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The Threshold Level of Economic Growth in BRI and Non-BRI Developing Countries for Better Environmental Quality

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Abstract: *This study investigates the nexus between economic growth and carbon dioxide (CO_2) emissions. Specifically, this study employs a dynamic panel threshold model to identify and compare the threshold levels of economic growth between developing countries participating and not participating in the Belt and Road Initiative (BRI). The findings signify a nonlinear relationship between the sampled countries' economic growth and their CO_2 emissions in both categories. Furthermore, the result of dynamic panel threshold model reveals that the threshold level of economic growth, in the category of BRI developing countries, was lower (US$ 887.49) as compared to non-BRI developing countries (US$ 1358.57). This implies that the impact of economic growth in developing countries participating in the BRI was less harmful to the environment, and that these countries are more alert to environmental issues once the threshold of their gross domestic product per capita was achieved. Hence, Chinese authorities should put in more effort in facilitating sustainable infrastructure development to attract more developing countries to join the BRI to mitigate environmental degradation.*

Keywords: CO_2 emissions; Economic growth; Dynamic panel threshold; Belt and Road Initiative; Developing countries.
JEL Classification: Q43, Q50, Q56

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1. Introduction

Preserving the environment and economic development is paradoxical, especially for developing countries. Significant environmental challenges are always present with large-scale infrastructure development projects. For example, road construction leads to deforestation, and port construction leads to the ballast tanks of ships releasing invasive aquatic species into the sea (Drake & Lodge, 2004). Cement production, the main component of the construction of global infrastructure, has already contributed 5% of global anthropogenic emissions of carbon dioxide (CO_2) (Worrell et al., 2001). This does not even include the environmental consequences of the roads and dams built with concrete made from cement (Doyle & Havlick, 2009).

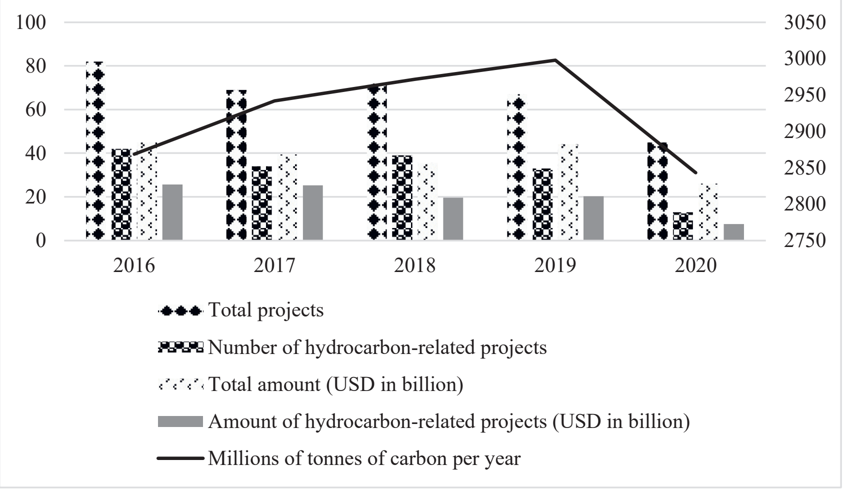
Infrastructure development is cardinal to economic growth and development. However, economic growth is always at the expense of environmental quality, particularly in developing countries. The environmental Kuznets curve (EKC) hypothesis shows an inverted U-shaped relationship between pollution and economic growth. This relationship is closely related to the scale, technique, and composition effects (Grossman, 1995; Copeland & Taylor, 2004; Brock & Taylor, 2006). At first, more output is produced, which implies that more resources and energy are required, and in turn causes a deterioration of environmental quality. This phenomenon is known as the scale effect, which has an adverse impact on the environment at the early stages of economic development. However, the pollution level can be alleviated through technique and composition effects at a later time. For instance, increases in income of developing countries may induce a change to a cleaner production method (technique effect) and a change in economic structure towards a cleaner activity (composition effect), which can lead to improved environmental quality at later stages of economic development.

To date, using different methodologies in either single-country or cross-country groups, a cornucopia of studies have been conducted to confirm the validity of the EKC hypothesis (see Coondoo & Dinda, 2002; Lee & Lee, 2009; Narayan & Narayan, 2010; Ulucak & Bilgili, 2018; Murshed et al., 2020; Pata, 2020; Murshed & Dao, 2022). However, studies concerning the identification of EKC threshold levels remain sparse, particularly in the countries participating in the Belt and Road Initiative (BRI). Undeniably, verifying the validity of the EKC hypothesis is essential; yet, realising its threshold level is indispensable. Hence, to fill this research gap, the present study employs a dynamic panel threshold model to determine the threshold level of economic growth of developing countries participating and not participating in the BRI. This study focuses on developing countries, as most of those participating in the BRI are developing countries that need large inflows of investment for development to achieve sustainable economic growth.

BRI developing countries are compared to non-BRI developing countries given that the initiative is the largest in the world in recent years. The BRI, which was announced by China President Xi Jinping in 2013, is a Chinese-led effort to advocate worldwide economic development and inter-regional connectivity. The BRI involves trillions of dollars' worth of investment, primarily in transportation, energy, telecommunications infrastructure, industrial capacity, and technical capacity building. Undoubtedly, the BRI is the most significant single investment in infrastructure in generations (UNEP, 2021).

The BRI, being the largest mobilisation of Chinese capital to date (Tritto, 2021), promotes the economic growth of participating countries through investment in infrastructure development. However, BRI projects have often been criticised for their environmental track records. According to Zhou et al. (2018), most of the BRI investments in energy and transportation between the years 2014 to 2017 had been tied to fossil fuel projects, which locked participating countries into carbon-emitting fuel sources for decades. Meanwhile, the Global Carbon Budget 2018, as stated in Carey and Ladislaw (2019), also highlights that 74% of the US$ 540 billion energy investment fund from Chinese development banks since 2005 have been invested in hydrocarbon-related projects, which would degrade environmental quality. Moreover, from 2016 to 2019, approximately 50% of BRI projects were hydrocarbon-related and worth over US$ 19 billion—more than 45% of the total amount invested, which contributes to higher carbon emissions (see Figure 1). In view of this, the BRI is said to create long-lasting adverse environmental effects in participating countries and undermines the ability of those countries to meet United Nations (UN) 2030 Agenda for Sustainable Development targets, as they are locked into unsustainable infrastructure and technology development as well as resource extraction (UNEP, 2021). Hence, if the Chinese government, in its stewardship of the BRI, does not overcome these problems, the impact on the environment may be catastrophic.

Figure 1: Number of BRI Projects and Carbon Emissions of Countries Participating in BRI



Note: Carbon emissions refer to the right axis while the number of projects and amount refer to the left axis.
Source: China Global Investment Tracker, American Enterprise Institute (AEI) and Global Carbon Budget 2021, Global Carbon Project.

Partly in response to these criticisms, several Chinese ministries have collectively called for green development that protects and ameliorates societal and ecological environments under the BRI (Belt and Road Portal, 2017; Ministry of Ecology and Environment, 2017). In June 2016, a 'greener' BRI was proposed. This revised version integrates green development with ecological and environmental protection into every aspect of the future development of the BRI, incorporating the principles of energy conservation and environmental protection under the guidance of ecological civilisation and green development concepts (CCICED, 2008).

As the BRI moves forward to become 'greener', participating countries are expected to experience mitigation of environmental pollution after a certain level of economic growth has been reached. Therefore, this study examines if participating countries will benefit from this 'greener' BRI, allowing them to alleviate the issue of pollution as early as possible.

Besides, Horri and Ikefuji (2015) state that apart from economic growth, other factors might also affect environmental degradation. Recent studies have employed multivariate models to conduct analyses to include variables that may affect environmental degradation. Nonetheless, their findings have been inconsistent (see Shahbaz et al., 2013; Al-mulali et al., 2014, Aye & Edoja, 2017; Pata & Caglar, 2021). Owing to the importance of including other important factors in the model, this study takes on board the relevant factors that might affect environmental degradation to produce a comprehensive analysis, while identifying and comparing the threshold levels of economic growth between developing countries participating and not participating in the BRI.

The empirical findings of this study contribute to the current debate on 'greener' BRI sustainability in terms of the link between economic development and the environment by providing an in-depth analysis of the EKC hypothesis, with the identification and comparison of threshold levels for developing countries participating in the initiative. In addition, the outcomes of this study provide insights for policymakers in participating countries to construct effective green energy infrastructure development policies and enjoy economic growth without compromising environmental quality. Furthermore, the findings of this study may pique the interest of non-participating countries in the 'greener' BRI to mitigate the environmental degradation caused by economic development and to achieve the SDGs. Last but not least, the findings may also remind Chinese authorities of the importance of the 'greener' BRI in facilitating sustainable infrastructure development in participating countries.

The outline of the remainder of this paper is as follows: Section 2 reviews related literature; Section 3 depicts the methodology and data used in this study; Section 4 discusses the results, and Section 5 offers concluding remarks.

2. Literature Review

Numerous studies examining the nexus between economic growth and environmental pollution have been published over the last decade. Among these studies, the EKC hypothesis has been a central topic of discussion (Sirag et al., 2017).

Grossman and Krueger (1991) were the pioneers in applying the EKC hypothesis to study the relationship between environmental pollution and economic growth. The EKC hypothesises that environmental pollution will be aggravated at the early stage of economic development. However, this will be mitigated after the country's income per capita reaches a certain level (also known as the income per capita turning point) (Stern, 2004). Graphically, the EKC hypothesis is reflected by an inverted U-shaped curve depicting the relationship between environmental pollution and economic growth. However, it is insufficient to only use economic growth to determine environmental degradation. Therefore, recent studies have included other important factors which might also affect the shape of the EKC and the threshold levels across countries.

In conducting a panel study, Heidari et al. (2015) supported the validity of the EKC hypothesis in the case of the Association of South-East Asian Nations (ASEAN) countries. By applying the panel smooth transition regression (PSTR) model, Heidari et al. (2015) realised that the threshold level of the EKC in five ASEAN countries (Malaysia, Thailand, Indonesia, the Philippines, and Singapore) was reached when the gross domestic product (GDP) per capita reached approximately US$ 4,686. Their study demonstrated that environmental quality deteriorated with economic growth when the GDP per capita was below the threshold level but improved when it rose above the threshold level. Furthermore, Heidari et al. (2015) found that energy consumption increased the level of CO2 emissions, regardless of whether the GDP per capita level was either below or above the threshold level.

By taking into account additional factors, such as energy consumption and trade openness, Sirag et al. (2017) used the dynamic panel threshold method to investigate the EKC hypothesis and estimate the threshold level for developed and developing countries. The samples were disaggregated into three different income groups, low-income, middle-income, and high-income, to reduce the heterogeneity among the sampled countries. The threshold levels for low-income, middle-income, and high-income countries were estimated at US$ 219.20, US$ 3,936.30, and US$ 11,813.50 respectively. The study results showed that the EKC hypothesis held only for high-income countries, and the samples were not separated into different income groups. In addition, Sirag et al. (2017) found that energy consumption was one of the cardinal factors related to CO_2 emissions. In contrast, trade openness was found to be irrelevant to the level of CO_2

emissions.

Similarly, Hanif and Gago-de-Santos (2017) tested the EKC hypothesis for 86 developing countries. Their empirical results confirmed the existence of the EKC in developing economies and found that the threshold level was US$ 984.32. They added that the rationale for having the EKC in the study was that developing countries were eager to improve their national living standards to enjoy prosperity in the short run. However, after reaching the threshold level, the preference of a country's citizens switched to desiring a cleaner environment, and the government would then reorient the country toward green technologies. Other than that, Hanif and Gago-de-Santos noted that economic instability caused by rising populations and poor economic performance in developing economies had an adverse impact to environmental quality. Thus, they suggested that efforts are needed to control rising populations and to adopt stabilising macroeconomic policies to minimise negative impacts on the environment.

On the contrary, the panel study of Ehigiamusoe and Lean (2019) for 122 countries discovered that environmental degradation was aggravated by energy consumption, economic growth, and financial development. Nonetheless, the results differed when the 122 countries were bifurcated into different income groups. The study showed that economic growth and financial development brought positive impacts to environmental quality in high-income countries, while adversely affecting it in middle- and low-income countries. They also noted that energy consumption deteriorated the environment, regardless of income group. Thus, Ehigiamusoe and Lean recommended that these countries should increase the use of renewable energy resources in the entire energy supply chain, and construct policies and activities that would alleviate negative environmental impact.

Considering that energy consumption plays a moderating role in the relationship between GDP and CO_2 emissions, Ehigiamusoe et al. (2020) used multiplicative interaction models to examine the EKC hypothesis. The results found no evidence of EKC and no evidence that energy consumption moderates the CO_2 emission-income nexus in the panel study of 64 middle-income countries. However, country-specific analysis showed conflicting results. Firstly, the study found that the EKC hypothesis was supported in approximately one-third of middle-income countries studied, while the rest were either inverted EKC or insignificant. Similarly, only a third of the middle-income countries showed that energy consumption moderates the

CO_2 emission-income nexus, while the others did not. Ehigiamusoe et al. claimed that this variance may be due to the implementation of different energy policies, environmental regulations, and industrial or service sector activities in the countries studied.

Furthermore, the findings of Ehigiamusoe (2020a), which includes diverse electricity sources and renewable electricity output as variables when determining the EKC in 25 African countries, confirmed the validity of hypothesis. It demonstrated that a 1% increase in real GDP per capita led to an increase of carbon emissions by 2.305 percentage points at the early stage of economic growth, and a drop of 0.096 percentage points after a certain level of growth was achieved. Simultaneously, the empirical results showed that clean electricity sources, such as hydro and renewable electricity output, mitigate carbon emissions, while electricity sources like natural gas, oil and coal intensify it. Thus, Ehigiamusoe emphasized the importance of using clean electricity sources in order to achieve sustainable development.

In another study, Ehigiamusoe (2020b) examined the validity of the EKC hypothesis in ASEAN with the inclusion of China. The study found evidence of the hypothesis in ASEAN, which was weakened with the inclusion of China. Besides, his study revealed that financial development favourably moderated the impact of energy consumption on environmental degradation. On the other hand, with the inclusion of China, financial development was found to adversely moderate the impact of energy consumption on the environment, which may be due to a greater proportion of loans going to products that produce carbon emissions. Meanwhile, the study found that urbanisation adversely moderated the impact of energy consumption on the environment in both cases, due to the concentration of economic activities and heavy vehicular traffic movement.

In their study on emerging economies, Dogan et al. (2020) found that environmental pollution was exacerbated in Brazil, Russia, India, China, South Africa, and Turkey (BRICST) even past the income threshold level. This result implied that the EKC hypothesis does not hold for BRICST countries. Nonetheless, the results showed that population, energy intensity and energy structure were important factors that impacted the environment. As income rises are unable to rectify environmental degradation, the researchers suggested that additional measures—such as environmental regulation and management, and incentives for green technological progress—should be put into practice.

However, Dogan and Inglesi-Lotz (2020) found mixed results when using different indicators as proxies for the economic structures of European countries. The study confirmed that the EKC hypothesis was invalid when using industrial share as a proxy for economic structure. In contrast, the hypothesis was valid when aggregate GDP growth was considered. In addition, Dogan and Inglesi-Lotz also suggested that living standards and purchasing power were cardinal to higher economic growth rates, as higher income levels lead people to become more demanding in terms of the environment.

Likewise, an inconsistent result was found in the study of Isik et al. (2021), when the GDP per capita data were decomposed. Their empirical results indicated that a model with decomposed GDP per capita did not support the EKC hypothesis in each of the eight Organisation for Economic Co-operation and Development (OECD) countries studied. In contrast, a model with undecomposed GDP per capita supported the EKC hypothesis in four of the eight countries studied. Moreover, increases in trade openness and energy consumption were shown to aggravate the level of environmental pollution in both models—except for the energy consumption of Canada, which was found to have a positive impact on the environment in the decomposed model.

By diverging into different sectors in Malaysia, Ehigiamusoe et al. (2021) found that the growth of the agricultural, industrial, and service sectors degraded the environment at the early stage of development. Sectoral growth would only mitigate CO_2 emissions and ecological footprints after achieving the threshold level of 11% (agricultural), 44% (industrial) and 49% (services) of the GDP. In contrast, the growth of the financial sector showed a U-shaped nonlinear nexus with CO_2 emissions and ecological footprints, and the turning point was 94% of the GDP.

In view of the important role of renewable energy consumption on carbon emissions, Ehigiamusoe and Dogan (2022) examined the interaction effects of real income and renewable energy consumption on carbon emissions in low-income countries. The results showed that renewable energy enhanced environment quality, but with a positive interaction effect on carbon emissions. In addition, the marginal effect of renewable energy on emissions differed with real income levels. Hence, Ehigiamusoe and Dogan (2022) argued that relevant policies and regulations that promote the use of renewable energy should be implemented, and policymakers should not only focus on renewable energy level and real income level, but also the interaction effect to ensure development that is not at the expense of environmental quality.

Taking energy consumption, financial development, and urbanisation into account, Ehigiamusoe et al. (2022) affirmed the existence of the EKC hypothesis in 31 African countries when the environmental quality was proxied by CO_2 emissions. The empirical result demonstrated that a 1% increase in GDP would lead to a rise of CO_2 emissions by 1.44 percentage points, while a 1% increase in GDP squared diminished the CO_2 emissions by 0.048 percentage points. However, the study did not confirm the EKC hypothesis when environmental quality was proxied by ecological footprint. The researchers observed that this is due to CO_2 emissions and ecological footprint being different measures of environmental quality. For instance, the prior variable is the main contributor of greenhouse gases which reduces environmental quality, while the latter is an index which evaluates environmental pressures on the ecosystem from human activities (Rudolph & Figge, 2017).

As the findings of previous studies have been mixed, and with China proposing a 'greener' BRI, it is worthwhile to study if the developing countries participating in the initiative can gain favourable impacts in terms of environmental quality, by way of confirming the EKC hypothesis and identifying the threshold level of BRI and non-BRI developing countries.

3. Methodology and Data

3.1 Theoretical framework

Following Ekins (1993), the *World Development Report* published in 1992 postulated that there might be a trade-off between economic growth and environmental protection. However, the report proved that gains from both economic growth and environmental protection were possible if severe poverty was eliminated. The report suggested stimulating economic growth to achieve higher income and improved environmental protection (Ekins, 1993). This proposal laid the foundation for the EKC in the early 1990s.

According to Kaika and Zervas (2013), the EKC hypothesis illustrates that an acceleration of economic growth could improve environmental quality after an economy has reached a threshold of growth. In the early stages, there is a positive relationship between economic growth (income per capita) and environmental pollution. However, further economic growth, improved services, technology advancement, and information diffusion can reduce environmental pollution.

Besides, at higher income levels, consumers start valuing the environment more and therefore start demanding a better-quality environment at higher stages of economic growth (Gill et al., 2018). Hence, the EKC hypothesis illustrates that environmental pollution increases with higher income per capita during the early stages of economic growth and decreases with higher income per capita at the later stages of economic development (Gill et al., 2018). Based on the above condition, the EKC has an inverted U-shape. Gill et al. (2018) further reveals that technological advancement and more environmentally friendly preferences take place in a dynamic instead of a static economy, and that economic growth was the key instead of a threat to environmental protection.

3.2 Empirical model

This study follows the empirical specification in Ozcan (2013) to measure the relationship between economic growth (GDP) and the emission of carbon dioxide (CO_2), as follows:

$$CO_{2it} = \beta_1 CO_{2it-1} + \beta_2 GDP_{it} + \beta_3 EC_{it} + \beta_4 TO_{it} + \epsilon_{it} \quad (1)$$

where CO_{2it} is the emission of carbon dioxide of a country i at time t, *GDP* is the gross domestic product per capita, *EC* is the primary energy consumption per capita, *TO* is trade openness and ϵ_{it} is the residual term. The signs of β_3 and β_4 are expected to be positive. This is because an increase in energy consumption will lead to an increase in CO_2 emission; and an increase in trade will result in an increase in the economy size and eventually increase pollution as well.

Considering that the relationship between economic growth and the emission of CO_2 can be nonlinear, this study estimated Equation (1) using the dynamic panel threshold method from Kremer et al. (2013) as follows:

$$\begin{aligned} CO_{2it} = {} & \alpha_i + \gamma_1 CO_{2it-1} + \gamma_2 GDP_{it} I(GDP_{it} \leq \lambda) + \gamma_3 I(GDP_{it} \leq \lambda) + \\ & \gamma_4 GDP_{it} I(GDP_{it} \geq \lambda) + \gamma_5 EC_{it} + \gamma_6 TO_{it} + \epsilon_{it} \end{aligned} \quad (2)$$

where α_i is the country-specific-effect and ϵ_{it} is the residual where $\epsilon_{it} \sim (0, \sigma^2)$. This study set the GDP per capita as the threshold variable, and λ was the unknown threshold parameter. The indicator function I was used to distribute the sample into regimes concerning the threshold variable. Besides, this study treated the lagged dependent variable CO_{2it-1} as endogenous, while the other variables were treated as exogenous.

In addition, to test for potential nonlinearity between economic growth and the emission of CO_2, this study applied the quadratic model as follows:

$$CO_{2it} = \beta_0 + \beta_1 CO_{2it-1} + \beta_2 GDP_{it} + \beta_3 GDP_{it}^2 + \beta_4 EC_{it} + \beta_5 TO_{it} + \epsilon_{it} \quad (3)$$

Equation (3) was estimated using the generalised method of moments (System-GMM) estimation technique.

3.3 Data

To get a complete data set, we filtered the sample to exclude missing values. After filtering, only 76 countries participating in the BRI and 21 developing countries not participating in the BRI provide the complete data set from 2002 to 2016 (the list of countries is provided in Appendix 1). Besides, to apply the system GMM estimation and smoothing the effect of fluctuations (Law & Singh, 2014), this study averaged the data over five years. There were three observations for each country.

This study employed the real GDP per capita as the proxy for the income level, carbon dioxide emissions (CO_2) per metric ton per capita as the proxy for environmental quality, per capita total energy consumption was measured by British thermal units (Btu) as the proxy for energy consumption, and the ratio of total trade to the GDP as the proxy for trade openness. All the data were collected from the World Bank, World Development Indicators (WDI), except for the data concerning energy consumption, which were obtained from the United States (US) Department of Energy, Energy Information Administration (EIA).

4. Results

The data obtained for developing countries were divided into two categories, namely, developing countries participating in the BRI and developing countries not participating in the BRI. The main aim of dividing the developing countries into BRI and non-BRI countries was to observe if there were differences in terms of the impact of economic growth on environmental quality. Tables 1 and 2 below show the descriptive statistics and the correlation matrix for each of the two categories.

Table 1: Descriptive Statistics

Variable	Obs.	Mean	Max	Min	Std. Dev.
BRI					
CO_2	228	0.416	3.197	-3.673	1.558
GDP	228	8.072	10.144	5.419	1.236
EC	228	-10.558	-7.464	-14.378	1.560
TO	228	-0.077	17.756	-1.429	2.098
Non-BRI					
CO_2	63	-0.055	1.530	-3.773	1.183
GDP	63	7.962	9.360	5.675	0.929
EC	63	-10.802	-9.311	-13.515	1.131
TO	63	-0.314	0.323	-1.706	0.515

Source: Authors' own.

The correlation matrix displayed in Table 2 shows that the correlation coefficient between each pair of variables was significant at the 1% significance level for each category. This implied an interrelationship among the variables.

Table 2: Correlation Matrix

	CO_2	*GDP*	*EC*	*TO*
BRI				
CO_2	1			
GDP	0.904*	1		
EC	0.973*	0.904*	1	
TO	0.249*	0.277*	0.260*	1
Non-BRI				
CO_2	1			
GDP	0.883*	1		
EC	0.732*	0.730*	1	
TO	-0.106*	-0.184*	-0.164*	1

Note: * indicates correlation coefficient is significant at the 1% level.

Source: Authors' own.

After that, a dynamic panel threshold model was adopted to identify the threshold value and investigate the differences between BRI and non-BRI countries. The threshold used for this model was GDP per capita, as per the EKC hypothesis. From the regression results shown in Table 3, the threshold for the countries participating in the BRI was US$ 887.49, while it was US$ 1358.57 for non-BRI countries.

Table 3: Dynamic Panel Threshold Model

	BRI (1)	**Non-BRI (2)**
Threshold λ	6.788 {887.14}	7.222 {1369.22}
Confidence Interval (95%)	[6.149 8.639]	[6.532 7.542]
$GDP_{it}\ I(GDP_{it} \leq \lambda)$	0.354** (0.166)	1.872* (0.234)
$I(GDP_{it} \leq \lambda)$	-1.153 (0.967)	-7.380 (0.635)
$GDP_{it}\ I(GDP_{it} \geq \lambda)$	0.196* (0.040)	0.795* (0.147)
CO_{2it-1}	1.755* (0.197)	0.393* (0.147)
EC_{it}	-0.849 (0.175)	-0.224 (0.017)
TO_{it}	-0.092 (0.036)	-0.048 (0.020)
Observation	228	63
N	76	21
Observation below λ	45	12

Notes: The standard errors are reported in ( ), the values of the threshold in US$. The unit of GDP growth is reported in { }, the 95% confidence intervals are reported in [ ]. *, ** indicate significant at 1%, 5% level, respectively.
Source: Authors' own.

The results for developing countries participating in the BRI implied that the GDP per capita was positive and significant both below and above the threshold. This result did not validate the EKC hypothesis, which was similar to the findings of both Aye and Edoja (2017), Dogan et al. (2020) and Villanthenkodath et al. (2021). However, it showed that the impact of the GDP per capita on CO_2 emissions reduced by 44.7% (from 0.354 to 0.196) when the GDP per capita was above the threshold. In a nutshell, the result implied that developing countries participating in the BRI would become more aware of environmental issues once they achieved a certain level of economic growth. A similar pattern was found for developing countries not participating in the BRI. In this group, the magnitude of the positive impact of the GDP per capita on CO_2 emissions reduced from 1.872 to 0.795 once the countries' GDP per capita increased from below to above the threshold.

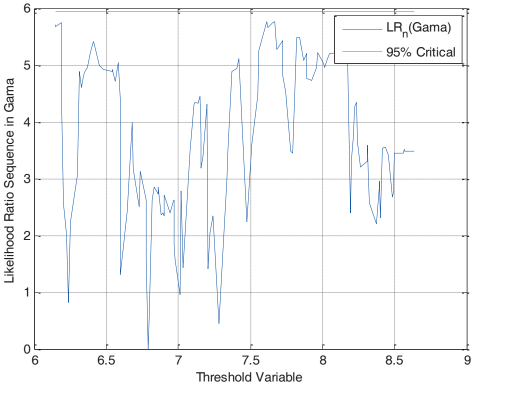
The main difference between these two groups of countries was that the impact of the GDP per capita on environmental issues was less harmful. The countries were more aware of ecological problems once their GDP per capita had achieved and moved beyond the threshold for BRI countries than that of non-BRI countries. This result might be contributable to the economic integration of the countries participating in the BRI. BRI countries exchange a flow of ideas to preserve the environment, despite emphasising economic growth.

All in all, although the EKC hypothesis was not validated, the results signified that the countries participating in the BRI were more aware of environmental issues as their income levels became higher and, therefore, the impact of GDP per capita on CO_2 emissions dropped significantly when income levels rose above the threshold. Besides, the findings revealed that both energy consumption and trade openness had no significant impact on the level of CO_2 emissions for the two categories. The result is similar to that of Salam and Xu (2021) as the authors found that trade openness among BRI member countries has no significant impact on CO_2 emissions. Likewise, Sirag et al. (2017) found that trade openness was irrelevant to the level of CO_2 emissions while energy consumption was insignificant to the level of CO_2 emissions for low-income countries. In a nutshell, the findings implied that energy consumption and trade openness, which both accelerate the economic growth of nations, would not significantly contribute to the environmental degradation of the countries studied, as the type of energy consumed and trade expansion owing to trade openness gradually skewed towards environmentally friendly.

Figure 2 shows that the Likelihood Ratio (LR), which was less than 6, was smaller than that of 95% of the critical value of asymptotic distribution, which was 6.788, as shown in Table 1. Similarly, the LR of Figure 3, which was less than 6, was smaller than that of the critical value of 7.222. In conclusion, the results indicated the threshold variable validity between the GDP per capita, which proxied economic growth, and CO_2 emissions, which proxied environmental pollution. In addition, the curves in Figures 2 to 3 also signified the nonlinearity between the GDP per capita and CO_2

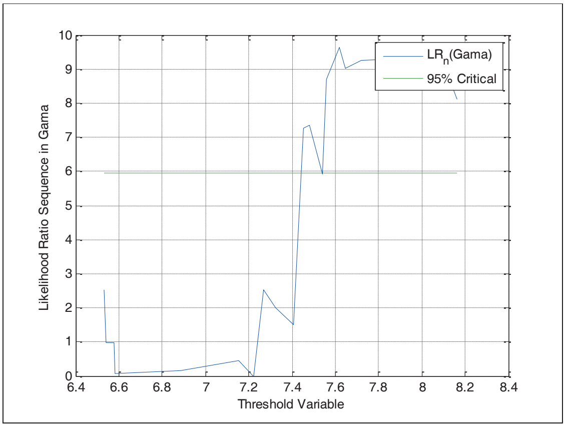
emissions.

Figure 2: BRI Countries



Source: Authors' own.

Figure 3: Non-BRI Countries



Source: Authors' own.

The system GMM estimation technique was also adopted in this study to examine the EKC curve based on the quadratic model. The results of the system GMM estimation are shown in Table 4. Based on the regression results, the thresholds for BRI countries and non-BRI countries were US$

910.61 and US$ 250,196.03 respectively. Like the dynamic panel threshold model results, the countries participating in the BRI had the lower threshold value. However, both threshold values were much higher than the results generated from the dynamic threshold model.

Table 4: System GMM

Variables	**BRI (1)**	**Non-BRI (2)**
Threshold $\lambda = \lvert \frac{\beta_2}{2\beta_3} \rvert$	6.814 {910.51}	12.430 {250,196.03}
GDP_{it}	4.429 (2.139)**	2.486 (0.761)
GDP_{it}^2	-0.325 (0.144)**	-0.100 (0.340)
CO_{2it-1}	2.598 (1.415)***	0.129 (0.761)
EC_{it}	-0.605 (0.979)	0.015 (0.435)
TO_{it}	0.120 (0.168)	-0.176 (0.647)
Constant	-20.816 (16.856)	-13.458 (23.980)
Observation	228	63
N	76	21
Sargan Test (p-value)	0.98	1.00
Autocorrelation of Order 2 (p-value)	0.45	0.99

Notes: The standard errors are reported in (), the values of the threshold in $US. The unit of GDP growth is reported in {}. **, *** indicate significant at 5% and 10% levels, respectively.
Source: Authors' own.

It is noticeable that the GDP (GDP per capita) and the GDP^2 (the square of GDP per capita) were significant only for the countries participating in the BRI. The GDP was positive and significant at the 5% significance level, while the GDP^2 was negative and significant at the 5% significance level. Hence, the findings from the countries participating in the BRI supported and validated the EKC hypothesis, where the EKC reflected an inverted U-shape, which was similar to the results of Ali et al. (2021), Hanif and Gago-de-Santos (2017) and Heidari et al. (2015) but was different from the results derived from the dynamic panel threshold model. The results revealed that the countries participating in the BRI would be more alert and concerned about environmental pollution or degradation than the countries not participating in the BRI as according to Tyler (2021), BRI is now focusing on green development via the investments in green technology and low-carbon infrastructure. On the other hand, the countries not participating in the BRI showed different results as the GDP and GDP^2 were not significant. Apart from the above, the system GMM estimator showed that all other variables, i.e., EC and TO, were not significant in influencing CO_2 emissions. These findings were similar and consistent with the result derived from the dynamic threshold model and aligned with the findings of Salam and Xu (2021), and Sirag et al. (2017). However, according to Sirag et al. (2017), GMM estimator findings might overstate the threshold value compared to the dynamic panel threshold model, which aims to test the nonlinear relationship and, therefore, produce a more precise estimation of the threshold (the turning point). This can be proven by the regression result, where the threshold values for all categories under the GMM estimator were higher than those of the dynamic threshold model. Hence, the results from the system GMM estimator were used only for comparison and reference purposes.

5. Conclusion and Policy Implication

This study compares the threshold of economic growth between countries participating and not participating in the BRI and examined the validity of the EKC in both categories. This study used a nonlinear estimating technique, namely, the dynamic panel threshold model, as it was the most appropriate method to treat the data. Besides, the GMM estimation method was also conducted to compare the results derived from both approaches. This study divided the data into two categories: BRI and non-BRI countries.

The findings signified a nonlinear relationship between GDP and CO_2 emissions for all categories under the dynamic panel threshold model. However, the empirical results failed to validate the EKC.

Nonetheless, the results revealed that the threshold values for BRI countries were lower than that of non-BRI countries. Therefore, as a comparison, this finding implied that the impact of GDP per capita of countries participating in the BRI was less harmful and more alert to environmental issues once the threshold of their GDP per capita was achieved and passed. As a result, these findings may encourage more developing countries to join BRI and to participate in its discussions and summits that formulate common policies to mitigate environmental issues attributable to the infrastructure development of BRI projects.

Besides, this study revealed that energy consumption and trade openness did not contribute to environmental degradation significantly for both categories. This result implied that companies in these countries have started to become aware of the importance of the UN Sustainable Development Goals (SDGs), particularly SDG 7 that focuses on affordable, reliable, sustainable, and modern energy, and SDG 12 on sustainable consumption and production patterns. These ensure that energy consumption and trade openness will not cause a significant harmful impact on the environment. However, according to the UN (2021), the awareness of the SDGs is still at the infancy level for developing countries. The policymakers should continue to enhance adherence to the SDGs so that BRI and non-BRI participating countries can enjoy economic growth and a clean environment at the same time.

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Appendix 1: List of BRI and Non-BRI Participating Developing Countries

BRI participating developing countries	Albania, Algeria, Angola, Armenia, Bahrain, Bangladesh, Belarus, Benin, Bolivia, Bulgaria, Burundi, Cambodia, Cameroon, Chile, Comoros, Costa Rica, Croatia, Cuba, Czech Republic, Dominican Republic, Ecuador, Egypt, Estonia, Gabon, Hungary, Indonesia, Iran, Kazakhstan, Kenya, Kyrgyzstan, Laos, Latvia, Lebanon, Lesotho, Liberia, Lithuania, Madagascar, Malaysia, Mali, Malta, Mauritania, Moldova, Morocco, Mozambique, Namibia, Nepal, Niger, Nigeria, North Macedonia, Oman, Pakistan, Panama, Peru, Philippines, Poland, Romania, Russia, Rwanda, Saudi Arabia, Senegal, Sierra Leone, Slovakia, Slovenia, South Africa, South Korea, Sri Lanka, Tanzania, Thailand, Togo, Turkey, Uganda, Ukraine, Uruguay, Uzbekistan, Vietnam, Zimbabwe
Non-BRI participating developing countries	Argentina, Belize, Bhutan, Botswana, Brazil, Burkina Faso, Colombia, Congo-Brazzaville (Congo Republic), Congo-Kinshasa (Congo Democratic Republic), El Salvador, Eswatini (Swaziland), Guatemala, Haiti, Honduras, India, Jordan, Mauritius, Mexico, Nicaragua, Palestinian Territories (West Bank and Gaza), Paraguay