

Article

Evaluating the EKC Hypothesis for the BCIM-EC Member Countries under the Belt and Road Initiative

Arifur Rahman ¹, S. M. Woahid Murad ², Fayyaz Ahmad ¹ and Xiaowen Wang ^{1,*}

¹ Lanzhou Univ, Sch of Economics, Lanzhou 730000, China; arifur16@lzu.edu.cn (A.R.); fayyaz@lzu.edu.cn (F.A.)

² Department of Economics, Noakhali Science and Technology University, Noakhali 3814, Bangladesh; w.murad@nstu.edu.bd

* Correspondence: wxwen@lzu.edu.cn; Tel.: +86-09318915129

Received: 30 December 2019; Accepted: 4 February 2020; Published: 17 February 2020



Abstract: This paper attempts to examine the environmental Kuznets curve (EKC) hypothesis for the BCIM-EC (Bangladesh–China–India–Myanmar economic corridor) member countries under the Belt and Road Initiative (BRI) of China. Both time series and panel data are covered, with respect to carbon dioxide (CO₂) emissions, GDP per capita, energy use, and trade openness. For panel data analysis, GDP per capita and energy consumption have positive effects on CO₂, while the effect of the quadratic term of GDP per capita is negative in the short-run. However, the short-run effects do not remain valid in the long-run, except for energy use. Therefore, the EKC hypothesis is only a short-run phenomenon in the case of the panel data framework. However, based on the Autoregressive Distributed Lag (ARDL) approach with and without structural breaks, the EKC hypothesis exists in India and China, while the EKC hypothesis holds in Bangladesh and Myanmar with regard to disregarding breaks within the short-run. The long-run estimates support the EKC hypothesis of considering and disregarding structural breaks for Bangladesh, China, and India. The findings of the Dumitrescu and Hurlin panel noncausality tests show that there is a unidirectional causality that runs from GDP per capita to carbon emission, squared GDP to carbon emission, and carbon emission to trade openness. Therefore, the BCIM-EC under the BRI should not only focus on connectivity and massive infrastructural development for securing consecutive economic growth among themselves, but also undertake a long-range policy to cope with environmental degradation and to ensure sustainable green infrastructure.

Keywords: BCIM-EC; environmental Kuznets curve (EKC); panel cointegration; ARDL; panel causality test

1. Introduction

The environmental Kuznets curve (EKC) hypothesis suggests that the earlier stage of economic development shows a negative relationship between low GDP per capita and environmental quality, but later, there is a positive relationship between higher level of growth or higher GDP per capita and environmental quality. Grossman and Krueger [1] were the ones to first introduce the idea of the environmental Kuznets curve (EKC), which suggests an inverted U-shaped curve as environmental quality decreases at the initial stage of economic development. However, propensity reverses later as higher-income increases environmental quality. The idea of the EKC was disseminated through a report of the International Bank for Reconstruction and Development IBRD [2] in 1992. The report postulated that more economic activities inexorably hurt the environment, and the demand for a good-quality environment will increase as income increases.

Beckerman [3] proposes that it is obvious that economic development commonly leads to the degradation of the environment in the initial stages of the process, and in the end, the greatest and perhaps only way to obtain a good-quality environment in most countries is to be financially rich. Grossman and Krueger [4] and Selden and Song [5] postulated that a country's economic development does not settle the positive or negative relationship between economic growth and environmental quality. Therefore, it may move from positive to negative depending on the income status of a particular country's citizens, whether they are able to afford the cost or not, and whether there is a demand for a pleasant, healthy environment, etc. Lopez et al. [6] considered emissions as an external effect on the economy. They defined a pollution-income relationship based on the elasticities of the substitution of goods and a household's risk preferences.

Panayotou [7] and Dinda [8] postulated that based on the EKC hypothesis, a production-intensive economy tends to move towards an industrial-based economy, that ultimately leads to a service-based economy over a period of time. The initial stage (e.g., agriculture) is considered to least pollution, and the second stage is related to high pollution as industries generate more waste which affects the natural environment. The final stage is considered to generate less pollution as the service sector extracts fewer resources, becoming more informative and more nonmaterial, etc. Taking into account environmental degradation and using carbon emissions as a proxy variable thereof, we attempted to identify the key variables (GDP per capita, energy use, and trade openness) concerned with carbon emissions by analyzing a more extended period of data.

Economic growth, which is substantially measured by GDP per capita, concerns the environment in all aspects. All economic activities, which are part and parcel of the natural environment and human economic activities, affect environmental quality in various ways. According to a World Bank estimation, the overall output of developing countries will be five times greater by 2030 than today. Based on a report by the National Oceanic and Atmospheric Administration, since 1800, the average world temperature has increased at an average of 0.07° Celsius per decade, and 0.17° Celsius per decade since 1970 owing to pervasive environmental problems, especially carbon intensity. According to the United Nations Framework Convention on Climate Change (UNFCCC), carbon dioxide (CO_2) is the main greenhouse gas; it was also reported that carbon dioxide comprises 75% of greenhouse gasses, ultimately leading to increased global warming and the degradation of the natural climate.

Large-scale economic activities require a large number of inputs that lead to the production of a higher amount of carbon emissions, resulting in environmental pollution. The degradation of the environment endangers the economic activities themselves. To make a steady-state economy and to ensure high environmental quality, economic development or growth of the economy should match with the issues of the environment. With high levels of production due to the demand for goods and services, and with the aim of creating jobs for a vast population, the Bangladesh–China–India–Myanmar economic corridor (BCIM-EC) countries create a lot of manufacturing and heavy industries, resulting in increasing carbon emissions and more energy. The dimensions of environmental quality and the EKC hypothesis vary from place to place and country to country. According to the executive summary report of the Environmental Performance Index (EPI) from 2018, three-fifths of the world's economies have reduced their carbon emissions, as the EKC hypothesis is commonly studied for developed countries by considering their economic growth and environmental indicators.

The BRI is a massive global initiative seeking to enhance connectivity, and the BCIM-EC is one of the six major economic corridors under the BRI of China. The BCIM-EC consists of countries whose GDP per capita and overall economic growth have been noteworthy over the last decade. China and India have accounted for 15% of the total global GDP and have achieved significant GDP growth and economic development during the last decade. The economic conditions in Bangladesh are more positive than ever. The growth of GDP and GDP per capita in Bangladesh and Myanmar also show increasing trends. Populous countries like China, India, and Bangladesh all have environmental concerns linked with the pace of economic growth. The growing demand for goods and services

and newly set-up industries further aggravate environmental problems, resulting in unprecedented changes in the natural environment.

Energy consumption leads to significantly increased carbon emissions. A great number of studies have sought to examine the relationship between energy use and carbon emissions while analyzing the EKC hypothesis (see Ahmad, Hengyi [9], Rahman, CAI [10], Obradović and Lojanica [11], Mohiuddin, Asumadu-Sarkodie [12], Wang, Chen [13]).

Grossman and Krueger [1] explained inverted U-shaped relationships and the nexus between economic growth and emissions on the basis of three different aspects: the scale effect, the composition effect, and the technological effect. The natural environment is affected by trade openness not only by the scale effect, but also by the composition and technological effects (see, Kais and Sami [14] Ertugrul, Cetin [15]). As for the scale effect, economic growth resulting from trade has an adverse effect (negative effect) on the environment, as increases in production negatively effect the natural environment, ultimately leading to increased carbon emissions. However, the composition effect may have the opposite effect, as changing the structures of the economy help reduce pollution. Finally, the technological effect encourages a better quality of the environment as old technologies are replaced by new, environmentally-friendly technologies which cause fewer carbon emissions.

Trade promotes economic growth but at the cost of the environmental degradation. Trade openness determines whether a particular country is more of an importer or exporter than other countries. In general, importing reduces carbon emissions, and exporting increases it. However, trade openness is either positive or negative, as higher trade does not always necessarily mean higher emissions and vice-versa. Therefore, trade openness is expected to have a mixed effect on carbon dioxide (CO₂) emissions, as it varies with each country's environmental situation.

Testing the EKC hypothesis is immensely important as it assumes that economic development is the ultimate solution to environmental degradation. We covered a more extended period of data (with updated GDP constant 2010 US\$) to identify the most robust results by using both panel and the ARDL analyses. We examined the Pooled Mean Group (PMG) proposed by Pesaran and Shin [16], and the recently-developed Common Correlated Effects Mean Group (CCEMG) test proposed by Chudik and Pesaran [17] to reveal the relationships among variables.

The structure of the rest of this paper is as follows: the second section consists of a literature review; the third section discusses the data and methodology used in the EKC studies; the fourth section discusses the empirical results; the fifth section implies the causality test of the model; finally, the sixth section presents the conclusion and the policy implications of this study.

2. Literature Review

Since the EKC hypothesis was developed, a number of studies have been conducted using different applied econometric techniques for different countries to address and investigate it; see Stern, Common [18]; Suri and Chapman [19]; Stern [20]; Munasinghe [21]; Dasgupta, Laplante [22]; Cole [23]; Dinda [24]; Galeotti, Lanza [25]; Jalil and Mahmud [26]; Luzzati and Orsini [27]; Saboori, Sulaiman [28]; Apergis and Ozturk [29].

A comprehensive literature review regarding the EKC hypothesis was presented by Dinda [8] and Stern [30], but the results were inconclusive. Jalil and Mahmud [26] tested the EKC hypothesis in China under the ARDL approach and found long-term relationships between variables (carbon emission to income per capita and carbon emission to energy use).

Ghosh [31] examined the EKC hypothesis in India by using the ARDL approach among variables (growth, energy use, and pollution). He found no support for the EKC hypothesis in long-term relationships and causalities, but some for short-run, bidirectional causality between carbon emissions and economic growth. Jayanthakumaran and Verma [32] sought to describe the cointegration results among the variables (carbon emission, energy use, economic activities, and income) using the ARDL approach in China and India. They found inconclusive results while incorporating the bounds testing approach in their analysis. Kanjilal and Ghosh [33] confined their application of the ARDL approach

to India, as it fails to show the cointegration relationship of the EKC hypothesis. However, they used threshold cointegration and regime-shift that confirmed cointegration and supported the EKC hypothesis. The results show the highly elastic relationships between carbon emissions and per capita income, and carbon emission and energy use. The results implied that a 1% increase in per capita income would lead to a 1.42% increase in carbon emissions and to a 1.46% increase in energy use. Rabbi and Akbar [34] investigated the dynamic relationship of the EKC hypothesis in Bangladesh by using Johansen cointegration and VECM techniques, and found long-term relationships, including short-term adjustments that imply that environmental quality in Bangladesh may improve because of the country's increasing trend of economic growth.

Husain [35] used a dynamic approach with the EKC hypothesis for Bangladesh and India. The results support the inverted U-shaped EKC for Bangladesh and India for the case of a quadratic approach in OLS estimation. The findings also show stronger evidence for an inverted U-shaped EKC in India rather than an N-shaped one, as the elasticity of carbon emissions to the growth of GDP is positive and significant. The outcomes for India are more significant than those of Bangladesh. Most importantly, energy consumption plays a vital role in increasing carbon emissions in India, but not in Bangladesh.

Kang and Zhao [36] explored the EKC hypothesis in China using a spatial panel data technique. The spillover effect ensured an N-shaped instead of a U-shaped curve in China. Carbon emissions are caused by urbanization and the combustion of coal used for various activities. However, trade openness plays a vital role in slightly reducing carbon emissions. Aung and Saboori [37] used the ARDL approach to investigate the existence of the EKC hypothesis in Myanmar and found no evidence in favor of the EKC hypothesis; their findings only suggested a positive relationship between carbon emissions and GDP for both short- and long-run relationships. The results also reported that environmental degradation would improve by increasing trade liberalization and financial openness, as these are negatively associated with carbon emissions.

Solarin and Al-Mulali [38] investigated the long-run cointegration of the EKC hypothesis in China and India by using the ARDL method with structural breaks, and found inverted U-shaped results that supported the EKC hypothesis. Furthermore, the results also suggested that there is a bidirectional relationship between variables (real GDP per capita and the square of real GDP per capita to carbon emissions and vice-versa). Pal and Mitra [39] examined China and India using the ARDL approach, and found that an N-shaped relationship, instead of U-shaped one, existed between carbon emissions and GDP per capita when applying the EKC hypothesis. They ultimately described that with both China and India, carbon emissions first increased (along with low per capita GDP) then decreased as GDP per capita increased. However, they again increased at an increasing rate with the more rapid economic growth.

Sinha and Shahbaz [40] applied the ARDL approach to examine the cointegration of the EKC hypothesis in India, and found that an inverted U-shaped EKC existed. The long-term elasticity of energy consumption was shown to be higher than the short-term one; their findings also showed a negative relationship between trade and carbon emission. Dong and Sun [41], using the ARDL approach in the presence of structural breaks, found results that support the EKC hypothesis for China. The results indicated that alternative energy use, especially nuclear and renewable energy, decreased carbon emissions by 0.0021% and 0.0192%, respectively. Alam and Adil [42] examined the EKC hypothesis in India based on the ARDL approach. The results postulated that no significant evidence existed in favor of the EKC hypothesis. On the other hand, increasing proportionate results have found relationships between energy supply and carbon emissions rather than carbon emissions and economic growth.

Ertugrul and Cetin [15] examined the relationship between CO₂ emissions, real income, trade openness, and energy consumption in the EKC framework over the period of 1971–2011 for the top ten carbon-emitting countries among developing economies. The empirical findings indicated that, for long-term estimates, the main factors of carbon emissions are energy consumption, real income, and trade openness. The results support the EKC hypothesis for India, China, Korea, and Turkey. Shahbaz and Solarin [43] examined the existence of the EKC hypothesis for 19 African countries for the

period of 1971–2012 by using an ARDL bounds testing approach. The findings suggested that only six countries support the EKC hypothesis, and that globalization plays an important role from country to country in decreasing CO₂ emissions. Al-Mulali and Ozturk [44] aimed to investigate the EKC hypothesis for 27 developed countries by using panel data methods. Their results show an inverted U-shaped relationship, which supports the EKC hypothesis.

The environmental issues that have emerged in different stages of the economic growth of BCIM-EC member countries have been gaining increasing attention in recent years. Despite a great quantity of literature examining the EKC hypothesis on an individual country or subregional level, there is still a lack of studies that have examined the causality with respect to carbon dioxide emissions, GDP per capita, energy use, in a subregional context, i.e., the four adjacent countries of the BCIM-EC under BRI, by using both panel and ARDL bounds tests with and without structural breaks. We incorporated Pooled Mean Group (PMG) and Common Correlated Effects Mean Group (CCEMG) to reveal the relationship between the variables that most prior studies did not consider.

Finally, with the above background in mind, this paper attempts to undertake an advanced econometric analysis of both panel cointegration and the ARDL bounds testing approach with and without structural breaks for the BCIM-EC member countries under BRI by fulfilling all the necessary advanced time-series properties.

3. Data and Methodology

Our empirical analysis consisted of the BCIM-EC member countries with respect to carbon emissions, GDP per capita, energy use, and trade openness based on the econometric methods used in the EKC studies. CO₂ or carbon emissions (metric tons per capita) are considered as a dependent variable. On the other hand, GDP per capita (constant 2010 US\$), energy use (kg of oil per capita), and trade openness (sum of merchandise exports and imports divided by the value of GDP, all in current U.S. dollars) are considered as independent variables. The time-series data from 1972–2018 for GDP and trade openness, and 1972–2014 for energy use and carbon emissions, were collected from the website of World Development Indicators [45] for each country in the BCIM-EC.

The basic structure of the EKC hypothesis is as follows:

$$C = f(Y, Y^2, E, T) \quad (1)$$

Where, C denotes CO₂ (carbon emissions per capita), Y denotes real GDP per capita, Y² denotes a square of real GDP per capita, E denotes energy use, and T denotes trade openness. The data have been transformed into a logarithmic format for our empirical analysis and are presented as follows:

$$\ln C_t = \alpha_0 + \alpha_1 \ln Y_t + \alpha_2 (\ln Y_t)^2 + \alpha_3 \ln E_t + \alpha_4 \ln T_t + \varepsilon_t \quad (2)$$

Where, α_0 indicates the intercept. $\alpha_1 > 0$ and $\alpha_2 < 0$ due to the EKC, which is considered as an inverted U-shaped curve. However, the shape of the EKC hypothesis varies from the signs of the parameters. For example, if $\alpha_1 = \alpha_2 = 0$, there is no effect of income on the environment.

Trade openness (sum of merchandise exports and imports divided by the value of GDP) has been extensively used in recent studies examining the EKC framework, as it yields significant results in empirical analyses (see Kisswani and Harraf [46], Ozatac and Gokmenoglu [47], Zhang and Liu [48], Dogan and Turkekul [49]), Ertugrul and Cetin [15], and Kais and Sami [14]). However, α_4 is expected to have a mixed effect on carbon emissions, as it varies with each country's environmental aspects. t denotes time period ($t = 1, 2, 3 \dots, n$). ε_t is a standard error term.

Descriptive statistics of all variables are shown in Appendix A (Table A1) where each of our variable is presented in details of summary statistics including measures of dispersion (e.g. standard deviation) and measures of normality (e.g. skewness, kurtosis, etc).

In contrast to an earlier study, our empirical analysis consisted of both the panel and the ARDL bounds testing approaches, with and without structural breaks for short- and long-term effects to reveal the relationships among the variables.

Thus, to examine the long-term relationships, a modification of Equation (2) of the EKC hypothesis is made, as follows:

$$\begin{aligned} \Delta \ln C_t = & \beta_0 + \sum_{i=1}^a \delta_{1i} \Delta \ln C_{t-i} + \sum_{i=1}^b \delta_{2i} \Delta \ln Y_{t-i} \\ & + \sum_{i=1}^c \delta_{3i} \Delta (\ln Y)_{t-i}^2 + \sum_{i=1}^d \delta_{4i} \Delta \ln E_{t-i} \\ & + \sum_{i=1}^x \delta_{5i} \Delta \ln T_{t-i} + \theta_1 \ln C_{t-1} + \theta_2 \ln Y_{t-1} \\ & + \theta_3 (\ln Y)_{t-1}^2 + \theta_4 \ln E_{t-1} + \theta_5 \ln T_{t-1} + \lambda \varepsilon_{t-1} + U_t \end{aligned} \quad (3)$$

Where Δ denotes the difference operator; a , b , c , d , and x denote lag length. θ and δ represent the long- and short-term coefficients, respectively. The error correction term (ECT) or speed of adjustment is denoted by λ , which is simply a one-period lagged value of the estimated residual obtained from Equation (2).

Figures 1–4 illustrate the carbon emissions (metric tons per capita), GDP per capita (constant 2010 US\$), energy use (kg of oil per capita), and trade openness (the ratio of imports plus exports to GDP) in the BCIM-EC countries and the world.

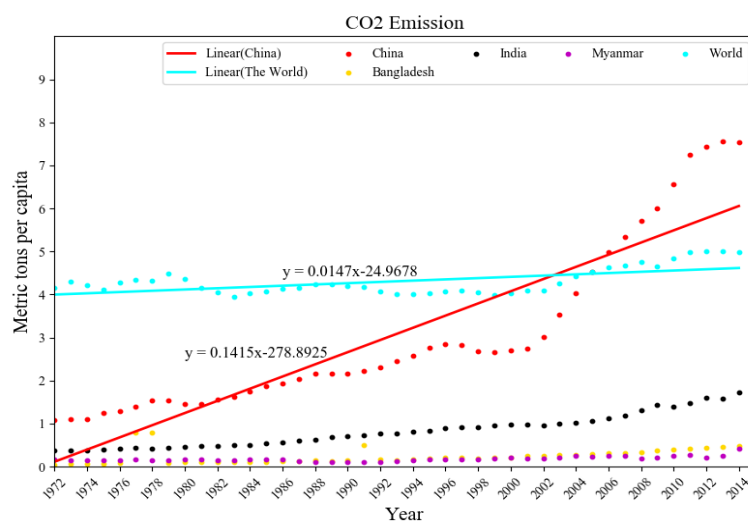


Figure 1. Carbon emissions.

In Figures 1–4, we see a synopsis of the data flow for each country of the BCIM-EC member countries and the world over the period of time. To understand the BCIM-EC member countries' data as a whole, we incorporated a linear regression for the country which surpassed or was close to the world data over the indicated period of time. From the following figures, we can observe the data trends for each variable of each country. Linear regression simply predicts the relationship based on data by following the linear trend. The figures show that during the last two decades, China has experienced rapid economic growth with higher demand for energy use and greater trade openness than other countries, which ultimately lead to increased carbon emissions. All these factors have resulted an unusual trend for China based on the data, whereby the trend of data is increasing at an increasing rate.

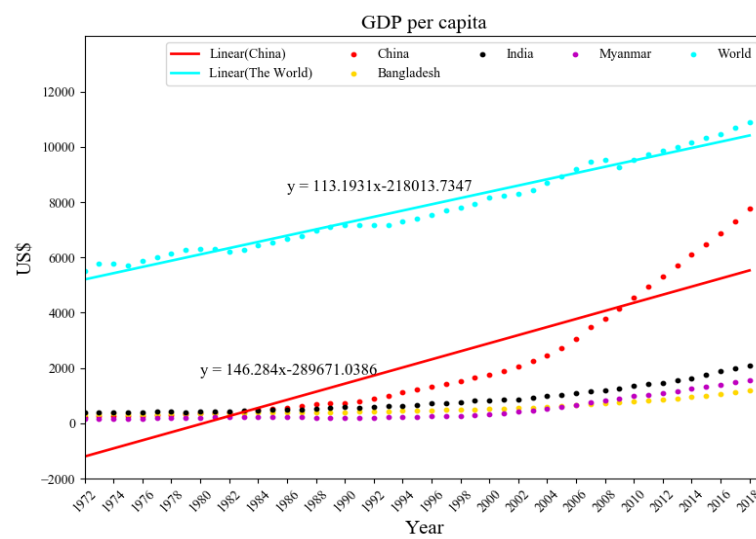


Figure 2. GDP per capita.

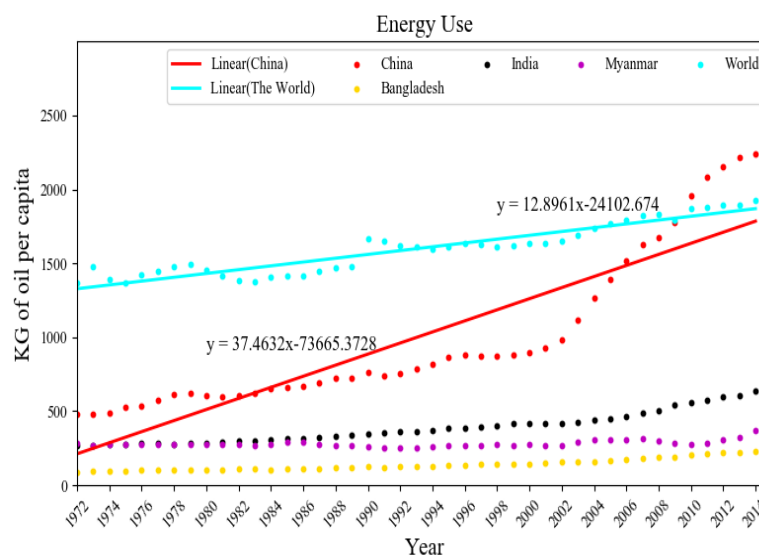


Figure 3. Energy use.

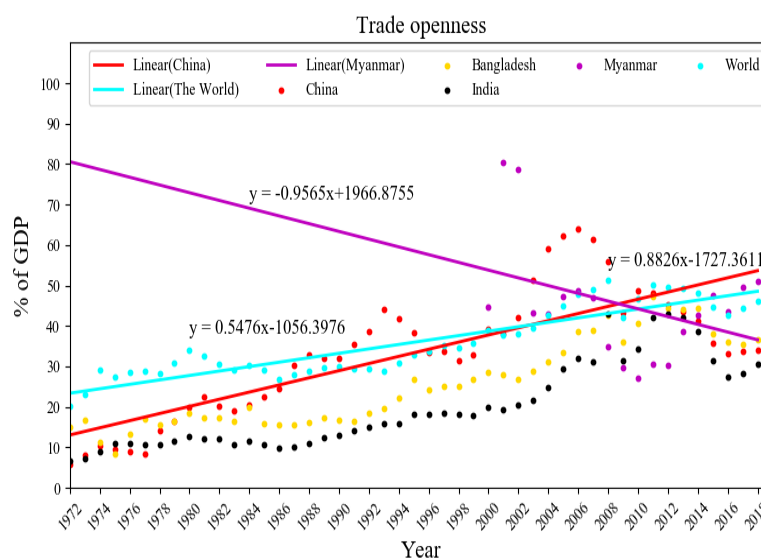


Figure 4. Trade openness.

Both times series and panel data analyses were covered in our empirical analysis using recently developed econometric tools. The ARDL bounds test with and without structural breaks goes into more detail regarding the ARDL bounds test analysis section. We conducted a Dumitrescu and Hurlin [50] noncausality test to examine the causality relationships between the variables.

4. Empirical Results and Discussion

4.1. Panel Unit Root Test

Our analysis started by checking the stationarity of the variables. We considered the first and second-generation panel unit root tests used by Maddala and Wu [51] and the cross-sectional augmented panel unit root (CIPS) test proposed by Pesaran [52]. The results are shown in Table 1, which indicates that the variables in the panel data set are integrated at 1% and 5% levels of significance, respectively.

Table 1. Panel Unit root test.

Variables	Maddala and Wu (MW); [51]		Pesaran (CIPS); [52]	
	First difference		First Difference	
	Intercept	Intercept and trend	Intercept	Intercept and trend
lnC	32.540 ***	26.316 ***	−7.548 ***	−6.848 ***
lnY	26.780 ***	40.472 ***	−7.107 ***	−6.554 ***
lnY ²	23.806 ***	73.399 ***	−6.972 ***	−6.315 ***
lnE	17.936 **	21.965 ***	−6.410 ***	−5.956 ***
lnT	21.605 ***	19.561 **	−8.320 ***	−6.061 ***

Notes: Null hypothesis is H_0 : Variable has a unit root or nonstationary. All variables are in logarithmic format. *** and ** indicate a 1% and 5% level of significance, respectively.

4.2. Cross-sectional Dependence Test

Due to the ambit of four adjacent countries of the BCIM-EC, it comes as no surprise that there may be cross-sectional dependence among the countries of this initiative. To check the cross-sectional dependence with fixed and random effects, we applied the cross-sectional dependence tests proposed by Friedman [53], Frees [54], and Pesaran [55] by using panel data model. Our null hypothesis (H_0) is that variables are cross-sectionally independent, or no cross-sectional dependence exists; the alternative hypothesis, H_1 , is that variables are not cross-sectionally independent or that the variables are cross-sectional dependent. The results of estimation of the fixed and random effects of the cross-sectional dependence test presented in Table 2 show that we can reject the null hypothesis and accept the alternative one as the estimation results in all models are significant, i.e., at a 1% level of significance.

Table 2. Cross-sectional dependence tests.

	Pesaran	Frees	Freidman
Fixed effect estimation	−3.295 ***	1.291 ***	22.789 ***
Random effect estimation	−1.930 ***	0.523 ***	19.592 ***

Notes: *** indicates 1% level of significance.

4.3. Panel Coefficient Estimate Results

The coefficient estimate results of short- and long-run dynamics are presented in Table 3, where we considered carbon emissions as a dependent variable in our empirical analysis. For the panel data analysis, the nexus between carbon emissions and all independent variables of each country of the BCIM-EC were conducted by estimating the Pooled Mean Group (PMG) and the Common Correlated Effects Mean Group (CCEMG) proposed by Pesaran and Shin [16] and Chudik and Pesaran [17],

respectively. The results of the coefficient estimate show that the environment Kuznets curve (EKC) hypothesis is statistically significant regarding short-term dynamics, with a 1% significance level in the case of PMG; however, no significance was found in the case of CCEMG. The long-term relationship does not support the EKC. The findings are only supported in the short-term by the EKC hypothesis, as our test statistics results for variables Y , Y^2 , and E are highly statistically significant but not supported in the long-term, except for energy use in PMG analysis.

Table 3. Coefficient estimate results.

Panel A: Short-Run Dynamics			Panel B: Long-Run Dynamics		
Pesaran et al., [16]		Chudik and Pesaran [17]	Pesaran et al., [16]		Chudik and Pesaran [17]
Variable	PMG	CCEMG	Variable	PMG	CCEMG
ΔY	8.854 *** (2.835)	7.309 ** (3.016)	Y	−2.413 (2.635)	0.170 (4.279)
ΔY^2	−0.730 *** (0.247)	−0.593 ** (0.267)	Y^2	0.253 (0.222)	−0.010 (0.329)
ΔT	−0.0189 (0.0277)	−0.003 (0.013)	T	−0.0063 (0.040)	0.133 (0.129)
ΔE	1.306 *** (0.126)	1.155 *** (0.118)	E	1.791 *** (0.558)	1.535 (0.961)
ECT	−0.135 (0.074)	−0.124 (0.378)			

Notes: All variables are in logarithmic form. Standard errors are in parentheses. ***, ** indicate 1% and 5% levels of significance, respectively.

4.4. Unit Root Test

Besides the panel unit root test, we applied the DF-GLS unit root test proposed by Elliott and Rothenberg [56]. Table 4 shows the test results of the DF-GLS unit root test, which consists of a constant and a trend for all variables for each country of the BCIM-EC.

Table 4. DF-GLS unit root test.

Country	Variable	Lags	Level	Lags	First Difference
Bangladesh	lnC	0	−4.222	0	−6.921 ***
	lnY	6	−1.728	0	−10.192 ***
	lnY ²	6	−1.741	0	−9.871 ***
	lnE	0	−1.233	0	−7.348 ***
	lnT	0	−3.053	0	−6.755 ***
China	lnC	1	−2.281	1	−3.484 **
	lnY	2	−1.805	1	−3.466 **
	lnY ²	2	−1.213	1	−3.352 **
	lnE	1	−1.426	0	−3.788 ***
	lnT	1	−1.104	0	−4.991 ***
India	lnC	0	−1.778	0	−6.116 ***
	lnY	0	−0.446	0	−8.691 ***
	lnY ²	1	−0.171	0	−8.494 ***
	lnE	0	−0.228	0	−6.157 ***
	lnT	0	−2.017	0	−6.575 ***
Myanmar	lnC	0	−1.647	0	−4.538 ***
	lnY	1	−1.112	0	−3.004 **
	lnY ²	1	−1.070	0	−2.987 *
	lnE	1	−1.605	0	−3.472 **
	lnT	0	−1.829	0	−4.348 ***

Notes: Elliott, Rothenberg and Stock [56] critical values are −3.770, −3.190, and −2.890 for 1%, 5%, and 10% significance levels, respectively. ***, **, and * are significant at 1%, 5%, and 10% respectively.

Our null hypothesis (H_0) is that the variable has a unit root or is not stationary; the alternative hypothesis (H_1) is that the variable does not have a unit root or is not stationary. Null hypothesis H_0 is rejected at 1%, 5%, and 10% significance levels, which means variables do not have a unit root, or the first difference of our variables do not have any unit root. Due to the different lag lengths preferred by the Schwarz information criterion (SIC) automatic lag length selection with a maximum of nine lags, the results of the DF-GLS unit root test with a constant and a trend are different.

4.5. Structural Breaks Test

Before conducting the ARDL bounds testing approach, we checked for whether our data have a unit root problem in the presence of structural breaks. To this end, we incorporated the Lee and Strazicich [57] LM unit root test, which considers two endogenously substantiated structural breaks.

The results are shown in Table 5, which presents the structural breaks by year. TB_1 and TB_2 indicate the first and second structural breaks, respectively.

Table 5. Lee-Strazicich LM unit root test with structural breaks.

Country	Variable	TB_1	TB_2	t-sta. (min)	Lags	Bootstrapped Critical Values		
						1%	5%	10%
Bangladesh	lnC	1982	1998	−5.113	0	−6.932	−6.175	−5.825
	lnY	1983	1989	−5.696	8	−6.750	−6.108	−5.779
	lnY ²	1983	1989	−5.938 *	8	−6.750	−6.108	−5.779
	lnE	1990	2000	−3.918	4	−6.978	−6.288	−5.998
	lnT	1993	2008	−7.031 ***	8	−7.004	−6.185	−5.828
China	lnC	1978	2007	−6.850 **	3	−6.932	−6.175	−5.825
	lnY	1982	2004	−6.925 ***	5	−6.691	−6.152	−5.798
	lnY ²	1991	1996	−5.895 *	7	−6.963	−6.201	−5.890
	lnE	1998	2007	−6.327 **	2	−6.932	−6.175	−5.825
	lnT	1987	2003	−7.090 ***	3	−7.004	−6.185	−5.828
India	lnC	1987	1999	−5.137	6	−6.932	−6.175	−5.825
	lnY	1986	1996	−5.696	6	−7.196	−6.312	−5.893
	lnY ²	1986	2001	−5.227	8	−7.004	−6.185	−5.828
	lnE	1993	1998	−6.566 **	5	−6.863	−6.268	5.956
	lnT	1983	2003	−5.599	6	−7.004	−6.185	−5.828
Myanmar	lnC	1982	1995	−5.158	4	−6.750	−6.108	−5.779
	lnY	1986	1998	−6.241 **	3	−6.932	−6.175	5.825
	lnY ²	1986	1998	−6.013 *	3	−6.932	−6.175	5.825
	lnE	1995	2007	−6.260 **	4	−7.004	−6.185	−5.828
	lnT	1982	2008	−5.920 **	1	−6.821	−5.917	−5.541

Notes: All variables are in logarithmic format. ***, **, and * imply the rejection of null hypothesis at 1%, 5%, and 10% significance levels, respectively.

To estimate the ARDL bounds testing approach with and without structural breaks, we considered two dummy variables ($TB = 1$ for $t \geq (\text{break year} + 1)$ and $TB = 0$ otherwise) and incorporated them in Equation (3). Now we can perform the ARDL bounds test with and without structural breaks.

4.6. The ARDL Bounds Test

The ARDL bounds test with and without structural breaks was performed according to the method described by Pesaran and Shin [58]. Our null hypothesis (H_0) is that there is no cointegration between the variables; the alternative hypothesis (H_1) is that variables are cointegrated, i.e., that H_0 is not valid. If the value of F -Statistics is greater than the critical value of the upper bound $I(1)$, then we can conclude that there is cointegration between the variables, meaning that a long-run relationship between the variables exists. Therefore, if the F -Statistics value is higher than the critical values, we can reject the null hypothesis. On the other hand, if the F -Statistics value is lower than the critical value of lower bound $I(0)$, then we can conclude that there is no cointegration between the variables, and we

cannot reject the null hypothesis. Finally, the result will be inconclusive if the *F*-Statistics value falls between the lower (0) and upper (1) *I* bounds.

4.7. The ARDL Bounds Test without Structural Breaks

First, we proceeded with the ARDL bounds test without structural breaks for each country of the BCIM-EC. Our *F*-Statistics results, shown in Table 6, indicate the calculated values, which are higher than the upper bound *I* (1) critical values at a 1% significance level, except for India. For individual country like India, *F*-Statistics is significant at a 10% significance level. *F*-Statistics values are significant for all member countries of the BCIM-EC, indicating that there is a strong long-run relationship between the variables, and that we can apply the ARDL bounds test to establish the long-run relationship.

Table 6. The ARDL bounds test without structural breaks.

Country	<i>F</i> -Statistics	Conclusion	Selected Model
Bangladesh	8.632 ***	Cointegration	ARDL (2,4,4,4,4)
China	6.106 ***	Cointegration	ARDL (4,6,6,3,5)
India	3.898 *	Cointegration	ARDL (4,3,4,2,4)
Myanmar	5.889 ***	Cointegration	ARDL (1,4,4,3,2)
Pesaran, Shin, Smith [58] critical values (k = 4)			
Significance level	Test-Statistics	<i>I</i> (0) Bound	<i>I</i> (1) Bound
10%	F	2.45	3.52
5%	F	2.86	4.01
1%	F	3.74	5.06

Notes: ***, * indicate the rejection of null hypothesis at 1% and 10% significance levels, respectively. Critical values are reported by using the Pesaran, Shin, and Smith [58] critical values (k = 4).

4.8. The ARDL Bounds Test with Structural Breaks

Now we proceed with the ARDL bounds test with structural breaks to identify whether a long-term relationship exists. According to Table 7, the *F*-Statistics value is significant for each country of the BCIM-EC at 1% and 5% significance levels, meaning that there is a long-run relationship between the variables. No inconclusive result existed in our research. Full information on the ARDL bounds test estimation with and without structural breaks, along with the short- and long-term coefficients and diagnostic measures, are presented in Table 8.

Table 7. ARDL bounds test with structural breaks.

Country	<i>F</i> -Statistics	Conclusion	Selected Model
Bangladesh	3.808 **	Cointegration	ARDL (4,3,1,2,2,2,0)
China	19.75 ***	Cointegration	ARDL (2,2,0,0,0,2,0)
India	11.866 ***	Cointegration	ARDL (1,3,1,1,0,1,3)
Myanmar	3.954 **	Cointegration	ARDL (1,1,0,1,1,0,1)
Pesaran, Shin, and Smith [58] critical values (k = 6)			
Significance level	Test-Statistics	<i>I</i> (0) Bound	<i>I</i> (1) Bound
10%	F	2.12	3.23
5%	F	2.45	3.61
1%	F	3.15	4.43

Notes: ***, ** imply the rejection of null hypothesis at 1% and 5% significance levels, respectively. Critical values are reported by using the Pesaran, Shin, and Smith [58] critical values (k = 6).

Table 8. Full information of the ARDL bounds test estimation with and without structural breaks.

i = Bangladesh	Coefficient		Std. Error		t-value	
	ARDL without Break	ARDL with Break	ARDL without Break	ARDL With Break	ARDL without Break	ARDL with Break
Panel A: Short-run estimates						
$\Delta \ln Y_t$	8.791	14.776	16.06	16.927	0.55	0.87
$\Delta \ln Y_{t-1}$	−36.902	0.385	18.307	0.828	−2.02 *	0.47
$\Delta \ln Y_{t-2}$	40.091	0.511	17.53	0.587	2.29 **	0.88
$\Delta \ln Y_t^2$	−0.813	−1.255	1.316	1.400	−0.62	−0.90
$\Delta \ln Y_{t-1}^2$	3.201		1.520		2.11 **	
$\Delta \ln Y_{t-2}^2$	−3.292		1.475		−2.23 **	
ΔT_t	−0.255	−0.075	0.075	0.100	−3.38 ***	−0.75
ΔT_{t-1}	0.127	0.050	0.076	0.057	0.117	0.88
ΔT_{t-2}	0.145		0.073		1.99 **	
ΔE_t	1.961	1.386	0.363	0.392	5.39 ***	3.53 ***
ΔE_{t-1}	−2.665		0.644		−4.14 ***	
$\Delta TB_{1,t}$		−0.071		0.042		−1.69
$\Delta TB_{2,t}$		−0.047		0.041		−1.14
Constant	−52.832	50.976	12.069	15.346	−4.38 ***	−3.32 ***
Panel B: Long-run estimates						
$\ln Y_t$	7.926	10.972	2.099	3.110	3.78 ***	3.53 ***
$\ln Y_t^2$	−0.692	−0.874	0.168	0.215	−4.12 ***	−4.05 ***
T_t	−0.336	−0.234	0.059	0.131	−5.61 ***	−1.78 *
E_t	3.474	2.664	0.387	0.538	8.97 ***	4.95 ***
$TB_{1,t}$		−0.006		0.053		−0.13
$TB_{2,t}$		−0.046		0.037		−1.21
Panel C: Diagnostics Statistics						
R-Squared	0.89	0.84				
Adj R-Squared	0.74	0.66				
ECT_{t-1}	−1.266	−1.031	0.208	0.212	−6.07 ***	−4.86 ***
i = China						
Panel A: Short-run estimates						
$\Delta \ln Y_t$	−1.932	0.790	3.717	0.148	−0.52	5.33 ***
$\Delta \ln Y_{t-1}$	−5.418	−0.217	2.844	0.131	−1.90 *	−1.65
$\Delta \ln Y_{t-2}$	−3.494		1.980		−1.76	
$\Delta \ln Y_{t-3}$	0.636		1.620		0.39	
$\Delta \ln Y_{t-4}$	4.061		2.003		2.03 *	
$\Delta \ln Y_{t-5}$	5.54		1.677		3.31 **	
$\Delta \ln Y_t^2$	0.146	−0.028	0.269	0.011	0.54	−2.47 **
$\Delta \ln Y_{t-1}^2$	0.425		0.207		2.05 *	
$\Delta \ln Y_{t-2}^2$	0.262		0.155		1.69	
$\Delta \ln Y_{t-3}^2$	−0.074		0.129		−0.57	
$\Delta \ln Y_{t-4}^2$	−0.289		0.158		−1.83	
$\Delta \ln Y_{t-5}^2$	−0.438		0.131		−3.34 **	
ΔT_t	−0.019	0.033	0.096	0.023	−0.20	1.40
ΔT_{t-1}	0.048		0.091		0.53	
ΔE_t	0.610	0.828	0.323	0.121	1.89 *	6.84 ***
ΔE_{t-1}	−1.474		0.538		−2.74 **	
$\Delta TB_{1,t}$		−0.041		0.017		−2.39 **
$\Delta TB_{2,t}$		0.058		0.017		3.30 ***
Constant	−26.066	−6.904	10.303	1.227	−2.53 **	−5.62 ***
Panel B: Long-run estimates						
$\ln Y_t$	1.903	0.590	0.396	1.557	4.80 ***	3.79 ***
$\ln Y_t^2$	−0.134	−0.032	0.027	0.119	−4.84 ***	−2.72 **
T_t	−0.193	0.038	0.060	0.029	−3.21 **	1.34
E_t	1.578	0.960	0.107	0.069	14.71 ***	13.90 ***
$TB_{1,t}$		−0.098		0.016		−5.97 ***
$TB_{2,t}$		0.067		0.021		3.09 ***
Panel C: Diagnostics Statistics						
R-Squared	0.97	0.93				
Adj R-Squared	0.90	0.90				
ECT_{t-1}	−1.573	−0.861	0.473	0.090	−3.32 ***	−9.49 ***
i = India						
Panel A: Short-run estimates						
$\Delta \ln Y_t$	8.143	9.309	2.478	1.905	3.29 ***	4.89 ***
$\Delta \ln Y_{t-1}$	−5.994	−0.380	3.359	0.151	−1.78 *	−2.50 **
$\Delta \ln Y_t^2$	−0.663	−0.744	0.197	0.152	−3.35 ***	−4.89 ***
$\Delta \ln Y_{t-1}^2$	0.485		0.266		1.82 *	
ΔT_t	−0.035	−0.145	0.057	−0.477	−0.62	−3.05 ***

Table 8. Cont.

	Coefficient		Std. Error		t-value	
	ARDL without Break	ARDL with Break	ARDL without Break	ARDL With Break	ARDL without Break	ARDL with Break
ΔE_t	1.963	1.490	0.255	0.229	7.68 ***	6.49 ***
ΔE_{t-1}	−2.380		1.025		−2.32 **	
$\Delta TB_{1,t}$		0.030		0.019		1.53
$\Delta TB_{2,t}$		−0.031		0.018		−1.66 *
Constant	−55.718	−26.606	19.166	3.598	−2.91 ***	−7.39 ***
Panel B: Long-run estimates						
$\ln Y_t$	4.961	4.625	0.238	0.358	20.82 ***	12.91 ***
$\ln Y_t^2$	−0.397	−0.326	0.017	0.028	−22.53 ***	−11.63 ***
T_t	0.050	−0.025	0.023	0.029	2.13 **	−0.85
E_t	2.248	1.385	0.090	0.175	24.97 ***	7.88 ***
$TB_{1,t}$		0.049		0.015		3.17 ***
$TB_{2,t}$		−0.037		0.021		−1.71 *
Panel C: Diagnostics Statistics						
R-Squared	0.87	0.84				
Adj R-Squared	0.72	0.72				
ECT_{t-1}	−1.927	−1.075	0.646	0.133	−2.98 ***	−8.04 ***
i = Myanmar						
Panel A: Short-run estimates						
$\Delta \ln Y_t$	16.167	−0.137	13.424	1.054	1.20	−0.13
$\Delta \ln Y_{t-1}$	5.129		16.512		0.31	
$\Delta \ln Y_{t-2}$	32.165		15.104		2.13 **	
$\Delta \ln Y_{t-3}$	29.336		15.104		2.13 *	
$\Delta \ln Y_t^2$	−1.344	0.111	1.235	0.103	−1.09	1.09
$\Delta \ln Y_{t-1}^2$	−0.314		1.550		−0.20	
$\Delta \ln Y_{t-2}^2$	−2.989		1.417		−2.11 **	
$\Delta \ln Y_{t-3}^2$	−2.710		1.439		−1.88 *	
ΔT_t	−0.081	−0.101	0.052	0.022	−1.55	−4.46 ***
ΔT_{t-1}	−0.112		0.044		−2.71 **	
ΔE_t	3.133	2.070	0.681	0.480	4.60 ***	4.31 ***
ΔE_{t-1}	−2.271		0.873		−2.60 **	
$\Delta TB_{1,t}$		−0.003		0.070		−0.04
$\Delta TB_{2,t}$		0.095		0.096		0.99
Constant	−9.807	5.360	11.345	5.501	−0.86	0.97
Panel B: Long-run estimates						
$\ln Y_t$	−6.489	−3.968	4.005	5.927	−1.62	−0.67
$\ln Y_t^2$	0.649	0.372	0.356	0.491	1.82 *	0.76
T_t	−0.021	0.014	0.035	0.056	−0.61	0.25
E_t	4.638	−1.640	0.863	2.175	5.37 ***	−0.75
$TB_{1,t}$		−0.010		0.231		−0.04
$TB_{2,t}$		−0.214		0.190		−1.12
Panel C: Diagnostics Statistics						
R-Squared	0.89	0.78				
Adj R-Squared	0.80	0.70				
ECT_{t-1}	−0.819	−0.3	0.227	0.155	−3.59 ***	−1.94 **

Notes: TB_1 and TB_2 indicate first and second structural breaks, respectively. All variables are in logarithmic format. ***, **, and * imply the rejection of null hypothesis at 1%, 5%, and 10% significance levels, respectively.

4.9. Analysis of the ARDL Bounds Test Results

Besides performing a panel cointegration analysis, we applied an ARDL bounds testing approach with structural breaks in our empirical research to reveal the relationship between the variables. To identify the EKC hypothesis, we evaluated both Equations (2) and (3) for the short- and long-run coefficients estimate, respectively. Table 8 represents all the estimation results for each country of the BCIM-EC. Our expected signs for the inverted U-shaped EKC hypothesis are $\alpha_1 > 0$, $\alpha_2 < 0$, $\alpha_3 > 0$, and α_4 is either positive or negative. Panels A and B present the short- and long-run estimation results, respectively, in the presence of two structural breaks (TB_1 and TB_2).

According to the short-run estimate results of the ARDL approach with and without structural breaks in Table 8, the EKC hypothesis does exist in India in both cases, and in China only after considering structural breaks. For India, the value of GDP per capita parameter $\alpha_1 = 8.143$ and 9.309, i.e., it is positive and significant. Squared GDP per capita parameter yielded $\alpha_2 = -0.663$ and -0.744 ,

i.e., negative and significant. The value of energy parameter was $\alpha_3 = 1.963$ and 1.490 , which is positive and significant; and finally, the trade openness parameter was $\alpha_4 = -0.145$, which is negative and significant in the case of the ARDL bounds test with the breaks. All the test statistics are highly statistically significant at 1% significance level. For India, the results imply that a 1% increase in GDP will lead to an increase in carbon emission of 8.143%, which is a higher value than that presented by Kanjilal and Ghosh [33]. However, in the long-term, the rate of carbon emissions will be 4.961%.

For China, the parameters α_1 and α_2 are significant at 1% and 5% significance levels, respectively, only after considering structural breaks. However, we obtained more significant results in support of the EKC hypothesis in the case of India than China. For short-term estimates, in the case of Bangladesh and Myanmar, the EKC is not as well-supported as it is in the case of India and China. For Bangladesh, the first and second lag estimation of variables Y and Y^2 are not significant (for example, the first differentiation of parameter $\alpha_1 = 8.791$ and 14.776 , which is positive but not statistically significant, and the expected sign of squared GDP parameter is positive instead of negative). For Myanmar, we saw the same phenomena as in the results for Bangladesh. However, for Bangladesh and Myanmar, the immediate impact does not support the EKC hypothesis, but later it becomes significant and does support it.

Based on the long-term estimates of the ARDL bounds test results in panel B with and without structural breaks, as shown in Table 8, the EKC hypothesis was supported for Bangladesh, China, and India, but not for Myanmar. The long-term estimates results show that the coefficient values α_1 and α_2 are significant, as α_1 is greater than 0 and α_2 is less than 0 for all countries except for Myanmar. For example: according to the ARDL bounds test without breaks, the long-term coefficients of α_1 for Bangladesh, China, and India are 7.926, 1.903, and 4.961, respectively. All presented positive values and were significant at 1% significance level, whereas the coefficients of α_2 are -0.692 , -0.134 , and -0.397 for these three countries (i.e., Bangladesh, China, and India). The results of Myanmar, based on ARDL with and without breaks, are $\alpha_1 = -6.489$ and -3.968 ; $\alpha_2 = 0.649$ and 0.372 , which does not fulfill our expected terms, and most importantly, is not statistically significant.

For long-run estimates, the results are highly statistically significant, which ensures the long-term inverted U-shaped of the EKC for the BCIM-EC member countries except for Myanmar. Our expected sign for energy use is positive ($\alpha_3 > 0$), as it has a positive effect on carbon emissions. The results of energy use for each country of the BCIM-EC are significant and positive for both short- and long-run estimates, except for Myanmar (in the case of long-term ARDL estimates with breaks). This implies that an increase in energy use will increase carbon emissions, leading to greater degradation of the environment.

Due to globalization, the production scenarios of developing countries, particularly in the manufacturing and industrial sectors, seem to be showing an increasing trend that will ultimately lead to the production of higher emissions. As a result, the gains from trade at the cost of the environment go from developing countries to developed countries. Developed countries also minimize carbon emissions by capitalizing upon the opportunities of globalization and free trade, implementing better regulations, using more energy-efficient technologies, and transferring “dirty” industries to developing countries, etc. Ertugrul and Cetin [15] showed that in the period from 1990 to 2012, the rate of increase of carbon emissions in developing countries was greater than that of developed countries. Therefore, our expected result for the variable trade openness is mixed. According to Table 8, the trade openness results are negative but significant for Bangladesh in both the short- and long-run. This means that a decrease in trade openness will decrease carbon emissions. In the case of China, it is significant for the long-run when there are no structural breaks. For India and Myanmar, we found mixed results.

The Lagrange Multiplier (LM) test for Autoregressive Conditional Heteroskedasticity (ARCH) in Table 9 shows that there is no sign of ARCH in the context of ARDL analysis. The Breusch-Pagan test (test for heteroskedasticity in a linear regression model) indicates that there is no conditional heteroskedasticity in the model. The diagnostics statistics were followed by the test statistics p -value and the Chi-Square.

Table 9. Details of diagnostics statistics test results of ARDL estimation.

Tests	ARDL without Break		ARDL with Break	
	Chi ²	P > Chi ²	Chi ²	P > Chi ²
Bangladesh				
LM (ARCH)	0.069	0.7930	0.717	0.3973
Breusch-Pagan	0.02	0.8896	0.01	0.9419
Durbin's alternative test for autocorrelation	1.535	0.2154	0.383	0.5259
China				
LM (ARCH)	0.001	0.9815	11.137	0.0008
Breusch-Pagan	0.45	0.5027	0.59	0.4434
Durbin's alternative test for autocorrelation	0.61	0.9952	29.685	0.0000
India				
LM (ARCH)	0.005	0.9415	0.007	0.9334
Breusch-Pagan	1.52	0.2172	1.21	0.2715
Durbin's alternative test for autocorrelation	3.913	0.0479	5.202	0.0226
Myanmar				
LM (ARCH)	0.003	0.9534	1.530	0.2161
Breusch-Pagan	0.89	0.3460	0.50	0.4816
Durbin's alternative test for autocorrelation	4.065	0.0438	6.432	0.0112

Finally, the coefficients of the speed of adjustment or ECT were all highly statistically significant, which indicates that the coefficients would get quickly return to a long-term equilibrium at different rates. For example, in the case of India, our speed of adjustment or error correction term was -1.927 or 192.7% for ARDL without breaks, and -1.075 or 107.5% for ARDL with structural breaks. This means that for ARDL without and with breaks, coefficients would result in a long-term equilibrium at a rate of 192.7% and 107.5% , respectively. Based on ECT, we obtained more significant results than Jayanthakumaran and Verma [32], as their findings failed to obtain substantial ECT results. However, based on the ARDL results, the error correction terms were all more significant than the panel coefficients estimate results. Therefore, the diagnostics statistics tests findings indicate that the model is perfect and well fitted.

5. Causality Test

We finally examined Dumitrescu and Hurlin [50] using the Granger noncausality test. Table 10 reports all the panel causality test results, which show that unidirectional causality exists between carbon emissions and GDP, and squared GDP to carbon emissions. Additionally, we found unidirectional causality between carbon emission and trade openness, as the p -value was highly statistically significant, and the null hypothesis was rejected at a 1% significance level. No bidirectional causality was found between the variables.

Table 10. Dumitrescu and Hurlin [50] Granger noncausality test.

Null Hypothesis	W-bar Stat.	Z-bar Stat.	p -value
Y does not Ganger cause C	3.507	3.546 ***	0.0004
C does not Ganger cause Y	0.683	−0.447	0.654
Y ² does not Ganger cause C	3.570	3.634 ***	0.0003
C does not Ganger cause Y ²	0.843	−0.222	0.824
T does not Ganger cause C	1.195	0.276	0.782
C does not Ganger cause T	3.726	3.856 ***	0.0001
E does not Ganger cause C	0.929	−0.099	0.920
C does not Ganger cause E	1.087	0.123	0.901

Notes: *** indicates 1% significance level.

6. Conclusions and Policy Implications

This paper examined the Environmental Kuznets Curve (EKC) hypothesis for the BCIM-EC member countries, as it is an empirical phenomenon which describes the relationship between economic growth and environmental degradation.

Our analyses consisted of both time series and panel data with respect to carbon dioxide emissions, GDP per capita, energy use, and trade openness. We considered first and second-generation panel unit root tests and the cross-sectional augmented panel unit root (CIPS) test. Additionally, we applied cross-sectional dependence tests by using panel data model. For panel data analyses, we found positive effects of GDP per capita and energy consumption on carbon emissions. On the other hand, the square of GDP per capita was negative in the short-run estimates. For long-run panel data analyses, the short-run effects do not remain valid, except for energy use. Therefore, in the case of panel data analyses, the EKC hypothesis is only a short-run phenomenon.

Besides examining the panel data framework, we applied the ARDL bounds testing approach in the presence of structural breaks. Based on ARDL bounds tests with and without structural breaks, the EKC hypothesis is valid in India and China. In contrast, the EKC hypothesis was shown to be applicable in Bangladesh and Myanmar in the case of disregarding breaks within the short-term. The long-term results of the ARDL approach with and without structural breaks do support the EKC hypothesis for the member countries of the BCIM-EC, except for Myanmar, and the results are highly statistically significant, which indicates a long-term inverted U-shaped for the EKC for India, China, and Bangladesh. Finally, the results of our Dumitrescu and Hurlin panel noncausality test indicated that unidirectional causality exists that runs from GDP per capita to carbon emissions, squared GDP to carbon emissions, and carbon emission to trade openness.

The BCIM-EC member countries have made good progress in almost all criteria of the Millennium Development Goals (MDG), but environmental issues remained one of the severe concerns. The country-level Environmental Performance Index (EPI) is a vital way to measure environmental performance. According to the EPI report of 2018, Bangladesh and India were at the bottom of the EPI rankings. Furthermore, China has experienced severe environmental problems such as hazardous air quality; this has prompted the Chinese government to declare a “war on pollution” by using less coal, imposing better regulations, implementing environmental taxes, and raising funds to ensure a good quality of the environment. As in China, environmental issues can be addressed when the BCIM-EC member countries apply long-term policies (e.g., on trade, energy use, environment protection, etc.) to address the negative externalities on the environment. Governments should always be committed to ensuring a good quality of the environment. Efficient energy use and renewable energy will lead to a reduction of carbon emissions. However, government targets should ensure fewer carbon emissions not by cutting energy usage or imposing energy taxes and tightening regulations, but rather, by raising money to move towards the implementation renewable energy.

Energy-efficiency is crucial at the macro level, but at the same time, it is hard to measure over time. In most cases, the BCIM-EC member countries’ governments own the energy sectors. Taking energy use into consideration, each country needs to formulate its own energy policies. However, the BCIM-EC should not only focus on connectivity and the development of infrastructure in order to secure economic growth domestically, but should also emphasize the transformation of advanced technologies and ensure energy efficiency and renewable energy use through closer connectivity that leads to fewer carbon emissions, e.g., hydro- and bio-energy, etc. Therefore, the BCIM-EC member countries should focus on improving production factors such as energy usage. It is hard and sometimes impossible to completely avoid damage to the environment. On the other hand, it was found that the levels of many environmental quality indicators have improved in developed countries over time thanks to strict regulations and technological improvements. According to the executive summary report of the Environmental Performance Index (EPI), three-fifths of the world’s economies have reduced their carbon emissions.

Future studies may consider the specific region to identify and assess the EKC hypothesis, as the BCIM-EC under BRI consists of four adjacent countries. In addition, to get more accurate results, future studies may consider either exports or imports, as these effect CO₂ emissions differently.

Hopefully, based on our empirical results, the BCIM-EC, under the BRI, will pave the way towards dealing with environmental issues from different vantage points, and reduce environmental degradation while, at the same time, making this as an inclusive initiative.

Author Contributions: Writing—original draft preparation, A.R., S.M.W.M., F.A. and X.W.; data curation, A.R. and S.M.W.M.; writing—review and editing, S.M.W.M., F.A. and X.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by National Philosophy and Social Science Foundation of China, grant number: 17XJL006.

Acknowledgments: The authors are profoundly grateful to the academic editor and three anonymous referees for their valuable comments and suggestions.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Descriptive Statistics.

	C	Y	Y ²	E	T
Bangladesh					
Mean	−1.652	1.829	3.351	4.893	3.159
Median	−1.619	1.813	3.287	4.842	3.190
Maximum	−0.223	1.959	3.837	5.434	3.883
Minimum	−2.937	1.753	3.075	4.479	2.137
Std. Dev.	0.687	0.059	0.218	0.268	0.424
Skewness	0.146	0.671	0.708	0.487	−0.057
Kurtosis	2.233	2.243	2.301	2.151	2.086
Jarque-Bera	1.207	4.641	4.890	2.989	1.659
Probability	(0.546)	(0.097)	(0.086)	(0.224)	(0.436)
China					
Mean	0.953	7.117	51.878	6.793	3.366
Median	0.893	7.110	50.560	6.669	3.520
Maximum	2.022	8.956	80.211	7.712	4.158
Minimum	0.077	5.486	30.105	6.167	1.750
Std. Dev.	0.579	1.117	16.072	0.461	0.595
Skewness	0.435	0.104	0.263	0.710	−1.055
Kurtosis	2.169	1.702	1.762	2.327	3.344
Jarque-Bera	2.596	3.379	3.543	4.429	8.966
Probability	(0.272)	(0.184)	(0.170)	(0.109)	(0.011)

Table A1. Cont.

	C	Y	Y ²	E	T
India					
Mean	−0.284	6.610	43.958	5.928	2.870
Median	−0.248	6.514	42.434	5.898	2.891
Maximum	0.546	7.651	58.548	6.456	3.762
Minimum	−0.980	5.944	35.333	5.588	1.877
Std. Dev.	0.457	0.520	6.999	0.252	0.518
Skewness	0.053	0.448	0.535	0.462	0.197
Kurtosis	1.842	1.949	2.051	2.187	1.937
Jarque-Bera	2.419	3.741	3.999	2.714	2.517
Probability	(0.298)	(0.154)	(0.135)	(0.257)	(0.284)
Myanmar					
Mean	−1.749	5.895	35.301	5.633	3.769
Median	−1.789	5.490	30.144	5.615	3.771
Maximum	−0.881	7.360	54.170	5.911	4.386
Minimum	−2.302	5.085	25.866	5.523	3.299
Std. Dev.	0.294	0.752	9.253	0.071	0.288
Skewness	0.358	0.724	0.804	1.573	0.468
Kurtosis	3.527	1.969	2.101	6.668	3.193
Jarque-Bera	1.421	6.190	6.654	41.864	0.724
Probability	(0.491)	(0.045)	(0.135)	(0.000)	(0.696)

References

- Grossman, G.; Krueger, A.B. *Environmental Impacts of a North American Free Trade Agreement*; National Bureau of Economic Research 1991. working paper 3914; NBER: Cambridge, MA, USA, 1991.
- IBRD. World development report 1992; development and the environment. In *World Development Report 1992; Development and the Environment*; Oxford University Press: Oxford, UK, 1992.
- Beckerman, W. Economic growth and the environment: Whose growth? Whose environment? *World Dev.* **1992**, *20*, 481–496. [\[CrossRef\]](#)
- Grossman, G.; Krueger, A.B. *Environmental Impacts of a North American Free Trade Agreement, The US-Mexico Free Trade Agreement*; MIT Press: Cambridge, MA, USA, 1993.
- Selden, T.M.; Song, D. Environmental quality and development: Is there a Kuznets curve for air pollution emissions? *J. Environ. Econ. Manag.* **1994**, *27*, 147–162. [\[CrossRef\]](#)
- Lopez, R. The environment as a factor of production: The effects of economic growth and trade liberalization. *J. Environ. Econ. Manag.* **1994**, *27*, 163–184. [\[CrossRef\]](#)
- Panayotou, T. Economic Growth and the Environment 2003. In *Economic Survey of Europe: UNECE, no. 2, Chapter 2*; UNECE: Geneva, Switzerland, 3 March 2003; no. 2.
- Dinda, S. Environmental Kuznets curve hypothesis: A survey. *Ecol. Econ.* **2004**, *49*, 431–455. [\[CrossRef\]](#)
- Ahmad, M.; Hengyi, H.; Rahman, Z.U.; Khan, Z.U.; Khan, S.; Khan, Z. Carbon emissions, energy use, gross domestic product and total population in China. *Ekon. I Środowisko* **2018**, *2*, 33–44.
- Rahman, Z.U.; Cai, H.; Ahmad, M. A new look at the remittances-FDI-energy-environment nexus in the case of selected Asian nations. *Singap. Econ. Rev.* **2019**, 1–19. [\[CrossRef\]](#)
- Obradović, S.; Lojanica, N. Energy use, CO2 emissions and economic growth—causality on a sample of SEE countries. *Econ. Res.-Ekon. Istraživanja* **2017**, *30*, 511–526.
- Mohiuddin, O.; Asumadu-Sarkodie, S.; Obaidullah, M. The relationship between carbon dioxide emissions, energy consumption, and GDP: A recent evidence from Pakistan. *Cogent Eng.* **2016**, *3*, 1210491. [\[CrossRef\]](#)
- Wang, Y.; Chen, L.; Kubota, J. The relationship between urbanization, energy use and carbon emissions: Evidence from a panel of Association of Southeast Asian Nations (ASEAN) countries. *J. Clean. Prod.* **2016**, *112*, 1368–1374. [\[CrossRef\]](#)
- Kais, S.; Sami, H. An econometric study of the impact of economic growth and energy use on carbon emissions: Panel data evidence from fifty eight countries. *Renew. Sustain. Energy Rev.* **2016**, *59*, 1101–1110. [\[CrossRef\]](#)

15. Ertugrul, H.M.; Cetin, M.; Seker, F.; Dogan, E. The impact of trade openness on global carbon dioxide emissions: Evidence from the top ten emitters among developing countries. *Ecol. Indic.* **2016**, *67*, 543–555. [[CrossRef](#)]
16. Pesaran, M.H.; Shin, Y.; Smith, R. Pooled mean group estimation of dynamic heterogeneous panels. *J. Am. Stat. Assoc.* **1999**, *94*, 621–634. [[CrossRef](#)]
17. Chudik, A.; Pesaran, M.H. Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors. *J. Econom.* **2015**, *188*, 393–420. [[CrossRef](#)]
18. Stern, D.I.; Common, M.S.; Barbier, E.B. Economic growth and environmental degradation: The environmental Kuznets curve and sustainable development. *World Dev.* **1996**, *24*, 1151–1160. [[CrossRef](#)]
19. Suri, V.; Chapman, D. Economic growth, trade and energy: Implications for the environmental Kuznets curve. *Ecol. Econ.* **1998**, *25*, 195–208. [[CrossRef](#)]
20. Stern, D.I. Progress on the environmental Kuznets curve? *Environ. Dev. Econ.* **1998**, *3*, 173–196. [[CrossRef](#)]
21. Munasinghe, M. Is environmental degradation an inevitable consequence of economic growth: Tunneling through the environmental Kuznets curve. *Ecol. Econ.* **1999**, *29*, 89–109. [[CrossRef](#)]
22. Dasgupta, S.; Laplante, B.; Wang, H.; Wheeler, D. Confronting the environmental Kuznets curve. *J. Econ. Perspect.* **2002**, *16*, 147–168. [[CrossRef](#)]
23. Cole, M.A. Development, trade, and the environment: How robust is the Environmental Kuznets Curve? *Environ. Dev. Econ.* **2003**, *8*, 557–580. [[CrossRef](#)]
24. Dinda, S. A theoretical basis for the environmental Kuznets curve. *Ecol. Econ.* **2005**, *53*, 403–413. [[CrossRef](#)]
25. Galeotti, M.; Lanza, A.; Pauli, F. Reassessing the environmental Kuznets curve for CO₂ emissions: A robustness exercise. *Ecol. Econ.* **2006**, *57*, 152–163. [[CrossRef](#)]
26. Jalil, A.; Mahmud, S.F. Environment Kuznets curve for CO₂ emissions: A cointegration analysis for China. *Energy Policy* **2009**, *37*, 5167–5172. [[CrossRef](#)]
27. Luzzati, T.; Orsini, M. Investigating the energy-environmental Kuznets curve. *Energy* **2009**, *34*, 291–300. [[CrossRef](#)]
28. Saboori, B.; Sulaiman, J.; Mohd, S. Economic growth and CO₂ emissions in Malaysia: A cointegration analysis of the environmental Kuznets curve. *Energy Policy* **2012**, *51*, 184–191. [[CrossRef](#)]
29. Apergis, N.; Ozturk, I. Testing environmental Kuznets curve hypothesis in Asian countries. *Ecol. Indic.* **2015**, *52*, 16–22. [[CrossRef](#)]
30. Stern, D.I. The rise and fall of the environmental Kuznets curve. *World Dev.* **2004**, *32*, 1419–1439. [[CrossRef](#)]
31. Ghosh, S. Examining carbon emissions economic growth nexus for India: A multivariate cointegration approach. *Energy Policy* **2010**, *38*, 3008–3014. [[CrossRef](#)]
32. Jayanthakumaran, K.; Verma, R.; Liu, Y. CO₂ emissions, energy consumption, trade and income: A comparative analysis of China and India. *Energy Policy* **2012**, *42*, 450–460. [[CrossRef](#)]
33. Kanjilal, K.; Ghosh, S. Environmental Kuznet's curve for India: Evidence from tests for cointegration with unknown structural breaks. *Energy Policy* **2013**, *56*, 509–515. [[CrossRef](#)]
34. Rabbi, F.; Akbar, D.; Kabir, S.Z. Environment Kuznets curve for carbon emissions: A cointegration analysis for Bangladesh. *Int. J. Energy Econ. Policy* **2015**, *5*, 45–53.
35. Husain, H. Determinants of environmental degradation and empirical investigation of Kuznets curve: A comparative study of India and Bangladesh. *Asian J. Empir. Res.* **2016**, *6*, 131–141.
36. Kang, Y.-Q.; Zhao, T.; Yang, Y.-Y. Environmental Kuznets curve for CO₂ emissions in China: A spatial panel data approach. *Ecol. Indic.* **2016**, *63*, 231–239. [[CrossRef](#)]
37. Aung, T.S.; Saboori, B.; Rasoulinezhad, E. Economic growth and environmental pollution in Myanmar: An analysis of environmental Kuznets curve. *Environ. Sci. Pollut. Res.* **2017**, *24*, 20487–20501. [[CrossRef](#)] [[PubMed](#)]
38. Solarin, S.A.; Al-Mulali, U.; Ozturk, I. Validating the environmental Kuznets curve hypothesis in India and China: The role of hydroelectricity consumption. *Renew. Sustain. Energy Rev.* **2017**, *80*, 1578–1587. [[CrossRef](#)]
39. Pal, D.; Mitra, S.K. The environmental Kuznets curve for carbon dioxide in India and China: Growth and pollution at crossroad. *J. Policy Modeling* **2017**, *39*, 371–385. [[CrossRef](#)]
40. Sinha, A.; Shahbaz, M. Estimation of Environmental Kuznets Curve for CO₂ emission: Role of renewable energy generation in India. *Renew. Energy* **2018**, *119*, 703–711. [[CrossRef](#)]

41. Dong, K.; Sun, R.; Jiang, H.; Zeng, X. CO₂ emissions, economic growth, and the environmental Kuznets curve in China: What roles can nuclear energy and renewable energy play? *J. Clean. Prod.* **2018**, *196*, 51–63. [\[CrossRef\]](#)
42. Alam, R.; Adil, M.H. Validating the environmental Kuznets curve in India: ARDL bounds testing framework. *OPEC Energy Rev.* **2019**, *43*, 277–300. [\[CrossRef\]](#)
43. Shahbaz, M.; Solarin, S.A.; Ozturk, I. Environmental Kuznets curve hypothesis and the role of globalization in selected African countries. *Ecol. Indic.* **2016**, *67*, 623–636. [\[CrossRef\]](#)
44. Al-Mulali, U.; Ozturk, I. The investigation of environmental Kuznets curve hypothesis in the advanced economies: The role of energy prices. *Renew. Sustain. Energy Rev.* **2016**, *54*, 1622–1631. [\[CrossRef\]](#)
45. WDI. *World Development Indicators, Online Edition*; World Bank: Washington, DC, USA, 2018; Available online: <http://databank.worldbank.org/data/reports.aspx?> (accessed on 22 August 2019).
46. Kisswani, K.M.; Harraf, A.; Kisswani, A.M. Revisiting the environmental kuznets curve hypothesis: Evidence from the ASEAN-5 countries with structural breaks. *Appl. Econ.* **2019**, *51*, 1855–1868. [\[CrossRef\]](#)
47. Ozatac, N.; Gokmenoglu, K.K.; Taspinar, N. Testing the EKC hypothesis by considering trade openness, urbanization, and financial development: The case of Turkey. *Environ. Sci. Pollut. Res.* **2017**, *24*, 16690–16701. [\[CrossRef\]](#) [\[PubMed\]](#)
48. Zhang, S.; Liu, X.; Bae, J. Does trade openness affect CO₂ emissions: Evidence from ten newly industrialized countries? *Environ. Sci. Pollut. Res.* **2017**, *24*, 17616–17625. [\[CrossRef\]](#) [\[PubMed\]](#)
49. Dogan, E.; Turkekul, B. CO₂ emissions, real output, energy consumption, trade, urbanization and financial development: Testing the EKC hypothesis for the USA. *Environ. Sci. Pollut. Res.* **2016**, *23*, 1203–1213. [\[CrossRef\]](#) [\[PubMed\]](#)
50. Dumitrescu, E.-I.; Hurlin, C. Testing for Granger non-causality in heterogeneous panels. *Econ. Model.* **2012**, *29*, 1450–1460. [\[CrossRef\]](#)
51. Maddala, G.S.; Wu, S. A comparative study of unit root tests with panel data and a new simple test. *Oxf. Bull. Econ. Stat.* **1999**, *61*, 631–652. [\[CrossRef\]](#)
52. Pesaran, M.H. A simple panel unit root test in the presence of cross-section dependence. *J. Appl. Econom.* **2007**, *22*, 265–312. [\[CrossRef\]](#)
53. Friedman, M. The use of ranks to avoid the assumption of normality implicit in the analysis of variance. *J. Am. Stat. Assoc.* **1937**, *32*, 675–701. [\[CrossRef\]](#)
54. Frees, E.W. Assessing cross-sectional correlation in panel data. *J. Econom.* **1995**, *69*, 393–414. [\[CrossRef\]](#)
55. Pesaran, M.H. General diagnostic tests for cross section dependence in panels. *J. Econom.* **2004**, *69*. [\[CrossRef\]](#)
56. Elliott, G.; Rothenberg, T.J.; Stock, J.H. *Efficient Tests for an Autoregressive Unit Root*; National Bureau of Economic Research: Cambridge, MA, USA, 1992.
57. Lee, J.; Strazicich, M.C. Minimum Lagrange multiplier unit root test with two structural breaks. *Rev. Econ. Stat.* **2003**, *85*, 1082–1089. [\[CrossRef\]](#)
58. Pesaran, M.H.; Shin, Y.; Smith, R.J. Bounds testing approaches to the analysis of level relationships. *J. Appl. Econom.* **2001**, *16*, 289–326. [\[CrossRef\]](#)

