficient in each regression as found by an equation below:

$$\text{CCEMG} = N^{-1} \sum_{i=1}^{N} \hat{\beta}_i \quad (8)$$

In the above Eq. (8), $\hat{\beta}_i$ is the coefficient of estimates.

Augmented mean group (AMG) estimator

To testify the EKC, we use the augmented mean group (AMG) estimator which is introduced by Eberhardt et al. (2010), Eberhardt and Bond (2009). Like common correlated effects mean group (CCEMG) estimator, AMG estimator

Table 3 Cross-sectional dependence tests

Pesaran CD	53.250[a]
Pesaran scaled LM	150.403[a]
Bias-corrected scaled LM	334.230[a]

[a] Represents 1% level of significance

Table 4 Residuals CD tests

Pesaran CD test	6.17[a]
Friedman test	76.872
Frees test	11.518[a]

[a] Represents 1% level of significance

Table 5 Panel unit root test

All (65 countries)								1538 Obs.
	I (0)				I (1)			
	LLC	LM	ADF	PP	LLC	LM	ADF	PP
CO2	13.5089	3.51468	120.987	108.167	3.27837	−1.20883	202.118[a]	934.338[a]
GDP	2.58458	8.14793	37.8551	29.2887	−7.78118[a]	−4.89512[a]	225.821[a]	404.578[a]
GDP2	1.71901	3.88984	81.7554	48.3245	−6.39558[a]	−7.15317[a]	291.148[a]	532.145[a]
EN	32.3681	13.9810	32.8914	25.1369	16.9316	6.20080	116.643	678.687[a]
POP	−20.4650[a]	−15.7619[a]	825.441[a]	246.102[a]	−20.8236[a]	−20.0028[a]	981.024[a]	1314.46[a]
East Asia (2 countries)								50 Obs.
	I (0)				I (1)			
	LLC	LM	ADF	PP	LLC	LM	ADF	PP
CO2	3.04104	−0.62031	7.13663	0.74242	−1.14459	1.55001	7.01107	15.5809[a]
GDP	−1.24186	0.21111	2.39490	1.14615	1.32486	0.65478	2.35024	3.60695
GDP2	−2.21823[a]	−1.08341	6.60414	0.86538	0.81762	−0.03540	2.03563	3.84992
EN	1.44288	−0.83098	5.58088	2.75985	4.28776	0.76975	2.36439	25.6925[a]
POP	−1.16941	−0.97944	9.57806	3.11980	−1.54763[b]	−3.12936[a]	16.9993[a]	26.0750[a]
Southeast Asia (11 countries)								257 Obs.
	I (0)				I (1)			
	LLC	LM	ADF	PP	LLC	LM	ADF	PP
CO2	3.34667	−1.08959	24.4476	19.8970	0.03780	−2.64795[a]	58.2794[a]	180.319[a]
GDP	3.78041	5.59415	2.89366	2.04276	−3.70617[a]	−2.60158[a]	40.2214[a]	65.1615[a]
GDP2	5.94882	5.98659	7.53099	3.40407	−0.95050	−1.25230	35.0414[b]	54.3398[a]
EN	5.86352	−0.08143	20.0164	12.4761	−0.76337	−2.06335[a]	35.4697[a]	144.639[a]
POP	−2.46512[a]	−4.67597[a]	82.3376[a]	73.6470[a]	−7.24913[a]	−9.89184[a]	137.701[a]	309.564[a]
Central Asia (5 countries)								125 Obs.
	I (0)				I (1)			
	LLC	LM	ADF	PP	LLC	LM	ADF	PP
CO2	2.70869	−0.61539	21.8887[a]	23.9875[a]	−0.88546	−1.76693[b]	22.2638[a]	68.5226[a]
GDP	−0.27702	1.38433	3.44299	1.15947	0.05201	−1.12154	14.1780	24.2259[a]
GDP2	−1.68917[b]	−0.13759	10.7337	2.01015	0.36869	−1.37612	15.3231	27.3074[a]
EN	3.06607	0.04147	9.63167	9.07209	−1.49424[a]	−2.25086[a]	21.3873[a]	61.9149[a]
POP	4.42450	4.71536	4.16221	9.02481	−6.69101[a]	−7.20294[a]	64.5115[a]	74.9485[a]
Middle East and North Africa (14 countries)								323 Obs.
	I (0)				I (1)			
	LLC	LM	ADF	PP	LLC	LM	ADF	PP
CO2	9.92162	2.96050	18.9545	9.97156	1.70192	−0.78804	48.3011[a]	200.334[a]
GDP	−0.70400	2.15456	13.0547	10.8008	−3.43525[a]	−4.22207[a]	68.2902[a]	116.819[a]
GDP2	0.35630	1.75914	15.4719	12.4157	−3.43194[a]	−4.78086[a]	74.6495[a]	143.114[a]
EN	10.1465	3.96452	8.28986	10.7361	5.30089	1.64080	30.8086	181.790[a]
POP	−0.73611	−1.54502[c]	39.5050[c]	44.6515[b]	−8.32809[a]	−9.35546[a]	140.121[a]	148.004[a]
South Asia (8 countries)								191 Obs.
	I (0)				I (1)			
	LLC	LM	ADF	PP	LLC	LM	ADF	PP
CO2	2.98301	−1.11796	19.6138	16.5828	7.81597	3.23170	5.86382	114.453[a]
GDP	4.75934	6.97303	0.99141	1.41877	−2.83599[a]	−2.76920[a]	38.2776[a]	66.4987[a]
GDP2	6.92689	8.48643	0.66508	0.29813	0.10581	−1.64674[a]	33.1327[a]	51.1495[a]
EN	4.64473	−0.65778	14.6676	9.48270	1.81478	0.67777	29.8439[a]	98.2571[a]
POP	2.38121	−1.32630[c]	52.3464[a]	9.74268	−8.11074[a]	−7.56445[a]	87.7386[a]	70.2318[a]
Europe (24 countries)								569 Obs.
	I (0)				I (1)			
	LLC	LM	ADF	PP	LLC	LM	ADF	PP
CO2	10.5445	5.57569	26.2510	33.0161	3.37061	−0.14931	50.9493	337.053[a]
GDP	−1.71993[b]	2.76166	16.2213	13.6245	−9.91471[a]	−8.34278[a]	158.796[a]	238.366[a]
GDP2	−0.48872	3.14228	15.5545	12.9708	−12.1572[a]	−11.6966[a]	223.704[a]	327.058[a]
EN	15.0160	4.84818	24.1535	20.6538	16.5131	2.30436	36.8311	246.433[a]
POP	−2.81659[a]	−4.90960[a]	141.071[a]	58.6206	−8.17974[a]	−12.0347[a]	259.066[a]	278.608[a]

[a] Represent 1% level of significance

[b] Represents 5% level of significance

[c] Represents 10% level of significance

analyzes the unobserved common factors (f_t) in Eq. (7). The common correlated effects mean group (CCEMG) estimator practices straight-lined blends of the cross-sectional means of the observed conjoint effects as well as the dependent and independent variables. Afterward, every single measurement is projected by simple regression. Initially, it enhances the equation with period models and types an approximation using the 1st difference in simple regression.

$$\Delta Y_{\mathrm{it}} = \alpha_{1\mathrm{i}} + \beta_{\mathrm{i}}\Delta \mathrm{x}_{\mathrm{it}} + \varphi_{\mathrm{i}} f_{\mathrm{t}} + \sum_{i=2}^{T} \tau_t \mathrm{DUMMY}_t + \varepsilon_{\mathrm{it}} \quad (9)$$

In Eq. (9), τ_t is the coefficient operator for time dummies, and "Δ" is a symbol used for first difference in the equation. Alike CCEMG estimator, the within-group strictures are centered across the panels. The MG estimators are obtained by the way same as used in CCEMG estimators as below:

$$\mathrm{AMG} = N^{-1} \sum_{i=1}^{N} \tilde{\beta}_i \quad (10)$$

In Eq. (10), $\tilde{\beta}_i$ means the coefficient estimates.

$$\Delta Y_{\mathrm{it}} = \alpha_{1\mathrm{i}} + \beta_{\mathrm{i}}\Delta \mathrm{x}_{\mathrm{it}} + \varphi_{\mathrm{i}} f_{\mathrm{t}} + \sum_{i=2}^{T} \tau_t \mathrm{DUMMY}_t + \varepsilon_{\mathrm{it}} \quad (11)$$

Mean group (MG) estimator

In case of panel data with small T and large N, fixed effect, random effect, and generalized method of the moment is contended by Pesaran and Smith (1995) to solve the heteroscedasticity problem in panel data. The MG estimators take the $\bar{x}$ of the coefficient and fix the heteroscedasticity issue in panel data. If T is longer than N, then MG estimator produces persistent outcomes but does not cop the cross-sectional dependence or unobservable linear trend. Our study includes MG estimator's results in the outcomes table to make the comparison with other regression analysis.

Pooled mean group (PMG) estimator

Pesaran et al. (1999) introduced pooled mean group (PMG) estimator to observe the correlation between CO2 emission and income per capita in the long run. The PMG estimator is considered more unswerving than the MG estimator as the PMG estimator inculcate both pooling and averaging of coefficients. The PMG method lets the difference in intercepts, error variance, and short-run coefficients but impose sameness in the coefficient in the long-run coefficients.

Table 6 CIPS test results

	Constant/ trend	Critical values		
	CIPS	10%	5%	1%
CO2	−5.770*	−2.52	−2.58	−2.69
GDP	−6.420*	−2.52	−2.58	−2.69
GDP2	−6.420*	−2.52	−2.58	−2.69
EN	−6.036*	−2.52	−2.58	−2.69
POP	−6.381*	−2.52	−2.58	−2.69

*Indicates the significance level at 1%

The panel ARDL (autoregressive distributive lag) model is employed by the PMG estimator to expose the correlation in the long run. The model modifies the issues of stationarity and cointegration among variables in a series. The econometric model for PMG estimators is mentioned below:

$$Y_{\mathrm{it}} = \sum_{j=1}^{p} \lambda_{ij} y_{it-j} + \sum_{j=0}^{q} \tau_{ij}' x_{it-j} + \mu_i + u_{it} \quad (12)$$

$$u_{\mathrm{it}} = \rho_i' f_{it} + \varepsilon_{it} \quad (13)$$

where u_{it} shows the fixed effect estimators, x_{it} postulates the 1xk vectors of independent variables for each cross-section, τ_{ij} is the coefficient vector (kx1), f_{it} is the unobservable common shocks, and λ_{ij} contend the lagged variable coefficient respectively. The above Eqs. (12) and (13) undertakes that variance of the explanatory variables that are not associated with the error term in a regression equation, and the unobserved common factors have zero mean. The Eq. (12) can also be expressed in the following manner:

$$\Delta Y_{\mathrm{it}} = \phi Y_{\mathrm{it-1}} + \beta' x_{\mathrm{it}} + \sum_{j=1}^{p-1} \lambda_{\mathrm{ij}}^{*} \Delta y_{\mathrm{it-j}} + \sum_{j=0}^{q-1} \delta_{\mathrm{ij}}^{*\prime} \Delta x_{\mathrm{it-j}} + \mu_{\mathrm{i}} + u_{\mathrm{it}} \quad (14)$$

$\delta_{ij}^{*\prime}$ is the vector of coefficients;

$$\phi_{\mathrm{i}} = -\left(1 - \sum_{\mathrm{j}=1}^{\mathrm{p}} \lambda_{\mathrm{ij}}\right) \quad (15)$$

$$\beta_{\mathrm{i}} = \sum_{j=0}^{q} \delta_{ij} \quad (16)$$

The PMG estimator has another parameter that inflicts additional constraint upon short-run equality known as DFE (dynamic fixed-effect). Our work postulates both the parameter in result upon all the categorized groups.

Table 7 Pedroni Residual Cointegration Test

	Statistic	Prob.	Weighted statistic	Prob.
Panel v-statistic	−3.405052	0.9997	−4.924727	1.0000
Panel rho-statistic	2.488124	0.9936	4.896707	1.0000
Panel PP-statistic	−15.12560	0.0000[a]	−11.21890	0.0000[a]
Panel ADF-statistic	−14.88421	0.0000[a]	−12.19740	0.0000[a]
Group rho-statistic	6.897642	1.0000		
Group PP-statistic	−14.30724	0.0000[a]		
Group ADF-statistic	−13.97561	0.0000[a]		

[a] Represents 1% level of significance

[b] Represents 5% level of significance

[c] Represents 10% level of significance

Table 8 Westerlund ECM panel cointegration tests

Statistic	Value	Z value	*p* value
Gt	−4.711*	−2.097	0.082
Ga	−2.247	8.653	1.0000
Pt	−9.063*	−3.134	0.099
Pa	−2.878	3.568	1.0000

*Shows 10% level of significance

Estimation results

Panel estimation results

Table 9 postulates the outcomes of variant PMG models in the shape of common correlated effects mean group (CCEMG) estimator, augmented mean group (AMG) estimator, and mean group (MG) estimator respectively with and without time trend. As per the fore stated mentioned PMG different estimators, the outcomes contend several results denoted in Table 9.

The MG estimator gives powerless confirmation for the EKC theory without a period drift as the coefficient of the income per capita variable is critical just at 10%. Besides, it recommends a defining moment for income per capita, which is unreasonable. The determination with a period incline unequivocally rejects the EKC as both the income per capita and income per capita-squared coefficients are immaterial. Like the AMG estimator, the MG estimator moreover gauges a very noteworthy coefficient for energy utilization. Be that as it may, it ought to be noticed that the MG estimator does not take cross-sectional reliance into account. The CCEMG estimator moreover gives blended outcomes. It emphatically rejects the EKC speculation if a period slant is incorporated. Nonetheless, in the wake of evacuating the time drift it provides feeble confirmation for the theory.

The AMG estimator I utilize an elective determination of the AMG estimator that increases the relapse by forcing a unit coefficient on each gathering part notwithstanding the customary AMG estimator. As per the reversion comes about, the AMG estimator emphatically approves the EKC speculation with exceptionally colossal income per capita (GDP) what is more, wage per capita-squared coefficients under the two details. Energy utilization is additionally unusually huge under all determinations inferring that a 1% expansion in energy utilization per capita increments CO2 discharges by 0.7–0.8%. Population development has a noteworthy positive coefficient under just AMG with force alternative and a period incline to infer that a 1% expansion in populace development builds CO2 emanations by 0.4%.

Table 9 exposes the aftereffects of the PMG estimators. As needs are, the PMG estimators approve the EKC theory with profoundly huge coefficients. The most striking distinction between the PMG and other gauges is the long-run flexibility of energy utilization. The coefficient of energy utilization is little contrasted with the CCEMG, MG, and AMG gauges through the short-run factors are close. It infers the impact of energy utilization on natural debasement step by step diminishes over the long haul. Another distinction is in the coefficient of population growth. The coefficient of population development which is inevitable and inconsequential in the short run is negative and exceptionally noteworthy over the long haul. This coefficient indicates out a fascinating outcome proposing that contamination will diminish as long-term populace development increments.

Table 10 elaborated in addition, the long run and short run estimation across the full and regional-based panels. The results affirmed the estimations through the CCEMG, MG, and AMG, where the EKC hypothesis strongly confirmed at long run only in 24 European nations. On contrary, short-run results of (ECT) negative and significance value is a screen for long-run nexus among the variables. Meanwhile, in short-run MENA and central Asian countries depicted the EKC confirmation across their panels.

Cross-sectional dependence tests hypothesis is defined as "The null hypothesis is either strict cross-sectional independence (Pesaran 2004) or a weak cross-sectional dependence (Pesaran 2015)." The CD tests and weak CD test in Table 11 employed in addition to re-affirm the dependence among the full and regional-based panel for results accuracy and strong policy implications.

Conclusion, recommendations, and policy implications

The central objective of on-hand investigation is to testify the EKC hypothesis for 65 BRI economies to cope the role of mega projects of (BRI) as an attribute to environmental degradation and energy-related challenges and prospects. The on-hand study engages fresh data information ranging from 1981 to 2016 holding with heterogeneity and cross-sectional dependence as a special deliberation. From the literature, it is experienced that very few studies count all the panel data diagnostics to place reliability. Our study uses stepwise econometric models to cope the panel data diagnostics issues (mostly faceted when T > N). Mean group (MG), common correlated error mean group (CCEMG), augmented mean group (AMG), and pooled mean group (PMG) estimators are applied to account for the slope heterogeneity and cross-sectional dependency issues which provide robust results. The long-run influence is measured by pooled mean group estimators which shows significance outcomes in every region; additionally, EKC hypothesis affirmed in the long run especially for developed economies.

The econometric analysis yields various outcomes for every category of whole-populated distribution. From Table 9, we see that only MG and AGM-I verify the existence of EKC notion in

Table 9 MG, CCEMG, and AMG estimators results

All (65 countries)								1538 Obs.
	MG	MG	CCEMG	CCEMG	AMG	AMG	AMG-1	AMG-1
GDP	.00003 (.00008)	.00023[b] (.0001)	.0001 (.0001)	.00002 (.0001)	.000162[c] (.000097)	.000118[c] (.00009)	.001319[a] (.000383)	.00034 (.00025)
GDP2	−4.7e-09 (3.3e-08)	−2.2e-08 (3.e-08)	2.58e-08 (4.0e-08)	3.82e-08 (4.70e-08)	1.99e-08 (3.06e-08)	2.58e-08 (3.30e-08)	−4.66e-07[b] (2.29e-07)	−5.66e-08 (1.20e-07)
EN	.0019[a] (.0001)	.0018[a] (.00013)	.0016[a] (.0002)	.0016[a] (.0002)	.001717[a] (.000144)	.001664 (.000142)	.00059[b] (.00027)	.00063[a] (.00023)
POP	−3.815 (2.646)	2.171 (1.647)	−.1222 (1.3974)	.1888 (1.8480)	.449327 (.540874)	1.51194 (1.5580)	−1.25755 (1.74014)	2.14245 (1.7302)
Const.	59.66 (39.82)	−32.97(25.42)	−.7805 (20.101)	.6740 (27.297)	−9.34354 (8.59547)	−24.2002 (24.5421)	18.3363 (26.1938)	−32.3466 (27.1129)
Trend		0.431		0.323		0.292		0.431
EKC prove	No	Yes	No	No	No	No	Yes	No
No. of trend		28		21		19		28
RMSE	1.1743	1.0167	0.6766	0.6433	0.9026	0.8264	1.1069	0.9656
East Asia (2 countries)								50 Obs.
	MG	MG	CCEMG	CCEMG	AMG	AMG	AMG-1	AMG-1
GDP	−.0005 (.0005)	−.0006 (.0010)	−.0007[a] (2.4e-10)	−.0001[a] (1.3e-10)	.00117 (.00113)	.00072 (.00034)	.00078[a] (.00024)	.00010 (.00013)
GDP2	2.2e-07 (2.2e-07)	2.43e-07 (2.e-07)	7.2e-08[a] (4.6e-14)	2.5e-08[a] (2.5e-14)	1.21e-09 (3.41e-09)	6.71e-08 (9.64e-08)	9.51e-08 (7.14e-08)	1.80e-07 (1.28e-07)
EN	.0041[a] (.0006)	.0040[a] (.0007)	.0036[a] (5.1e-10)	.0038[a] (1.1e-09)	.00327[a] (.00018)	.003291[a] (.00004)	.00344[a] (.00026)	.00358[a] (.00030)
POP	−.0863 (.1308)	−.1026 (.0840)	−.0066[a] (4.0e-08)	−.0186[a] (4.3e-08)	.08716[a] (.02609)	.099907 (.11357)	.25727 (.26825)	.31455 (.26411)
Const.	−.8153 (.5028)	−.8346 (.5451)	3.47e-07 (.1662)	3.4e-07 (.1350)	−.48432 (.18283)	−.54341 b (.25629)	−.45195 (.45994)	−.52371 (.51232)
Trend		0.500		0.000		1		0.000
EKC prove	No	No	No	No	No	No	No	No
No. of trend		1		0		2		0
RMSE	0.6392	0.6345	0.0526	0.0471	0.2449	0.1688	0.4728	0.4530
Southeast Asia (11 countries)								257 Obs.
	MG	MG	CCEMG	CCEMG	AMG	AMG	AMG-1	AMG-1
GDP	.0003 (.0002)	.0006[c] (.0003)	.0001 (.0002)	−.00003 (.0002)	.00016 (.00020)	.00022 (.00017)	−.00066 (.00099)	−.00158[b] (.00072)
GDP2	−1.8e-07 (1.1e-07)	−2.0e-07[c] (1.e-07)	6.22e-08 (8.8e-08)	9.18e-08 (8.54e-08)	−4.88e-08 (1.07e-07)	−2.48e-08 (1.19e-07)	3.70e-07 (5.11e-07)	5.78e-07 (4.47e-07)
EN	.0014[a] (.0002)	.0012[a] (.0003)	.0008[b] (.0003)	.0008[b] (.0003)	.00136[a] (.00028)	.00114 (.00040)	.00079[b] (.00037)	.00038 (.00062)
POP	−1.5871 (1.518)	7.9637 (5.671)	1.5834[b] (.8065)	2.8478 (4.0046)	.73546[c] (.42609)	4.5418 (2.4485)	1.1969 (2.1030)	10.5821[c] (5.8228)
Const.	25.678 (24.415)	−122.45 (83.962)	−25.501[c] (14.015)	−37.0607 (59.9966)	−10.8977 (7.7853)	−68.3349 (35.3022)	−23.952 (35.677)	−165.016[c] (89.630)
Trend		0.364		0.182		0.273		0.636
EKC prove	No	Yes	No	No	No	No	No	No
No. of trend		4		2		3		7
RMSE	0.9861	0.7411	0.5266	0.4953	0.5732	0.5504	0.9083	0.7075
Central Asia (5 countries)								125 Obs.
	MG	MG	CCEMG	CCEMG	AMG	AMG	AMG-1	AMG-1
GDP	.0003[a] (.00007)	−.00006 (.0001)	−.0002 (.0003)	−.0002 (.0003)	−.00032 (.00053)	−.00050 (.00037)	−.00080[c] (.00046)	−.00093[b] (.00043)
GDP2	−1.05e-07 (8.26e-08)	−3.18e-08 (7.24e-08)	2.27e-08 (1.7e-07)	−1.90e-08 (1.72e-07)	1.42e-07 (1.81e-07)	7.74e-08 (6.15e-08)	4.96e-07[b] (2.39e-07)	4.82e-07[c] (2.85e-07)

Table 9 (continued)

EN	.0022[a] (.0003)	.0024[a] (.0003)	.0018[a] (.0004)	.0017[a] (.0004)	.00233 (.00025)	.002322 (.00031)	.00121 (.00084)	.00133[b] (.00063)
POP	−1.3602 (1.1695)	−5.8596 (7.279)	2.5111 (1.6446)	−.3054 (.4982)	−.65499 (.62980)	3.97997 (10.532)	−1.2056[c] (.66531)	5.5240 (6.1072)
Const.	21.767 (17.731)	91.4745 (111.29)	−39.054 (24.496)	1.8718 (8.6269)	11.6400 (9.7645)	−72.3625 (170.158)	20.804[b] (10.340)	−88.531 (96.653)
Trend		0.400		0.000		0.600		0.200
EKC prove	Yes	No	No	No	No	No	No	No
No. of trend		2		0		3		1
RMSE	0.3252	0.3151	0.1453	0.1425	0.2473	0.2207	0.2810	0.2666
Middle East and North Africa (14 countries)								323 Obs.
	MG	MG	CCEMG	CCEMG	AMG	AMG	AMG-1	AMG-1
GDP	−.0004[b] (.0001)	−.0002 (.0002)	−.0004 (.0004)	−.0004 (.0004)	−.00001 (.00025)	−.00011 (.00022)	.00130[b] (.00058)	.00042 (.00028)
GDP2	9.39e-08 (5.92e-08)	5.64e-08 (4.78e-08)	1.19e-07 (1.1e-07)	4.91e-08 (4.45e-08)	6.42e-08 (4.80e-08)	4.02e-08 (4.43e-08)	−2.22e-07 (1.36e-07)	−1.05e-07 (8.76e-08)
EN	.0024[a] (.0002)	.0022[a] (.0002)	.0018[a] (.0004)	.0017[a] (.0004)	.00199 (.00022)	.00193 (.00023)	.00141[a] (.00037)	.00155[a] (.00028)
POP	−.7695 (.9353)	.4474 (.8842)	.4507 (1.9360)	−.0751 (1.8736)	.16545 (.88012)	.16231 (.92539)	.33163 (.84234)	.27528 (.93197)
Const.	5.7288[b] (2.5676)	−10.582 (9.7321)	−21.145 (26.054)	−17.1853 (26.4383)	−8.0635 (11.6267)	−4.8980 (11.087)	−11.803 (9.3717)	−5.2308 (11.508)
Trend		0.357		0.000		0.214		0.286
EKC prove	No	No	No	No	No	No	No	No
No. of trend		5		0		3		4
RMSE	2.0870	1.8368	1.3500	1.2717	1.6542	1.5304	1.9696	1.7497
South Asia (8 countries)								191 Obs.
	MG	MG	CCEMG	CCEMG	AMG	AMG	AMG-1	AMG-1
GDP	.0003 (.0002)	.0005 (.0004)	−.0002 (.0003)	−.0002 (.0003)	.00021[b] (.00009)	.00007 (.00022)	.00131[a] (.00036)	.00087[c] (.00052)
GDP2	8.59e-08 (1.57e-07)	2.56e-08 (2.07e-07)	−3.06e − 10 (7.8e-08)	−1.52e-08 (8.98e-08)	−1.93e-08 (4.01e-08)	5.24e-08 (1.09e-07)	−7.98e-07[a] (2.86e-07)	−5.73e-07[b] (2.52e-07)
EN	.0009[b] (.0004)	.0009[b] (.0004)	.0015[a] (.0004)	.0014[a] (.0003)	.00090[b] (.00037)	.00094[b] (.00037)	−.00069 (.00046)	−.00071 (.00045)
POP	.2507 (.2789)	.1356 (.1693)	.3194 (.3302)	.0193 (.0377)	.32288 (.33304)	−.06382 (.06047)	.4089 (.4411)	−.45765 (.4210)
Const.	−4.8765 (4.5748)	−2.9717 (2.7361)	−5.4266 (5.4904)	−.4809 (.5361)	−5.4701 (5.5442)	1.11973 (1.00352)	−7.2196 (7.2546)	7.1397 (7.1442)
Trend		0.500		0.125		0.375		0.250
EKC prove	No	No	No	No	No	No	Yes	Yes
No. of trend		4		1		3		2
RMSE	0.2060	0.2035	0.0318	0.0290	0.0469	0.0434	0.1440	0.1383
Europe (24 countries)								569 Obs.
	MG	MG	CCEMG	CCEMG	AMG	AMG	AMG-1	AMG-1
GDP	−.00004 (.00008)	.0002[b] (.0001)	.0001 (.0002)	.0001 (.0001)	.00002 (.00006)	.00007 (.00005)	.00053[a] (.00015)	.00050[b] (.00024)
GDP2	5.14e-09 (1.48e-08)	−7.54e-09 (1.67e-08)	1.96e-09 (2.6e-08)	2.15e-08 (3.25e-08)	1.93e-08 (1.56e-08)	1.04e-08 (1.06e-08)	−3.40e-08 (2.90e-08)	−3.39e-08 (3.83e-08)
EN	.0021[a] (.0001)	.0019[a] (.0001)	.0017[a] (.0003)	.0017[a] (.0002)	.00161[a] (.00030)	.00155 (.00029)	−.00001 (.00025)	−.00010 (.00029)
POP	−9.1617 (7.1779)	3.2488 (3.3443)	1.7780 (2.3310)	7.4843 (6.0870)	.97461 (1.58162)	2.5654 (3.2473)	−1.2242 (2.2861)	2.2130 (3.0447)
Const.	146.864 (107.873)	−46.6365 (53.830)	−32.7211 (36.187)	−121.415 (103.936)	−14.730 (24.872)	−33.9518 (49.7234)	22.339 (34.2413)	−24.044 (45.967)
Trend		0.500		0.417		0.500		0.458
EKC prove	No	Yes	No	No	No	No	No	No
No. of trend		12		10		12		11
RMSE	0.8603	0.7467	0.2899	0.2608	0.3535	0.3106	0.5997	0.5299

[a] Represents 1% level of significance

[b] Represents 5% level of significance

[c] Represents 10% level of significance

Table 10 PMG estimator results

	Time	GDP	GDP2	EN	POP	Const.	ECT
All	Short run	−.00003[a] (9.62e-06)	1.62e-09[a] (5.91e-10)	.00247[a] (.00001)	−.02781[b] (.01267)		
	Long run	−.00009 (.00007)	7.02e-08[b] (3.37e-08)	.00092[a] (.00016)	−4.0284 (3.7053)	−.04731 (.13035)	−.26085[a] (.0584)
East Asia	Short run	.00005 (.00032)	−9.18e-09 (4.49e-08)	.00291[a] (.00046)	−.0306 (.1641)		
	Long run	−.00121 (.00159)	4.00e-07 (3.91e-07)	.00231+ (2.64e-06)	−.09789 (.11091)	.18624 (.17996)	−.36584[a] (.02890)
Southeast Asia	Short run	.00009[a] (.00003)	−5.17e-10 (8.47e-10)	.00256[a] (.00006)	.01234 (.01947)		
	Long run	−.00005 (.00018)	6.53e-08 (1.14e-07)	.00020 (.00042)	1.9798 (7.5961)	−.71582[c] (.42474)	−.47991[a] (.09725)
Central Asia	Short run	.00041[a] (.00004)	−5.73e08[a] (7.57e-09)	.00244[a] (.00003)	.04834[b] (.01899)		
	Long run	.00005 (.00036)	−3.34e-07 (2.27e-07)	.00049 (.00084)	−5.8453 (5.4398)	−.49653[c] (.27552)	−.70408[a] (.19002)
Middle East and North Africa	Short run	−.00002 (.00002)	−2.75e-09[a] (6.98e-10)	.00286[a] (.00008)	−.02752 (.02619)		
	Long run	−.00041[b] (.00016)	2.12e-09 (4.01e-08)	.00063 (.00042)	1.2024 (2.8036)	.60440 (.48019)	−.56665[a] (.09144)
South Asia	Short run	.00109 (.00070)	−6.39e-08 (9.08e-08)	.00258[a] (.00092)	.09692 (.08169)		
	Long run	.00035 (.00031)	8.03e-08 (1.90e-07)	.00104[b] (.00042)	−.12500 (.12651)	−.05493[c] (.03160)	−.06340[c] (.03760)
Europe	Short run	−.00006[a] (.00002)	1.42e-09 (1.43e-09)	.00216[a] (.00005)	−.00915 (.02256)		
	Long run	−.00014 (.00012)	3.79e-08[c] (2.03e-08)	.00099[a] (.00020)	−13.0981[b] (6.7095)	−.07314 (.39828)	−.14655 (.13091)

[a] Represents 1% level of significance

[b] Represents 5% level of significance

[c] Represents 10% level of significance

an overall population of the BRI-listed economies. No econometric panel data estimator verifies the existence of EKC hypothesis in East Asia and Southeast Asia except MG estimator. Central Asia also has the same situation as Southeast Asia and the Middle East and North Africa which consists of 14 countries also not in congruence with EKC hypothesis. The existence of EKC hypothesis is contended in South Asia by AMG and AMG estimators respectively. It means that South Asia (which consists of eight emerging economies) is significantly responding to environmental degradation in the long run, the BRI mega projects in the said region may degrade the environment adversely in impending time.

The positive association between carbon emission and energy consumption annoy the government to make policies to curb carbon emission and control the energy usage to sustain the prudent environment to its original position. Hence, the contemporary paper reported some strategical-guiding principle for energy, sustainable development, and environmental capacities and combats in approaching time. Moreover, the study would impart policy inferences for 65 states full and regional-based panels. Next, the valuations depict the dense recommendations for country administrations and experts in the capacity of rigorous level supremacy, trash managing campaigns, renewable energy reliance, and advance for desirable judgments to sterilize the atmosphere.

At the international level, many measures have been taken by developed economies like China took nationally determined contribution (NDC) to cop over the carbon emission control, Emissions Reduction Purchase Agreement (ERPA) by Kyoto Protocol, Paris Agreement (2015) which includes 195 economies of the whole world. It is experienced that the economies where environmental control agreements prevail, the EKC hypothesis holds there. According to the Association of Southeast Asian Nations (ASEAN) report, the energy demand for Asian regions augmented up to 60% from the last 15 years. Meanwhile, energy-associated CO2 emission also perturb dwellers health at risk even conflicting to Paris Climate Change Agreement. The International Energy Agency (IEA 2017) contend that the volume of energy augmented 1.8% in 2015. However, this phenomenon postulates that Asian countries still in a low spot in the energy efficiency scoring from European and US-based nations.

All in all, an improvement in GDP for every capita as procuring would encourage the general population to get into the more incredible and eco-accommodating comforts. The exaggerated expanding pattern of ozone depleting substances in scene coordinates that these states are constrained to observe toward supportable economic actions and reasonable condition. Similarly, BRI full and territorial savvy policymakers, specialists, and governments prescribed to highlighting while in transit to green awareness in atmosphere escalated and natural-based undertakings. Therefore, the vital notice should be satisfied to eco-accommodating viewpoints during end in decisions about the realistically sustainable development.

Table 11 CD test and weak CD test by Pesaran (2004, 2015)

	Test	CO2	GDP	GDP2	EN	POP
All	Pesaran 2004	141.11[a]	196.69[a]	191.30[a]	0	2.42[a]
	Pesaran 2015	122.733[a]	186.531[a]	182.352[a]	112.675[a]	5.642[a]
East Asia	Pesaran 2004	4.14[a]	4.87[a]	4.68[a]	4.33[a]	−1.53
	Pesaran 2015	4.779[a]	4.940[a]	4.785[a]	4.866[a]	−2.363[b]
Southeast Asia	Pesaran 2004	25.43[a]	32.67[a]	33.34[a]	0	3.27[a]
	Pesaran 2015	22.733[a]	31.847[a]	31.216[a]	17.362[a]	3.524[a]
Central Asia	Pesaran 2004	10.18[a]	15.21[a]	15.00[a]	9.68[a]	3.39[a]
	Pesaran 2015	14.877[a]	15.453[a]	15.268[a]	15.015[a]	13.852[a]
Middle East and North Africa	Pesaran 2004	34.17[a]	38.81[a]	32.43[a]	32.73[a]	0.31
	Pesaran 2015	26.573[a]	30.123[a]	30.377[a]	26.376[a]	−1.565
South Asia	Pesaran 2004	22.38[a]	24.33[a]	25.39[a]	0	−2.64[a]
	Pesaran 2015	21.562[a]	24.452[a]	24.223[a]	11.533[a]	−0.925
Europe	Pesaran 2004	54.10[a]	75.95[a]	78.12[a]	55.76[a]	−1.31
	Pesaran 2015	42.390[a]	75.278[a]	74.504[a]	43.056[a]	−0.699

[a] Represents 1% level of significance

[b] Represents 5% level of significance

[c] Represents 10% level of significance

The impending work emphasis on supplies of all energy forms by promoting sustainable energy policies that limb economic development and environmental fortification in the global context. Furthermore, research on renewable energy and technology is needed to predict future energy supplies and alleviate their environmental influence. The global energy challenges also need to be addressed by future research work with IEA member and non-members nations.

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Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflict of interest.

Ethical statement The manuscript has not been previously published, is not currently submitted for review to any other journal and will not be submitted elsewhere before a decision is made by this journal.

Appendix

Table 12 Countries list by their regional wise line up with BRI

No.	Central Asia	No.	East Asia	No.	Southeast Asia	No.	South Asia	No.	Middle East and North Africa (MENA)	No.	Europe
1	Kazakhstan	1	China	1	Brunei Darussalam	1	Afghanistan	1	Bahrain	1	Albania
2	Kyrgyz Republic	2	Mongolia	2	Cambodia	2	Bangladesh	2	Egypt, Arab Rep.	2	Armenia
3	Tajikistan	3		3	Indonesia	3	Bhutan	3	Iran, Islamic Rep.	3	Azerbaijan
4	Turkmenistan	4		4	Lao PDR	4	India	4	Iraq	4	Belarus
5	Uzbekistan	5		5	Malaysia	5	Maldives	5	Iraq	5	Bosnia and Herzegovina
				6	Myanmar	6	Nepal	6	Jordan	6	Bulgaria
				7	Philippines	7	Pakistan	7	Kuwait	7	Croatia
				8	Singapore	8	Sri Lanka	8	Lebanon	8	Czech Republic
				9	Thailand			9	Oman	9	Estonia
				10	Timor-Leste			10	Qatar	10	Georgia
				11	Vietnam			11	Saudi Arabia	11	Hungary
								12	Syrian Arab Republic	12	Latvia
								13	United Arab Emirates	13	Lithuania
								14	Yemen, Rep.	14	Macedonia, FYR
										15	Moldova
										16	Montenegro
										17	Poland
										18	Romania
										19	Russian Federation
										20	Serbia
										21	Slovak Republic
										22	Slovenia
										23	Turkey
										24	Ukraine

Source: World Bank Classification (http://data.worldbank.org/about/country-classifications/country-and-lending-groups)

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