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Industrial structure, energy intensity and environmental efficiency across developed and developing economies: The intermediary role of primary, secondary and tertiary industry

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ABSTRACT

This article contributes to the existing literature by examining the nonlinear relationship between industrial structure, energy intensity and environmental efficiency across developed and developing countries by utilizing three sectors of industry i.e., Primary, Secondary and Tertiary industry. Panel data includes 64 Belt and Road Initiative (BRI) from 2000 to 2017, which are further divided into two groups of developed and developing countries. SBM-DEA model is employed to measure the environmental efficiency. Random effect (RE) and Fixed effect (FE) models are employed as basic estimating techniques, while IV-GMM (Generalized Method of Moments) is utilized as robust estimator to handle endogeneity problem. The results of SBM-DEA model show that the environmental efficiency of BRI countries has deteriorated over the years. However, developed countries have the higher average environmental efficiency than developing countries. The results further show that all three sectors of industry deteriorate environmental efficiency. However, the negative impact of secondary industry on environment is more severe than primary and tertiary industry particularly across developing countries. Furthermore, a nonlinear U-shaped curve is confirmed only between secondary industry and environmental efficiency across developed countries. Our findings suggest that adopting industrial agglomeration approach and restructuring energy system can improve environmental efficiency.

1. Introduction

In the last several decades, the world economy witnessed immense industrialization across developed and developing countries. Industrialization propelled an economy towards social and economic modernization. Industrial growth uplifts the economic condition of a country, increases urbanization, and paves the way for modernization. However, modernization due to the industrial revolution comes at the expense of environmental pollution. Industrialization promotes the demand for energy consumption, especially nonrenewable fuel energy such as oil, natural gas, and coal which exude large amounts of greenhouse gases (GHGs) particularly carbon dioxide [1].

China started Belt and Road initiative (BRI) in 2013 to enhance industrial cooperation and expand trade activities with the countries along Belt and Road route. BRI project includes the construction of economic corridors and the establishment of industrial zones. Belt and Road economies have a total population of 4.4 billion, and their GDP comprises one-third of world's economy. BRI is considered as the new driving force behind industrialization in developing countries along the BRI route [2]. Moreover, China intends to invest heavily in various industrial sectors of Belt and Road countries. Just in two years of 2016 and 2017, Chine has injected US$ 29bn in the industrial sector of BRI countries as a foreign FDI [3]. This will result in the growth of industrial sector, which will be beneficial for the economy; however, it might also affect the natural environment. The World Bank data shows that, the CO_2 emissions of BRI countries has increase more than 100% in the last two

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Abbreviations		Nomenclature	
BRI	Belt and Road Initiative	*Ln*	Natural logarithm
GHGs	Greenhouse gas	*E*	Random disturbance
EMT	Ecological modernization theory	CO_2	Carbon dioxide
VECM	Vector error correction model	GDP	Gross domestic product
FMOLS	Fully modified ordinary least square	ECM	Error correction model
MENA	Middle East and North Africa	DUSR	Dynamic unrelated seemingly regression
APEC	Asia-Pacific Economic Cooperation	POP	Population
SI	Secondary industry	EI	Energy intensity
TI	Tertiary industry	PI	Primary industry
LR	Labor	CS	Capital stock
FE	Fixed effect	EKC	Environmental Kuznets curve
IV-GMM	Instrumental variable − Generalized method of moments	RE	Random effect
		DEA	Data envelopment analysis
		ICT	Information and communication technologies
ETT	Environmental transition theory	$ß_i$	Coefficient of variable *i*

decades [4]. Furthermore, numerous studies in the existing literature also identified that various economic and social indicators such as GDP, urbanization, trade and energy consumption are promoting environmental pollution across belt and road countries [3,5,6]. Therefore, it is of great potential to study the environmental impact of industrialization across BRI countries.

History has always proved that industrialization has a major impact on the economic sustainability of an economy. Many researchers investigate the effect of industrialization on environmental pollution from a national perspective without considering developmental level [7–10]. Different countries have different endowment factors, development levels, and institutional quality. Therefore, the influence of industrialization on environmental quality varies across different levels of development [1]. As a consequence, it is important to take into account the level of development to better understand the nexus between industrialization and environmental efficiency. Furthermore, while studying industrialization-environment nexus, the majority of studies focused on an individual industry like manufacturing, construction, iron and steel, food or transportation [11–15]. While some studies focused on overall industrialization (ratio of industrial value added in GDP) or secondary industry [16–18]. However, the industrialization-environment nexus based on industrial structure (i.e., Primary, Secondary and Tertiary industry) is lacking. According to Hu and Liu [19] the effect of industrial pollution varies across different industrial structures and scales. In this regard, it is important to realize the structure of the industry to get a clear picture of the relationship. Furthermore, existing literature focused only on carbon emissions, with only a few studies addressed the relationship between industrialization and environmental efficiency, Therefore, keeping in mind the shortcomings of existing literature, this study investigates the relationship between industrialization and environmental efficiency across developed and developing countries by taking all three sectors of the industry i.e., Primary, Secondary and Tertiary industry.

The main objectives of this study are: 1) To measure the environmental efficiency of BRI countries on the basis of development level. 2) To examine the relationship between industrial structure and environmental efficiency by using three different industrial sectors including Primary, Secondary and Tertiary industry. 3) To probe the nonlinear relationship between industrial structure and environmental efficiency on the basis of development level by using 64 Belt and Road countries.

The novelty of this study is as follow. We believe this is the first study to analyze the effect of different industrial structures on environmental efficiency on the basis development level using a nonlinear econometric model. Furthermore, this study employed environmental efficiency using DEA analysis, instead of relying on existing indicators such as, CO_2 emissions.

The remaining article is arranged in the following way. Section 2 presents literature review where we explained the link between environment and industry on the basis of previous literature and theoretical grounds. In section 3 we explained the methodologies used in this study for measuring environmental efficiency and econometric analysis. In addition, data summary statistics is also presented in this section. In section 4, we displayed the results of environmental efficiency and econometrics analysis. Lastly, section 5 presented the conclusion summary of the whole research and policy implications are recommended on the basis of findings.

2. Literature review

In 1982, Shantora [20] studied the environmental concerns related to environment with respect to economy and industry. According to the author, the negative impact of industry on environment is inevitable unless strict environmental regulations are followed to reduce the pollution. In 1985, Tuntawiroon [21] stated that the negative impact of industry on environment is more severe in third world developing countries and it can't be solved without the help of international community cooperation. These were some of the initial studies regarding the nexus between industry and environment, which inspires the researchers to further dig different aspects of this nexus.

Industrialization is the measure of industrial activities taking place in an economy. It may have a direct or indirect effect on a country's economy and environmental quality. Industrialization raises the economic situation of the country, provides more jobs, and increases urbanization. However, industrialization also increases the demand for energy usage which has led to increased environmental contamination and deteriorating environmental efficiency [22]. Two different schools of thought exist regarding the relationship between industrialization and environmental pollution. The first school of thought argues that industrialization enhances environmental pollution by expanding energy consumption demand particularly fossil fuels which release more carbon emissions [23]. In addition, industrialization requires more raw materials which lead to the reduction of environmental resources more rapidly and deteriorates environmental efficiency. However, the second school of thought argues that industrialization can improve environmental efficiency by uplifting the economy of the country and increasing income level. High income and developed countries are likely to care more about environmental pollution and try to reduce it by employing strict environmental policies and adopting advanced energy structures [24]. In addition, industrialization can abate environmental pollution by using green technologies in various industrial sectors. The arguments of these two schools of thought can be linked with Ecological Modernization theory (EMT) in terms of industrialization. EMT emerged as a theoretical approach in early 1980s, which explains the relationship between economic sector and pollution [25]. According to this theory, industrialization increase environmental pollution in developing countries due to weak environmental regulation, poor energy structure, and high rate of energy consumption. However, industrialization may decrease environmental pollution in developed countries due to strong environmental regulations, advance energy structure, adoption of green technologies, public awareness and knowledge spill over [26]. Li et al. [27] analyzed the relationship between industrialization and carbon emission across China, and testifies that their results are in line with EMT theory. Er et al. [28] tested EMT theory in Malaysian industrial sector and reported that, technological development, innovative policies of government, and transfer of technology has modernized the Malaysian industrial sector, which could help in pollution reduction. Industrial Agglomeration Effect (IAE) is another famous theory which explains the relationship between industrialization and environmental pollution. According to this theory, the effect of industrial activities on environment depends upon its geographical location. Industrial agglomeration refers to the clustering of many industries in nearby location, which create economies of scale and network effect and thereby sharing resources, energy, transportation and technology. Which results in reducing pollution and improving environmental quality. Shen and Pend [29] studied the effect of industrial agglomeration across China and testified that IAF help to reduce carbon emissions. Tanaka and Managi [30] also testified that industrial agglomeration improve energy efficiency and reduce environmental pollution.

Overall industrialization is regarded as a cluster of many industries including manufacturing, agriculture, construction, transport, and services, etc. The initial classification of industries was done by Fisher in 1939 [31] by proposing the “Three-sector Model”. According to the Three-Sector model, industries are divided into three major sectors such as primary, secondary, and tertiary industry. Primary industry compromises of agriculture, mining, fisheries, forestry as well as animal husbandry. The secondary industry refers to construction and manufacturing and tertiary industry involves transportation, restaurants, wholesale, hotels, retail trade and other services. In the existing literature, many researchers investigate the relationship between industrialization and environmental pollution, especially carbon emissions. The majority of studies focused on the overall impact caused by industrialization on carbon emission, without differentiating among different sectors and industrial structures. As for instance, Wang et al. [32] investigated the impact of industrialization on carbon emissions in China by using the error correction model (ECM) and concluded that industrialization has a positive impact on environmental pollution and it promotes carbon emissions. Kermani et al. [33] explored the casual links between carbon emissions and industrialization in Iran covering the period of 1980–2011. The author report that a bidirectional causality exists between industrialization and carbon emissions. Xu and Lin [9] analyzed the impact of industrialization on carbon emissions across 30 provinces of China by using Quantile regression. The author found that industrialization increase CO_2 emissions across all provinces, however, the intensity of industrial pollution varies across provinces on the basis of different industrial structures and different provincial income level. Liu and Bae [8] explored the nexus between industrialization and carbon emissions in Chine from 1970 to 2015 by employing VECM granger causality and found a positive association between the two parameters. They reported that a1% increase in industrialization increases carbon emissions by 0.3%. In addition, the author also confirmed a bidirectional causality running between industrialization and carbon emissions. Some researchers also used panel data covering several countries to explore the relationship. Al-Mulali and Ozturk [34] used panel FMOLS and Granger causality to study the relationship across 14 MENA countries (Middle East and North African). They confirmed the negative impact of industrialization on the environment and report that, 1% increase in industrialization increase carbon emissions by 0.68%. Wang et al. [35] employed DUSR (Dynamic Unrelated Seemingly Regression) estimation to investigate the relation between industrialization and carbon emission in APEC countries from 1990 to 2014. The author reported that industrialization increases carbon emissions and pollutes the environment. A unidirectional causality was also encountered running from industrialization towards Carbon dioxide emissions. Asane-Otoo [36] used the panel of 45 African countries from 1980 to 2009 and divide them into two groups based on income level i.e., low-middle income groups. Results revealed that industrialization increases carbon emissions across both lower and middle income countries, however industrialization's impact on carbon emission is more severe in middle income countries. On the contrary, few researchers have also mentioned that relationship between industrialization and carbon emissions is nonlinear. For instance, Shahbaz et al. [37] examined nonlinear nexus between the two variables in Bangladesh from 1975 to 2010 and confirmed a nonlinear inverted U-shaped curve, which supports the theory of EKC. Xu and Lin [38] also investigated nonlinear relationship and concluded that industrialization initially results in increase of carbon emissions but later it tends to reduce CO_2 due to advance energy structure.

In addition, some researchers also focused on individual industries or sub-sectors. For instance, Zhang and Liu [39] explored the relationship between the ICT industry and CO_2 across three regions in China by using panel data from 2000 to 2010. The author employed FGLS and Fixed Effect estimations and found that the ICT industry promotes carbon emissions across different regions in China. Poveda and Martinez [40] studied the impact of the manufacturing industry on carbon emissions across three developed European countries by utilizing panel data from 1995 to 2008. Their results indicate that increase in manufacturing decreases carbon emissions due to better energy structure and use of non-fossil fuel energy. Their results supported the theory of Ecological Modernization. Talib [41] examined the nexus between CO_2 and the transport sector in Tunisia for the period of 1980–2014 by using Vector Autoregressive (VAR) model. The author report that industrial energy consumption plays a critical role and CO_2 emissions in the transport sector can be reduced by enhancing energy efficiency. Xu and Lin [42] explored the link between High-Tech industry and carbon emissions across thirty provinces of China covering the period of 1999–2015. They used STRIPAT model and employed Geographically Weighted Regression (GWR) technique to probe the nexus. Their results show that High Tech industry reduce pollution. Lin and Lei [14] explored the relationship between energy consumption, Chinese food industry and CO_2 emission from 1996 to 2000. They found that energy structure plays an important role in controlling the industrial emissions of food industry.

Furthermore, several studies also focused on the structure of the industry. Hao et al. [18] studied the impact of secondary industry on CO_2 emissions across 29 Chinese provinces from 1995 to 2012 using GMM (generalized method of moments) estimator. The author found that secondary industry has a positive effect and it promotes CO_2 emission. Wang et al. [17] used the rate of secondary and tertiary industry as a proxy for industrialization to investigate its impact on carbon emissions across China between 1980 and 2010. The author report that secondary and tertiary industry play an essential role in promoting carbon emissions. Zhu et al. [43] analyzed the effect of tertiary industry on carbon emissions across ASEAN-5 countries by using quantile regressions. However, they found that influence of tertiary industry upon CO_2 emissions is insignificant. Aboagye et al. [44] studied the impact of primary, secondary and tertiary industrial growth on environmental degradation across Ghana and concluded that all three sectors of industry accelerate environmental degradation.

This study is unique from previous research in two aspects. First, it investigates the effect of industrial structures on environmental efficiency (instead of carbon emissions) by taking all three sectors of the industry i.e., primary, secondary and tertiary industry. Second, it examined industrial structure's impact upon environmental efficiency across developed and developing countries.

Theoretical contribution for this paper is as follows. First, it measures the environmental efficiency of BRI countries across developed and developing groups using Data Envelopment Analysis (DEA) input/output method. Second, it investigates the relation between environmental efficiency and industrial structure across developed and developing countries by considering three sectors of industry such as primary, secondary and tertiary industry. Third, the impact of different determinants of carbon emissions are investigated and compared across developed and developing countries. Last, Fixed effect and Random effect estimation is employed to explore the nexus between environmental efficiency and its determinants. Panel IV-GMM technique is utilized for robust analysis and to resolve endogeneity problem.

3. Methodology and data

3.1. Environmental efficiency

This study utilized SBM (slack-based measure) model to measure the environmental efficiency. SBM model was initially developed by Tone in 2001 [45], which added slack variable in the linear programming to evaluate the efficiency. SBM model provide more efficient results than other DEA models, as it avoid deviation and reflect the nature of the efficiency evaluation [46]. However, the original SBM model had a drawback while measuring environmental efficiency as it does not differentiate between good and bad output. Therefore, Tone modified the SBM model in 2003 [47] with desirable and undesirable output. This study has employed SBM undesirable model to measure the environmental efficiency of BRI countries over the period.

Assuming that there are N decision making units (DMU), where each DMU has input $x \in R^m$, desirable output $y^g \in R^{s_1}$ and undesirable output $y^b \in R^{s_2}$. Therefore, three vectors for input (X), desirable output (Y^g) and undesirable output (Y^b) can be written as, $X = (x_1, x_2, \ldots x_n) \in R^{m\times n}$, $Y^g = (y_1^g, y_2^g, \ldots, y_n^g) \in R^{s_1\times n}$, $Y^b = (y_1^b, y_2^b, \ldots, y_n^b) \in R^{s_2\times n}$. The production possibility set (P) as follow:

$$P = \left\{ \left(x, y^g, y^b\right) | x \geq X\lambda,\ y^g \leq Y^g\lambda,\ y^b \geq Y^b\lambda,\ \geq 0 \right\} \tag{1}$$

Where $\lambda \in R^n$ denotes variable's intensity. The SBM model with undesirable outputs can be written as below.

$$\rho^* = min \frac{1 - \frac{1}{m}\sum_{i=1}^{m} \frac{s_i^-}{x_{i0}}}{1 + \frac{1}{s_1+s_2}\left(\sum_{r=1}^{s_1} \frac{s_r^g}{y_{r0}^g} + \sum_{r=1}^{s_2} \frac{s_r^b}{y_{r0}^b}\right)} \tag{2}$$

$$\text{S.t. } x_0 = X\lambda + s^-$$

$$y_0^g = Y^g\lambda - s^g$$

$$y_0^b = Y^b\lambda + s^b$$

$$s^- \geq 0,\ s^g \geq 0,\ s^b \geq 0,\ \lambda \geq 0$$

where $s^- \in R^m$ is the excesses of inputs, $s^b \in R^{s_2}$ is the excesses of undesirable outputs and $s^g \in R^{s_1}$ is the shortage of desirable output. The value of ρ represents EE which ranges from 0 to 1. If $\rho < 1$, it means that DMU is inefficient and has the room to improvement.

3.2. Econometric model

The base of our study rests upon a famous conceptual framework, IPAT model. IPAT model (I=PAT) is widely used by researchers and was first introduced by Ehrlich and Holdren [48] to study the impact of human and economic activity on environment. The environmental impact (I) is determined by three major factors: population (P), affluence (A), and technology (T). IPAT model is a simple and useful model but it also has some limitations. It has strong proportionality among factors and testing for hypothesis is not possible. Hence, to suppress these limitations, Dietz and Rods [49] modified IPAT model into STRIPAT as below:

$$\mathrm{I}_{it} = \alpha_{it}\ \mathrm{P^b}_{it}\ \mathrm{A^c}_{it}\ \mathrm{T^d}_{it}\ \varepsilon_{it} \tag{3}$$

In above STRIPAT model, α represent constant term whereas P, A and T are just similar to the original IPAT model. While, b, c and d represent parameters for P, A and T. ε denoted random error term. In the present study we suggested STRIPAT econometric model considering the studies of Wang et al. [17] and Xu and Lin [9] as below, Eq. (4):

$$\mathrm{lnEE}_{it} = \alpha_{it} + \beta_1 \mathrm{lnPOP}_{it} + \beta_2 \mathrm{lnGDP}_{it} + \beta_3 \mathrm{lnEI}_{it} + \varepsilon_{it} \tag{4}$$

where, EE is environmental efficiency representing environmental impact (I), POP represents population, GDP (gross domestic products) represents the affluence (A), while EI, denotes intensity of energy, applied as a proxy for technology (T). EI is measured as total energy consumption divided by GDP. Energy intensity is used by many studies as a proxy for technology (T) in STRIPAT model [13,17,42].

To investigate the effect of industrial structure on environmental efficiency, we expand the STRIPAT model by adding the variables of primary, secondary and tertiary industry. In addition, we incorporate capital stock and labor as control variables in our model. The extended STRIPAT model is expressed as below in Eq. (5).

$$\begin{aligned} \mathrm{lnEE}_{it} &= \alpha_{it} + \beta_1 \mathrm{lnPOP}_{it} + \beta_2 \mathrm{lnGDP}_{it} + \beta_3 \mathrm{lnEI}_{it} \\ &+ \beta_4 \mathrm{lnPIit} + \beta_5 \mathrm{lnSI}_{it} + \beta_6 \mathrm{lnTI}_{it} + \varepsilon_{it} \end{aligned} \tag{5}$$

where, PI represents primary industry, SI denotes secondary industry and TI represents tertiary industry.

This study employed Fixed effect (FE) and Random effect (RE) models as basic regression estimation. The FE estimation portions of specification are controlled through orthogonal forecasts. These forecasts of projection removes the specific mean from the cross-sections and the period from the dependent variables and the exogenous regressor and then employ the quantified regression using the demeaned data. The major advantage of FE estimation is that it removes the regression bias which arise from omitted variables [50]. While, RE estimation assume that the equivalent effect of the cross-section effect vector and the time period effect vector are not correlated. Meaning that, the RE estimation accept that the effects are not correlated with the residuals [51]. However, the drawback of these FE and RE estimation is that they do not control endogeneity, heteroskedasticity and autocorrelation issues. Therefore, to overcome the short comings of fixed and random effect, we also employed IV-GMM as a robust estimator to control these issues and provide consistent results. IV-GMM yield reliable results in the presence of unknown heteroskedasticity and is robust to autocorrelation. Furthermore, IV-GMM also handle the primary econometric concern of endogeneity [52]. In existing literature, many researchers [51,53,54] employed IV-GMM along with FE and RE models to verify the consistency and validity of results.

3.3. Data

This study utilized the data of 64 belt and road countries over the period of 2000–2017. The time series of 18 years is chosen on the basis of data availability. Two separate group were created by dividing BRI countries into developed and developing countries (*see* Appendix A). First, to calculate EE we utilized three input variables and two output variables (desirable and undesirable). Labor, capital stock and energy consumption are input variables. While, GDP (desirable output) and CO_2 emissions (undesirable output) are output variables. Table 1 presents the descriptive analysis of input and output variables. Primary industry (PI) is the rate of agriculture, mining, forestry, fisheries and animal husbandry in total GDP, measured in percentage. Secondary industry (SI) is the rate of manufacturing and construction industry in total GDP, measured in percentage. Tertiary industry is the rate of transport, restaurants, hotels, wholesale, retail trade and other service sectors in total GDP, measured in percentage. Table 2 presents the statistical summary of variables used in this study. Data is collected from World Bank [4] and UN [55] databases. The framework of study is presented in Fig. 1 below.

4. Empirical results

4.1. Environmental efficiency

We employed SBM-DEA analysis to measure the environmental efficiency of BRI countries at panel and two groups of developed and developing countries (*See* Fig. 2). The results indicate that developed countries have a higher average environmental efficiency than developing countries. This is because developed countries are more conscious about environmental issues and have strict environmental regulations as compared to developing countries. Furthermore, developed countries are using high tech and advanced technologies in their industrial process, which perform at the optimum level, providing the best possible output with minimum input. In addition, majority of the population in developed countries lives in urban cities, where people share the resources and public infrastructure through economies of scale, which reduces energy usage and improve environmental efficiency. The results further indicate that the environmental efficiency of developed countries deteriorate over the period, where the average EE was 7.5 in the year 2000, which peaked in the year 2004 with the value 7.9. However, after 2004 the EE declined gradually over the years and in 2017 the average EE of developed countries was around 6.5. This is because, with passage of time the growth of bad output (CO_2) surpasses the growth of good output (GDP), resulting in EE reduction.

For developing countries, the results indicate that the environmental efficiency (EE) initially increased and reached the peak value of around 4.4 in 2007. However, it declined gradually and in 2017 the average EE of developing countries was 3.6. The total EE of developing countries is lower than the overall panel and developed

Table 1
Statistical summary of input and output variables.

Input/Output	Variable	Unit	Mean	St. dev	Minimum	Maximum
Input	EC	Kiloton of oil equivalent	100559.6	371110.8	227.44	3923287
	CS	US$ 100 million	13830.09	31269.18	35.31	299310.70
	LR	10,000 persons	3061.55	10971.22	9.02	78495.01
Output	GDP	US$ 100 million	2502.04	8039.32	6.61	101853.10
	CO_2	Kiloton	249219.8	1002840	308.02	1.03e+07

Table 2
Descriptive statistics of explanatory variables.

Variable	Unit	Developed Countries				Developing Countries			
		Mean	St. dev	Min.	Max.	Mean	St. dev	Min.	Max.
POP	10,000 persons	793.06	1002.69	33.31	3825.86	8612.45	25184.3	27.93	138639.5
GDP	US$ 100 million	1694.03	1576.43	119.71	6900.68	2771.37	9224	6.610	101853.10
EI	Ratio	28.81	14.02	9.73	72.62	46.23	37.09	8.65	224.49
PI	% of GDP	0.01	0.01	0.0003	0.05	0.13	0.08	0.01	0.57
SI	% of GDP	0.37	0.14	0.12	0.74	0.33	0.12	0.07	0.76
TI	% of GDP	0.45	0.10	0.21	0.66	0.51	0.10	0.10	0.77

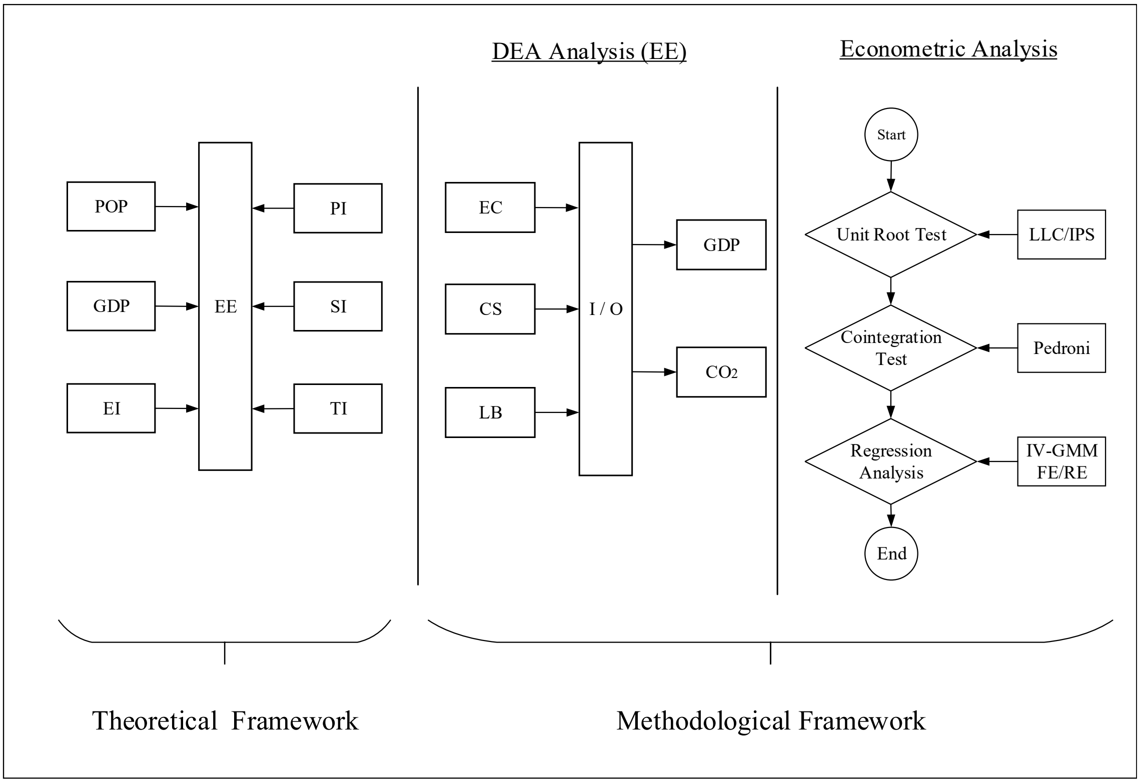

Fig. 1. Conceptual framework of the study.

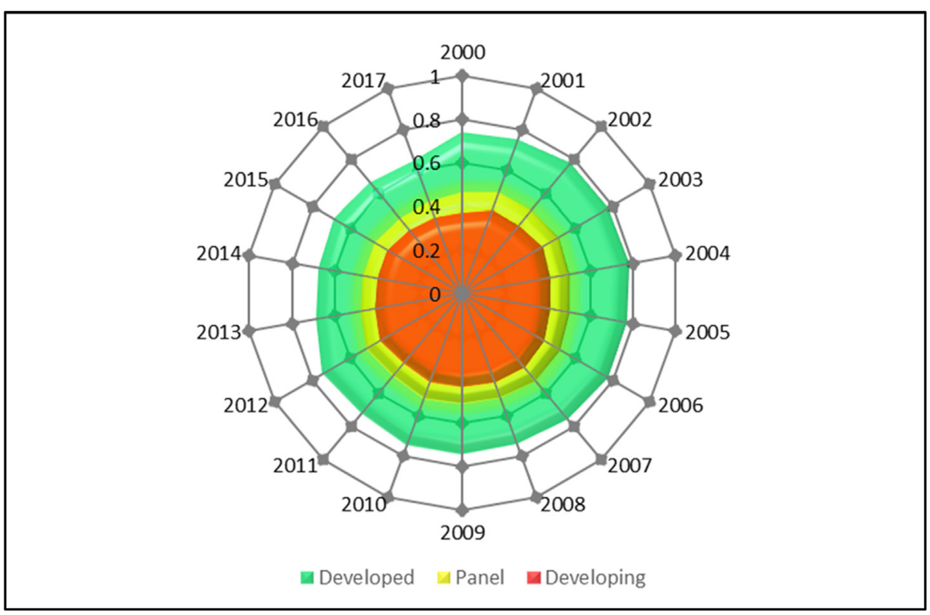

Fig. 2. Environmental efficiency of developed and developing countries over the years.

countries. Developing countries usually focus on sharp economic growth without environmental concerns, which lead to more pollution and decline in environmental efficiency.

The environmental efficiency of BRI countries for selected years is presented in Fig. 3. The results indicates that the efficiency of the majority of countries decreased over the years. Most notably Russia, China, India, Bangladesh, UAE, and Sri Lanka. The environmental efficiency of these countries decreased significantly and

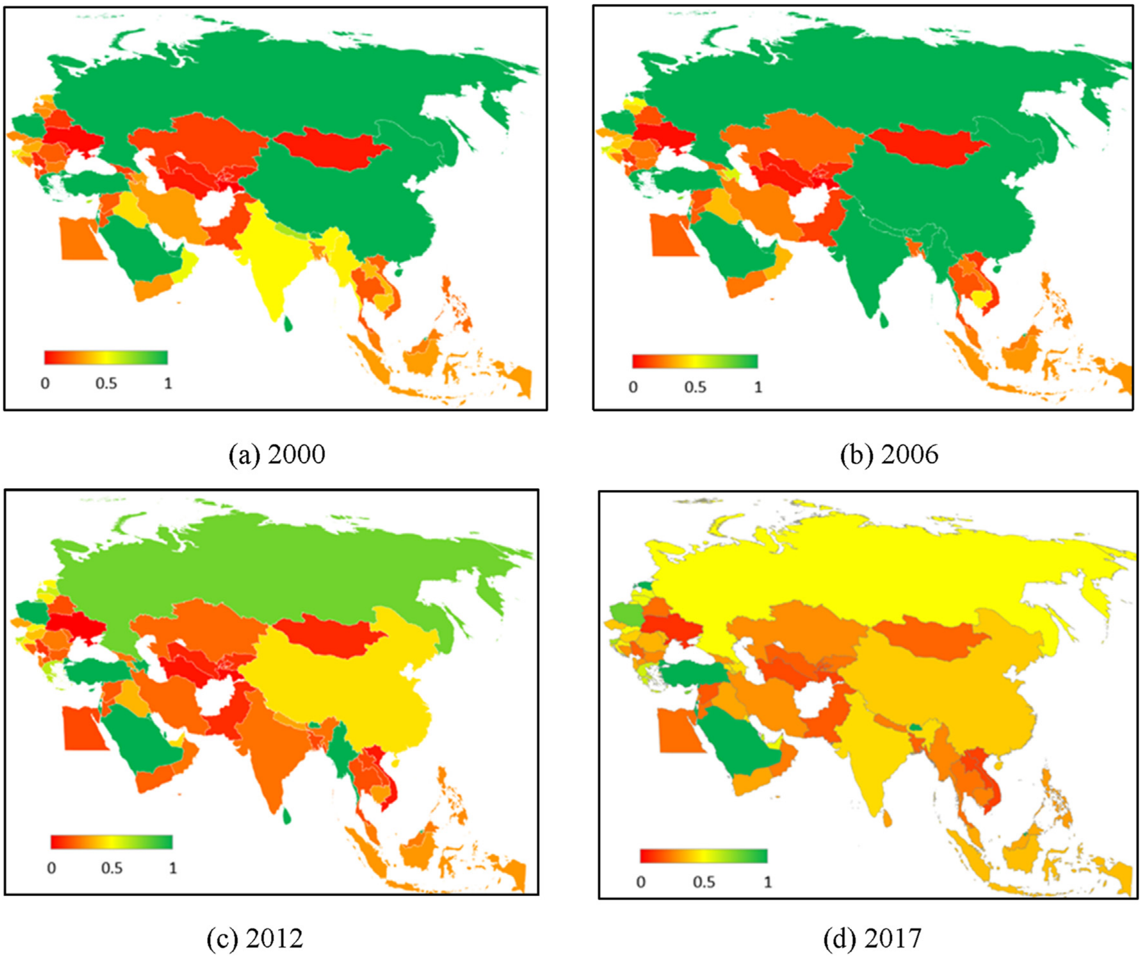

Fig. 3. Environmental efficiency of BRI countries over the years.

prominently. However, the EE of several European and other developed countries remained stable or improved, such as, Poland, Greece, Cyprus, Saudi Arabia, Bhutan, and Brunei etc. Although the EE of several countries improved over the years, however, the overall average efficiency decreased. This is because of the huge decline in the EE of major contributing countries such as China, India and Russia etc. The result further indicates that the EE of majority of the countries deteriorate over the years from 2000 to 2017.

Fig. 4 presents the comparative analysis of environmental efficiency and carbon emissions of belt and road countries at panel level and two groups of developed and developing countries. The result indicates that carbon emissions increased linearly across both developed and developing countries, however, a sharp increase in CO_2 was recorded across developing countries. While developed countries showed a steady increase in CO_2 emissions as compared to developing countries. The result further indicates that environmental efficiency and carbon emissions showed an opposite growth trend, whereas carbon emissions increased over the years the environmental efficiency decreased.

The environmental efficiency of developed and developing groups of belt and road countries are presented in Fig. 5. The results show that developed countries have overall higher environmental efficiency then developing countries, where the green color (higher environmental efficiency) is dominant. While, developing countries are dominated by more yellow and red color (low environmental efficiency) schemes. The results further show that the environmental efficiency of both developed and developing nations deteriorate over the years.

4.2. Correlation and cross-sectional dependence (CD) tests

Correlation matrix and cross-sectional dependence (CD) test is presented in Table 3. The correlation results indicates that there is no multicollinearity issue among the variables. Furthermore, we employed Pesaran test [56] for cross-sectional dependence, which has the null hypothesis of no cross-sectional dependence. The results shows that the null hypothesis is rejected at 1%.

4.3. Unit root test

Testing for unit root is a standard procedure for performing an

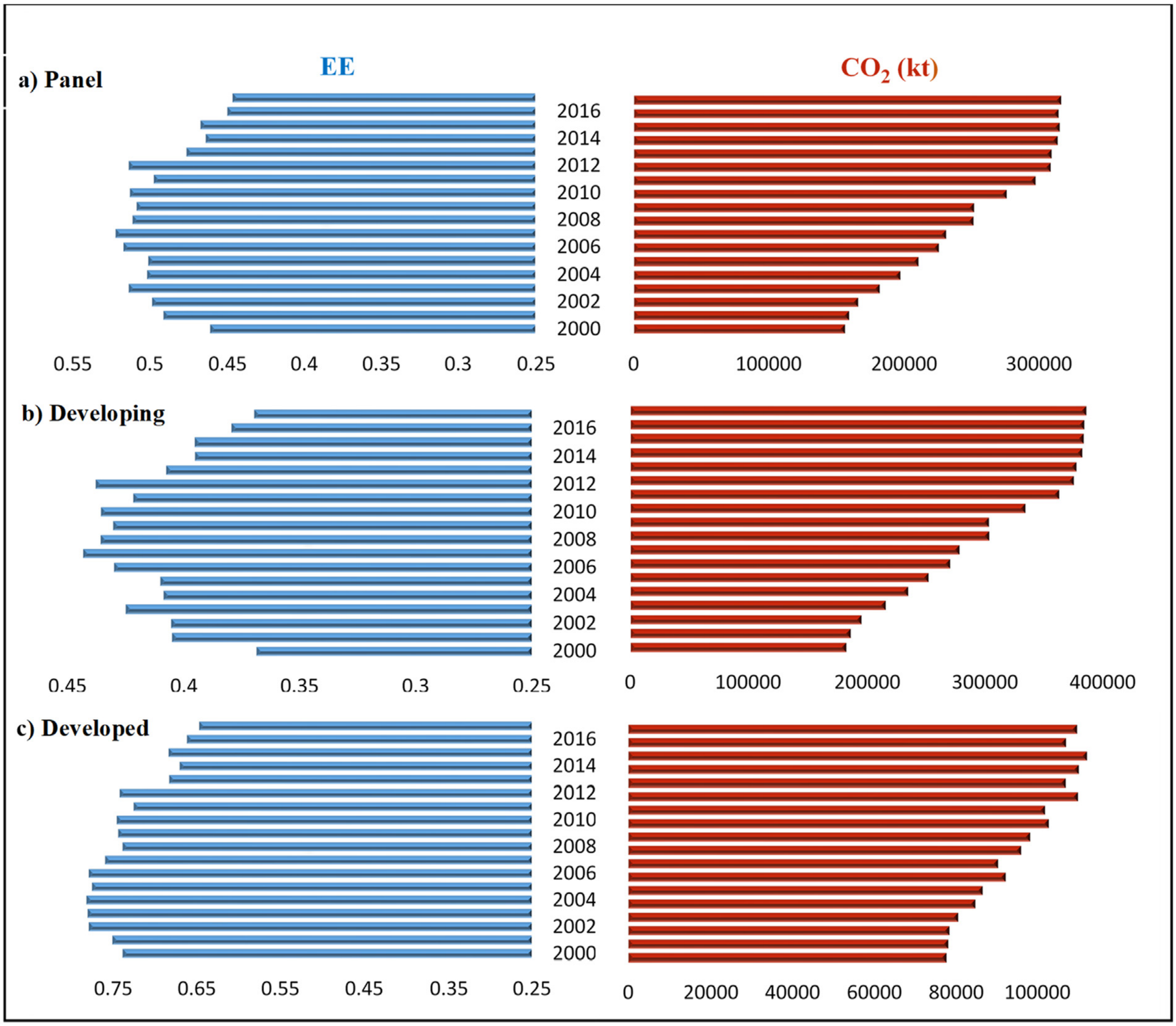

Fig. 4. Environmental efficiency and CO_2 emissions of BRI countries.

econometric analysis. The data must be stationary and free of unit root before performing a regression estimation. Therefore, to the check stationarity properties of variables, we employ two unit root tests, namely Levin Lin Chu (LLC) [57] and Im Pesaran Shin (IPS) [58] (*see* Table 4). LLC and IPS tests both have same null hypothesis that the data is not stationary. The results indicates that all of the variables are non-stationary at level I(0), however the variable sequence became stationary by taking first difference I(1), where null hypothesis is rejected at 1% significance level.

4.4. Cointegration test

This study employed panel cointegration test [59] to check the long run association among the variables (*see* Table 5). Pedroni test comprise of two sets i.e., panel and group statistics. Panel has four statistics which are based on within dimension approach. While group has three statistics and based on between dimension approach. Pedroni test has the null hypothesis of no cointegration. The results shows that the null hypothesis of no cointegration is rejected at 1% and 5%.

4.5. Panel analysis

The panel analysis of environmental efficiency and its determinants are estimated using Fixed effect, Random effect IV-GMM (*see* Table 6). The results indicates that population decreases environmental efficiency at the panel level. Increase in population promotes the demand of energy consumption, infrastructure development and deforestation, which elevates pollution and reduces environmental efficiency. In addition, population growth causes the exhaustion of natural resources even faster, which results in the decline of environmental efficiency. Our results are consistent with the studies of Muhammad [3] and Salman [60] who also summarized that population enhance environmental degradation. Furthermore, the results show that economic growth promotes pollution and deteriorates environmental efficiency. The coefficient of GDP is positively significant at 5% (FE) and 1% (IV-GMM), and its value ranges from 0.341 to 0.515 This suggests that BRI countries have a greater focus on accelerating economic growth and have least concern about environmental pollution. Economic growth largely influences the industrial sector of a country, where

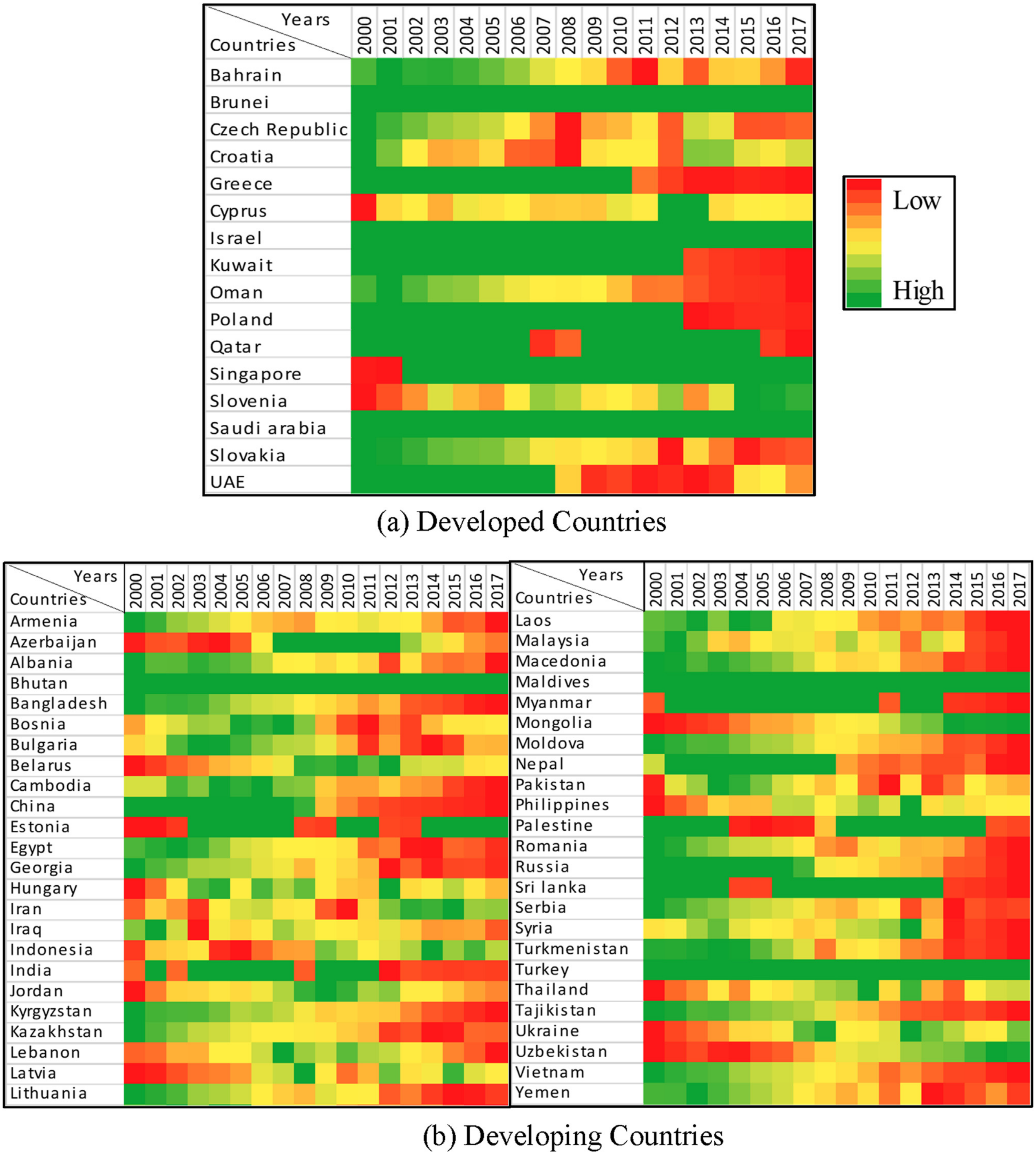

Fig. 5. Environmental efficiency of developed and developing countries.

economic growth promotes industrial activities, infrastructure development and transport activities. All these activities increase the demand for energy consumption which reduces environmental efficiency. Our results are consistent with the findings of Al-Mulali [61] and Salman [62] who also confirmed the negative impact of economy on environment. Energy intensity exerts a significantly negative impact on environmental efficiency across FE and GMM regression techniques at 1% and 10% significance level, respectively. The coefficient of energy intensity is negative and ranges from 0.346 to 0.683, which means that energy efficiency is low. This indicates that the energy structure of BRI countries largely depends upon fossil fuels rather than clean and renewable energy. Our

Table 3
Results of Correlation and cross-sectional dependence (CD) tests.

Variables	*ln*EE	*ln*POP	*ln*GDP	*ln*EI	*ln*PI	*ln*SI	*ln*TI
*ln*EE	1						
*ln*POP	0.125	1					
*ln*GDP	0.046	0.341	1				
*ln*EI	0.222	0.166	0.041	1			
*ln*PI	0.098	0.241	0.177	0.206	1		
*ln*SI	0.101	0.100	0.099	0.188	0.044	1	
*ln*TI	0.304	0.036	0.051	0.086	0.163	0.255	1
CD-Test	4.352***	6.278***	8.444***	5.202***	6.475***	4.871***	7.053***

CD-test H_o: No cross-sectional dependence.
***Rejection of null hypothesis at 1% significance level.

Table 4
Results of LLC and IPS panel unit root tests.

Variables	LLC		IPS	
	Level	First difference	Level	First difference
*ln*EE	−6.242	−11.454***	−7.054	−19.142***
*ln*POP	−4.193	−15.919***	4.226	−8.243***
*ln*GDP	−4.694	−19.373***	1.258	−10.888***
*ln*EI	−0.316	−10.492***	3.492	−16.201***
*ln*PI	−1.767	−15.537***	−2.729	−9.500***
*ln*SI	−6.200	−13.051***	−4.272	−11.964***
*ln*TI	−4.017	−12.973***	3.120	−9.445***

H_o = Data is not stationary and unit root exists.
H_1 = Data is stationary and unit root does not exists.
***Rejection of null hypothesis at 1% significance level.

Table 5
Pedroni cointegration test.

Pedroni Test	Panel level	Developed Countries	Developing Countries
Panel v- statistics	3.124***	−1.024***	3.207**
Panel ρ- statistics	1.045***	−0.235**	−0.301***
Panel PP- statistics	−4.017**	2.038***	1.068***
Panel ADF- statistics	2.384***	3.048***	2.186***
Group ρ- statistics	0.314**	−0.182***	−2.014***
Group PP- statistics	1.286	3.674***	0.851**
Group ADF- statistics	−2.367**	1.054***	1.057**

H_o = No cointegration among the variables.
***Rejection of null hypothesis at 1% significance level.
**Rejection of null hypothesis at 5% significance level.

Table 6
Panel analysis of environmental efficiency.

Variables	Fixed Effect (FE)	Random Effect (RE)	IV-GMM
*ln*POP	−0.121 (0.010)	−0.235** (0.018)	−0.230*** (0.037)
*ln*GDP	−0.515** (0.055)	0.341 (0.019)	−0.440*** (0.045)
*ln*EI	−0.349*** (0.042)	−0.496 (0.014)	−0.683* (0.044)
*ln*PI	0.019 (0.082)	−0.035 (0.048)	−0.088** (0.009)
*ln*SI	−0.687*** (0.015)	−0.416**** (0.037)	−0.587*** (0.065)
*ln*TI	−0.317 (0.010)	0.372 (0.004)	−0.311*** (0.043)
Constant	−8.354*** (4.571)	−9.347*** (3.674)	−4.257** (1.247)
R^2	0.911	0.708	0.746
F-Statistics (*P*-value)			0.723*** (0.000)
Hansen test (*P*-value)			0.214 (0.183)

F-Statistics for weak instruments identification. H_o: Instruments are weak.
Hansen test for over identification of instruments. H_o: Instruments are valid and not over-identified.
*, ** and **** indicates the statistical significance at 10%, 5% and 1% respectively. Standard deviations are in parenthesis.

results supports the findings of Muhammad [3] and Xu and Lin [9] who also concluded that higher energy intensity promote environmental pollution.

The results further indicate that primary industry exerts a negative effect and decreases environmental efficiency across BRI countries. However, it is important to note that the coefficient of primary industry is significant at 10% (IV-GMM) significance level, with value ranges from 0.019 to 0.088. This indicates that primary industry decreases environmental efficiency, however, its effect on the environment is not very severe. The reason for this might be the less pollution intensive sectors in primary industry such as agriculture, mining, fisheries and animal husbandry. As, these sectors are relatively less pollution-intensive and have minimal effect on the natural environment. Our findings are in line with the results of Gu et al. [16], who used primary industry as a structure of industrialization and validate the negative impact of primary industry on environmental pollution.

Secondary industry also exerts a significantly negative impact on environmental efficiency at a 1% significance level with the coefficient values range from 0.416 to 0.687. This indicates that secondary industry deteriorates environmental efficiency across BRI countries. Secondary industry includes sectors like manufacturing and construction, which required the highest energy input and emit most of the carbon emissions. In addition, secondary industry is considered as the industry with high energy intensity and low energy efficiency as compared to other industries [63]. Furthermore, the majority of countries in the BRI group are low or middle income countries, which focus more on economic growth by accelerating their industrial output, while concerning less about environmental pollution. This type of behavior led to an increase in carbon emissions and degrade environmental efficiency. Our results are consistent with the studies of Hao et al. [18] and Wang and Fan [63] who also confirmed the negative impact of secondary industry on environmental pollution.

The coefficient of tertiary industry is negatively significant at 1% (IV-GMM), with values ranging from 0.311 to 0.372. This indicates that tertiary industry decreases environmental efficiency across BRI countries. Tertiary industry includes sectors like transportation, restaurants, hotels, wholesale, retail trade, etc. Among all sectors of tertiary industry, transport is considered as the highest energy consuming sector. Increase in transport activities raises the demand for energy consumption which emit more pollution and worsen environmental efficiency. Our results are in line with the findings of Wang et al. [17] who also explored that tertiary industry deteriorate environmental quality. The results indicate that among all three types of industries the impact of the secondary industry is more severe on environmental quality, followed by tertiary and primary industry respectively.

4.6. Interacting effect

The interacting effect of industrial sectors and economic growth is presented in Table 7. The interacting effect of primary industry and economic growth (lnPI $\times$ lnGDP), secondary industry and economic growth (lnSI $\times$ lnGDP), and tertiary industry and economic growth (lnTI $\times$ lnGDP) is analyzed by model 1, 2 and 3 respectively (See Table 7). The interacting effect of different industrial sectors and economic growth shows a heterogeneous effect on environmental efficiency. The interacting effect of secondary industry and economic growth (lnSI $\times$ lnGDP) and interacting effect of tertiary industry and economic growth (lnTI $\times$ lnGDP) decline environmental efficiency. However, the interacting effect of primary industry and economic growth (lnPI $\times$ lnGDP) is positively significant and improves environmental efficiency. According to the results of fixed effect (FE) and IV-GMM the interacting relationship between (lnSI $\times$ lnGDP) and environmental efficiency negatively significant at 1% and 10% level, respectively. While the relationship is insignificant according to random effect (RE) analysis. The negative relationship indicates that industrial activities in secondary sector deteriorate environmental efficiency as the economy grows. When a country transforms from agriculture to industrial economy, the proportion of secondary industry increases. This includes the expansion of heavy industry such as iron and steel, manufacturing industry and other infrastructures. All these activities raise the demand for energy consumption and eventually exerts a negative impact on environmental efficiency. Furthermore, the results show that the interacting effect of tertiary industry and economic growth (lnTI $\times$ lnGDP) also decline environmental efficiency. As, Tertiary industry largely comprises of high energy consuming sectors, such as transportation sector, which emit pollution. When economy grows the transportation sector expands, which consumes more energy and exerts a negative effect on environmental efficiency.

4.7. Comparative analysis

To gain more insight into the impact of industrial structure on CO_2 emissions based on development level, this section presents a discussion of the impact of primary industry, secondary industry and tertiary industry on environmental efficiency across BRI countries by dividing them into two groups of developed and developing countries.

The results of IV-GMM for developed and developing countries are shown in Table 8. The results show that population growth exerts a negative effect on environmental efficiency across both developed and developing countries. Economic growth improves environmental efficiency across developed countries; however, it deteriorates environmental efficiency across developing countries. This suggests that, developed countries have achieved the threshold level, where the increase in economic growth improves environmental efficiency. While developing countries are still in the phase of industrialization, where they focus more on economic growth and care less about the environment. Our results of population and economic growth are in line with the findings of Muhammad et al. [5].

Primary industry (lnPI) decreases environmental efficiency across developing countries. However, the impact of primary industry is insignificant across developed countries. This indicates that developed countries might be using advanced technologies in their primary sectors like agriculture, fisheries, animal husbandry, etc, which neutralized its effect on environmental quality. Furthermore, the results do not support any nonlinear relationship between primary industry and environmental efficiency across developed or developing countries (*see* Model 1).

Secondary industry (lnSI) decreases environmental efficiency across both developed and developing countries. However, the nonlinear relationship between secondary industry and environmental efficiency is confirmed only in developed countries (*see* Model 2). Where the coefficient of (lnSI) is significantly negative, while the coefficient of $(ln\mathrm{SI})^2$ is significantly positive across

Table 7
Interaction effect analysis.

Variables	Fixed Effect (FE)			Random Effect (RE)			IV-GMM		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
*ln*POP	0.261 (0.154)	0.184 (0.395)	0.185 (0.094)	−0.480** (0.025)	−0.332** (0.033)	−0.462** (0.100)	−0.355** (0.555)	−0.630*** (2.066)	−0.588*** (0.091)
*ln*GDP	−0.246** (0.073)	−0.121*** (0.051)	−0.357*** (0.043)	−0.133 (0.014)	0.219 (0.044)	0.211 (0.016)	−0.369** (0.128)	−0.049*** (0.118)	−0.330** (0.120)
*ln*EI	−0.129*** (0.073)	−0.390*** (0.103)	−0.240*** (0.100)	0.220 (0.405)	0.380 (0.017)	0.465 (0.104)	−0.581*** (0.002)	−0.086*** (0.125)	−0.216*** (0.010)
*ln*PI	−0.247 (0.006)	−0.135 (0.031)	−0.193 (0.036)	0.158 (0.420)	0.237 (0.045)	0.181 (0.107)	−0.370* (0.059)	−0.249* (0.092)	−0.173** (0.019)
*ln*SI	−0.357*** (0.030)	−0.557*** (0.300)	−0.485*** (0.302)	−0.533* (0.110)	−0.614** (0.017)	−0.264*** (0.052)	−0.411*** (0.550)	−0.481*** (0.043)	−0.284*** (0.017)
*ln*TI	−0.246* (0.063)	−0.235 (0.017)	−0.185 (0.027)	0.420 (0.633)	0.316 (0.070)	0.200 (0.008)	−0.502*** (0.010)	−0.272*** (0.090)	−0.491*** (0.123)
*ln*PI × *ln*GDP	0.268*** (0.092)			0.166 (0.011)			0.376*** (0.200)		
*ln*SI × *ln*GDP		−0.324*** (0.017)			0.529 (0.120)			−0.515* (0.003)	
*ln*TI × *ln*GDP			−0.223*** (0.063)			−0.193*** (0.313)			−0.437*** (0.008)
Constant	−7.244*** (4.201)	−8.235*** (3.661)	−3.250*** (1.287)	−6.327*** (2.077)	−1.687*** (6.377)	−5.321*** (3.278)	−3.114*** (2.092)	−3.111*** (4.587)	−1.112*** (3.578)
R^2	0.708	0.825	0.833	0.953	0.977	0.910	0.728	0.826	0.888
F-Statistics (*P*-value)							2.404*** (0.00)	0.014*** (0.00)	2.398*** (0.00)
Hansen test (*P*-value)							0.890 (0.318)	0.147 (0.543)	1.835 (0.359)

F-Statistics for weak instruments identification. Ho: Instruments are weak.
Hansen test for over identification of instruments. Ho: Instruments are valid and not over-identified.
*, ** and **** indicates the statistical significance at 10%, 5% and 1% respectively. Standard deviations are in parenthesis.

Table 8
Comparative analysis between developed and developing countries (IV-GMM estimation).

Variables	Developed Countries						Developing Countries					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
*ln*POP	0.443	0.351	0.294	−0.283***	−0.070***	−0.112***	0.386	0.572	0.24 (0.455)	−0.363***	−0.264***	−0.531***
	(0.054)	(0.044)	(0.485)	(0.084)	(0.014)	(0.053)	(0.042)	(0.210)		(0.006)	(0.071)	(0.012)
*ln*GDP	0.222**	0.136**	0.211***	0.323*	0.413***	0.329*	−0.182**	−0.252**	−0.331*	−0.257***	−0.630***	−0.710**
	(0.083)	(0.063)	(0.015)	(0.024)	(0.102)	(0.034)	(0.003)	(0.066)	(0.098)	(0.139)	(0.720)	(0.280)
*ln*EI	−0.581***	−0.438***	−0.280***	−0.350***	−0.350***	−0.420***	−0.464***	−0.135***	−0.171***	−0.288**	−0.146***	−0.196***
	(0.023)	(0.063)	(0.113)	(0.200)	(0.305)	(0.027)	(0.003)	(0.004)	(0.012)	(0.105)	(0.310)	(0.510)
*ln*PI	0.077	0.247	0.315	0.283	0.248	0.345	−0.119*	−0.071***	−0.060	−0.144*	−0.133***	−0.076*
	(0.004)	(0.005)	(0.013)	(0.025)	(0.080)	(0.065)	(0.005)	(0.307)	(0.049)	(0.098)	(0.109)	(0.129)
*ln*SI	−0.116***	−0.246***	−0.117***	−0.245***	−0.123***	−0.004**	−0.684***	−0.454***	−0.391***	−0.841***	−0.384***	−0.354***
	(0.020)	(0.020)	(0.030)	(0.102)	(0.010)	(0.091)	(0.020)	(0.049)	(0.350)	(0.034)	(0.002)	(0.027)
*ln*TI	−0.276*	−0.456**	−0.324**	−0.275**	−0.110***	−0.476*	−0.114*	−0.010***	−0.292***	−0.022***	−0.131***	−0.111***
	(0.043)	(0.053)	(0.071)	(0.016)	(0.360)	(0.068)	(0.054)	(0.056)	(0.021)	(0.009)	(0.013)	(0.023)
(lnPI)^2	0.254						0.105					
	(0.052)						(0.071)					
(*ln*SI)^2		0.378***						−0.183***				
		(0.081)						(0.363)				
(*ln*TI)^2			0.343						−0.385**			
			(0.026)						(0.210)			
*ln*PI × *ln*GDP				0.331						−0.155***		
				(0.042)						(0.001)		
*ln*SI × *ln*GDP					0.586***						−0.227***	
					(0.041)						(0.028)	
*ln*TI × *ln*GDP						−0.579**						−0.415***
						(0.130)						(0.111)
R^2	0.815	0.805	0.725	0.891	0.938	0.871	0.715	0.782	0.861	0.873	0.911	0.895
F-Statistics	15.436**	13.160***	15.270***	21.883***	3.150***	4.713***	15.265***	11.513***	1.613***	10.098***	1.333***	31.215***
(*P*-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Hansen test	0.854	0.626	0.778	0.712	0.835	0.773	0.718	0.783	0.719	−0.032	1.824	1.506
(*P*-value)	(0.132)	(0.412)	(0.132)	(0.172)	(0.522)	(0.432)	(0.142)	(0.187)	(0.231)	(0.194)	(0.406)	(0.254)

F-Statistics for weak instruments identification. H_o: Instruments are weak.
Hansen test for over identification of instruments. H_o: Instruments are valid and not over-identified.
*, ** and **** indicates the statistical significance at 10%, 5% and 1% respectively. Standard deviations are in parenthesis.

developed countries. Hence, confirming a U-shape relationship between secondary industry and environmental efficiency. This implies that only developed countries have achieved the threshold point to lower pollution and improve environmental efficiency through development. This signifies that developed countries in BRI group have advance energy structure, strict climate policies and utilize advanced technology in their manufacturing and construction sector which help them to improve environmental efficiency.

The coefficient of tertiary industry (*ln*TI) is negatively significant and decreases environmental efficiency across both developed and developing countries. However, the negative effect of tertiary industry on environmental efficiency is more severe across developed countries. The reason for this might be high urban density and higher energy consumption due to vast network of transportation. This supports the argument of Environmental Transition Theory (ETT), which postulates that environmental pollution related to energy consumption is more severe in developed countries due to higher rate of urbanization. Furthermore, the results did not confirm nonlinear relationship between tertiary industry and environmental efficiency (*see* Model 3).

The interacting effect of primary industry and economic growth (*ln*PI × *ln*GDP) is insignificant across developed countries, however, the interacting effect of (*ln*PI × *ln*GDP) decreases environmental efficiency across developing countries (*see* Model 4). The interacting effect of secondary industry and economic growth (*ln*SI × *ln*GDP) increases environmental efficiency across developed countries, while it decreases environmental efficiency across developing countries (*see* Model 5). This indicates that secondary industry in developed countries decreases pollution and improves environmental efficiency due to strict environmental regulations, advanced energy structure and adaptation of green technologies. On the other hand, developing countries focused more on rapid industrial growth without worrying about environmental pollution. Furthermore, the interacting effect of tertiary industry and economic growth (*ln*TI × *ln*GDP) decrease environmental efficiency across both developed and developing countries. This indicates that tertiary industry increases pollution and deteriorates environmental quality irrespective of income level or developmental level.

F-statistics and Hansen test are employed to confirm the validity of instruments used in IV-GMM estimation. Cragg-donald F-statistics is used for weak instruments identification [64], which has null hypothesis that instruments are weak. While, Hansen test is used to check the validity of instruments [65], which has null hypothesis that instruments are valid and not over identified. The results of F-statistics and Hansen test confirmed that the instruments are valid and not over identified.

5. Conclusion and policy implications

This research provides fresh evidence on the relationship between industrial structure and environmental efficiency by using three sectors of industry i.e., Primary, Secondary and Tertiary industry. Panel data covers 64 BRI from 2000 to 2017, which are divided into two groups i.e., developed and developing countries. DEA-SBM is used to measure environmental efficiency. Fixed effect (FE) and Random effect (RE) regressions are used as basic estimation techniques, while IV-GMM is employed as a robust estimator to control the issue of endogeneity.

The empirical results show that the environmental efficiency of BRI countries has deteriorated over the years. However, developed countries have a higher average environmental efficiency than developing countries. This is because developed countries care more about environmental issues and have strict environmental regulations as compared to developing countries. The econometric results indicates that all three sectors of industry i.e., primary, secondary and tertiary industry exert a negative effect on environmental efficiency. However, the negative effect of secondary industry on the environment is more severe as compared to primary and tertiary industry. Furthermore, the results show that primary industry decrease environmental efficiency across developing countries, while the impact of primary industry is insignificant across developed countries. This indicates that developed countries might be using advanced technologies in their primary sectors like agriculture, fisheries, and animal husbandry, etc., that neutralized its effect on environmental quality. However, the nonlinear relationship between primary industry and environmental efficiency is not confirmed across developed or developing countries. Secondary industry decreases environmental efficiency across both developed and developing countries. However, the nonlinear U-shaped relationship between secondary industry and environmental efficiency is confirmed only across developed countries. This implies that only developed countries of BRI group have achieved the threshold level to improve environmental efficiency through development. Moreover, the results show that tertiary industry decreases environmental efficiency across both developed and developing countries. However, the negative effect of tertiary industry on environmental efficiency is more severe across developed countries. In addition, the results did not confirm nonlinear relationship between tertiary industry and environmental efficiency across developed or developing countries. Regarding the interacting effect, the results indicate that the interacting effect of primary industry and economic growth ($ln\mathrm{PI} \times ln\mathrm{GDP}$) is insignificant across developed countries, however the interacting effect of ($ln\mathrm{PI} \times ln\mathrm{GDP}$) decrease environmental efficiency across developing countries. The interacting effect of secondary industry and economic growth ($ln\mathrm{SI} \times ln\mathrm{GDP}$) increases environmental efficiency across developed countries, while it decreases environmental efficiency across developing countries. This indicates that secondary industry in developed countries reduces pollution and improves efficiency due to strict environmental regulations, advance energy structure and adaptation of green technologies. Furthermore, the interacting effect of tertiary industry and economic growth ($ln\mathrm{TI} \times ln\mathrm{GDP}$) decrease environmental efficiency across both developed and developing countries. This indicates that tertiary industry promotes pollution across BRI countries irrespective of developmental level.

According to empirical results, policy recommendations are proposed as below.

1) The negative impact of secondary industry on the environment is more severe, especially across developing countries. Thus, it is imperative to promote green technologies and advance energy structure across different sectors of secondary industry especially in developing countries to abate carbon emissions.
2) Belt and Road countries should adopt industrial agglomeration approach to reduce energy consumption and improve environmental efficiency through industrial cooperation and economies of scale.
3) Energy intensity exerts a negative impact on environmental efficiency across both developed and developing countries of BRI group, thus it is important to restructure the energy system and shift the balance from conventional fossil fuels to renewable energy. In addition, energy saving technologies should be used in urban infrastructures to control high energy demand.
4) Belt and road countries should implement strict environmental laws, especially on industrial firms for lower carbon emissions. In addition, governments should increase environmental awareness and green vegetation to decrease pollution.

6. Limitations

This study has several limitations. First, this research focused on 64 BRI countries by dividing them into two groups of developed and developing countries. In future research we expect to cover more countries and divide them into groups based on income level. Such as, low income, lower middle income, upper middle income and high income groups. Second, the data used in this research covers 18 years from 2000 till 2017. In future, we expect to use longer time series.

Authorship contributions

Sulaman Muhammad: Conceptualization, data acquisition, writing, editing, revision. Yanchun Pan: Conceptualization, Supervision, writing, Funding acquisition and revision. Mujtaba Hassan Agha: Writing, editing, revision. Muhammad Umar: Writing, editing, revision. Siyuan Chen: Writing, editing, revision.

Declaration of competing interest

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

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Appendix A

Belt and Road countries classification according to World Bank [4].

Developing countries		Developed countries
Armenia	Laos	Bahrain
Azerbaijan	Malaysia	Brunei
Albania	Macedonia	Czech Republic
Bhutan	Maldives	Croatia
Bangladesh	Myanmar	Greece
Bosnia & Herzegovina	Mongolia	Cyprus
Bulgaria	Moldova	Israel
Belarus	Nepal	Kuwait
Cambodia	Pakistan	Oman
China	Philippines	Poland
Estonia	Palestine	Qatar
Egypt	Romania	Singapore
Georgia	Russia	Slovenia
Hungary	Sri Lanka	Saudi Arabia
Iran	Serbia	Slovakia
Iraq	Syria	UAE
Indonesia	Turkmenistan	
India	Turkey	
Jordan	Thailand	
Kyrgyzstan	Tajikistan	
Kazakhstan	Ukraine	
Lebanon	Uzbekistan	
Latvia	Vietnam	
Lithuania	Yemen	

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