Working Paper 2024.1.4.4
- Vol 1, No 4

REVISITING THE VALIDITY OF ENVIRONMENTAL KUZNETS CURVE (EKC) IN SIX ASEAN COUNTRIES: COMPOSITE MODEL

Huỳnh Thị Thắm[1], Lê Thị Thanh Tâm

Sinh viên K61 CLC6 - Kinh tế đối ngoại

Trường Đại học Ngoại thương Cơ sở II, TP. Hồ Chí Minh, Việt Nam

Nguyễn Vũ Phương Thảo

Sinh viên K61D - Kinh tế đối ngoại

Trường Đại học Ngoại thương Cơ sở II, TP. Hồ Chí Minh, Việt Nam

Trần Thị Huỳnh Như

Sinh viên K61 CLC7 – Truyền thông Marketing kết hợp

Trường Đại học Ngoại thương Cơ sở II, TP. Hồ Chí Minh, Việt Nam

Huỳnh Hiền Hải

Giảng viên Cơ sở II

Trường Đại học Ngoại thương Cơ sở II, TP. Hồ Chí Minh, Việt Nam

Abstract

In the context of ASEAN's rapidly developing economies, this study examines the validity of the Environmental Kuznets Curve (EKC) hypothesis by employing a unique composite model that integrates elements of both the EKC and Armey curves. This innovative approach aims to shed light on the complex interactions between economic growth, government spending, and environmental pollution within six ASEAN countries: Singapore, Thailand, Vietnam, Malaysia, Philippines, and Indonesia. Drawing on panel data from 1995-2020, the study suggests that government spending serves as a transmission mechanism influencing economic growth, which subsequently impacts environmental degradation as measured by CO2 emissions. The composite model offers a nuanced understanding of these dynamics, potentially leading to policy recommendations that promote sustainable development through strategic government spending initiatives. Interestingly, by

[1] Corresponding author: k61.2212155182@ftu.edu.vn;

implementing proposed research methodology, the research has found the optimal government spending that would maximize CO_2 emission in Vietnam.

Keywords: Environment Kuznets Curve (EKC), Armey Curve (AC), composite model, ASEAN countries, environmental sustainablity

ĐÁNH GIÁ LẠI HIỆU LỰC ĐƯỜNG CONG MÔI TRƯỜNG KUZNETS (EKC) Ở SÁU NƯỚC ASEAN: MÔ HÌNH TỔNG HỢP

Tóm tắt

Trong bối cảnh các nền kinh tế các nước ASEAN đang phát triển một cách nhanh chóng, nghiên cứu này dùng để xem xét tính hợp lệ của giả thuyết Đường cong Môi trường Kuznets (EKC) bằng cách sử dụng một mô hình tổng hợp độc đáo kết hợp các yếu tố của cả đường cong EKC và đường cong Armey. Cách tiếp cận này nhằm làm sáng tỏ các tương tác phức tạp giữa tăng trưởng kinh tế, chi tiêu của chính phủ và ô nhiễm môi trường trong sáu quốc gia ASEAN: Singapore, Thái Lan, Việt Nam, Malaysia, Philippines và Indonesia. Dựa trên dữ liệu từ năm 1995 đến 2020, nghiên cứu cho thấy rằng chi tiêu của chính phủ đóng vai trò trung gian làm ảnh hưởng đến tăng trưởng kinh tế, từ đó tác động đến tình trạng suy thoái môi trường được đo lường bằng lượng khí thải CO_2. Mô hình tổng hợp giúp nâng cao hiểu biết về các vấn đề này, có tiềm năng dẫn đến các khuyến nghị chính sách thúc đẩy phát triển bền vững thông qua các sáng kiến chi tiêu chiến lược của chính phủ. Bằng phương pháp nghiên cứu đã đề xuất, bài nghiên cứu đã tìm ra mức chi tiêu chính phủ tối ưu cho Việt Nam.

Keywords: đường cong môi trường Kuznets (EKC), đường cong Armey (AC), mô hình tổng hợp, các nước ASEAN, phát triển bền vững

1. Introduction

After the COVID-19 pandemic and other challenges, ASEAN stands out with exceptional economic growth at a 5% average annual rate. This strength stems from its diverse population, focus on innovation, and inclusivity initiatives like the marketplace lending platform and ASEAN QR code aim to empower all through digital tools and services. This positions ASEAN as an economic powerhouse, with initiatives like the ASEAN Business Entity and Summit showcasing its potential. However, ASEAN's economic progress must be traded off with environmental sustainability. Despite initiatives like the ASEAN Carbon Market and Net Zero Hub, air pollution is worsening, with a 61% CO_2 emission increase from the oil industry between 2014-2025. The driving force behind this is urban lifestyles (Sibuea et al. 2021), and the power sector - the largest source of (direct) CO_2 emissions in all ASEAN countries except for Cambodia. The question being raised is, how can ASEAN continue its economic progress without affecting the sustainability of the environment?

One common approach is to validate the environmental Kuznets curves (EKC) by Grossman and Krueger (2019), which hypothesize an inverted U-shaped relationship between economic progress and environmental degradation. It suggests pollution rises with initial economic growth but falls at higher income levels due to technology. In other words, the hypothesis implies there is a self-fixing system between environmental degradation and economic growth, which implies that the best solution to solving a country’s environmental deterioration is fostering its economy. Another approach is to utilize the composite model introduced first by Işık et al. (2022). This method incorporates the Armey curve (AC) linking government spending and GDP into the Kuznets curve and has been seen as an alternative approach to test the EKC hypothesis. This approach is capable of numerically determining a maximum real GDP per capita level that would minimize or maximize

CO_2 emission levels for the examined nations and has attracted several authors in the field. Although the majority of papers use the composite model to point out the invalidity of EKC, larger sample countries examined are predicted to bring out positive results.

The present study aims to: (i) develop a composite model incorporating the EKC and Armey curve hypotheses to assess the complex interplay between economic growth, government spending, and environmental pollution in Singapore, Thailand, Vietnam, Malaysia, Philippines, and Indonesia; and (ii) suggest some potential policy recommendations for 6 ASEAN countries based on the research findings, aiming to achieve sustainable development through optimal utilization of government spending

2. Literature review

2.1. The Armey Curve

The Armey Curve (AC) hypothesis proposes a non-linear relationship between government expenditure and economic growth, suggesting that there exists an optimal level of public spending that maximizes economic performance. According to Olaleye et al. (2014), early studies by Armey (1995), Vedder & Gallaway (1998), Sheehey (1993), and Forte and Magazzino (2010) were among the first to conclude that the relationship between government expenditure and economic growth is inconsistent and exhibits a non-linear pattern. Building on this foundation, subsequent studies have explored the validity of the AC hypothesis in different countries and time periods.

It can be observed that most of the reviewed studies support the validity of the Armey Curve hypothesis, indicating a non-linear relationship between government expenditure and economic growth in different countries and time periods. Regarding the statement by Bozma et al. (2019) that in developing and especially in developed economies, it is commonly claimed that the increase in public volume has negative effects on economic growth, the findings from the reviewed studies do not fully support this claim. While the AC hypothesis is partially valid in some countries, the relationship between government expenditure and economic growth is not uniformly negative. For example, De Witte & Moesen (2010) conducted a study on 23 OECD countries using the non-parametric DEA method and found that the Armey Hypothesis was not valid. Fallahi & Shoorkchali (2012) examined the Greek economy and found a positive relationship between government expenditure and economic growth in both regimes, indicating the absence of an Armey Curve. Martins & Veiga (2014) studied 156 countries and found that the relationship between expenditure composition and development had both inverted U-shaped and U-shaped patterns, depending on the type of expense. Therefore, it is important to consider the specific context of each country and the magnitude of government expenditure when assessing its impact on economic growth.

There is a substantial body of research suggesting an optimal level of government expenditure that maximizes economic growth in various countries and regions. However, the diverse findings suggest that the relationship between government expenditure and economic growth is complex and can be influenced by various factors. Further research is needed to explore the nuances of this relationship and provide a more comprehensive understanding of the Armey Curve hypothesis.

2.2. The Environmental Kuznet Curve

Due to high economic strength and the ability to meet with various environmental preservation solutions, high-income and upper-middle-income countries are usually considered to record the validation EKC. However, this assumption comes with mixed results. Several studies have explored the validity of the EKC hypothesis in diverse economic contexts. Al-Mulali et al. (2015) examined a panel of 93 countries across varying income levels, finding support for the EKC only within higher-income nations. Their findings were corroborated by Al-Mulali & Ozturk (2016), who specifically analyzed 27 advanced countries, confirming the relationship between economic growth and environmental improvements.

However, the opposite finding was found in Azam & Khan (2016) paper when they utilized the ordinary least square method to estimate the EKC hypothesis for four countries groups: low-income, lower-middle-income, upper-middle-income, and high-income countries (Tanzania, Guatemala, China, and the USA). The result shows that EKC is only validated in low and lower-middle-income countries, rather than in high-income and upper-middle-income ones as concluded in the previous part. This conclusion is supported by many other studies. A paper on Denmark, the United Kingdom, and Spain (Beşe & Kalayci, 2021) confirmed the inexistence of EKC despite the countries listed belonging to developed groups. Usama, et al. (2020); Gbatu, et al. (2019); Kyophilavong, et al. (2020); Murshed (2022); Aziz et al. (2020); Shahbaz, et al. (2014); Danish et al. (2021), on the other hand, found evidence to support the EKC hypothesis in Ethiopia, Liberia, Lao PDR, Bangladesh, Pakistan, Turnesia, India although those countries are the low-income and lower-middle-income economy.

Some other paper comes up with a mixed result when stating that EKC exists in both high-income and low-income economies. Samia (2015) and Chow & Li (2014) when investigating 59 countries including high-income, middle-income, and low-income panels and 132 developed and developing countries also came to the same result. It can be seen that the conclusions on EKC validation have been mixed.

2.3. The Composite model

Scholars have been paying more attention to this approach ever since Işık et al. (2021) first introduced the composite model between EKC and AC in 50 US states. To verify the existence of the EKC curve in NAFTA countries through the transmission mechanism of the ARMEY curve hypothesis in a single composite model, Ongan et al. (2022) employed the Augmented Mean Group (AMG) estimator. The results imply that the EKC hypothesis is unique to the US and cannot be found in any other NAFTA nation. The authors suggest that if more sample nations are closely examined, this approach will produce positive results in subsequent empirical studies.

Ayad et al. (2023) recent studies, which employ the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model, validate the composite model in only one of the four most polluting African countries. They highlighted the fact that 16.88% of GDP is the ideal amount of government spending to maximize CO2 emissions. They also highlighted the importance of population growth and energy consumption in reducing environmental degradation in three countries that do not qualify.

According to an empirical study on the G7 nations—Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States—only the United States and Canada support the EKC hypothesis. The discrepancy in the highest percentage of government spending is also noted; for the USA, Canada, and the UK, it was 29.87%, 29.22%, and 28.30% of gross domestic output, respectively. Additionally, they imply that maintaining government spending restraint is essential to the nation's continued economic growth and development.

3. Research method

3.1. Data

This research use panel data in the period from 1995 to 2020, focusing on ASIAN-5, the five founding members of ASEAN (namely Singapore, Philippines, Indonesia, Thailand and Malaysia) and Vietnam. Other members (Brunei, Cambodia, Lao PDR, Myanmar) are not tested in this research due to the unavailablity of data.

Table 1: Summary of collected data

Abbr	Variable	Unit	Source
CO_2	CO_2 emissions	metric million tons	World Bank Database (WDI, 2023)
GDP	GDP per capita	current US dollars	World Bank Database (WDI, 2023)
GDP^2	GDP per capita squared	current US dollars squared	Own calculation
GS	Government spending	current US dollars	World Bank Database (WDI, 2023)
GS	Government spending squared	Current US dollars squared	Own calculation
EC	Energy consumption	kg of oil equivalent per capita	World Bank Database (WDI, 2023)
POP	Total Population	residents	World Bank Database (WDI, 2023)
TO	Trade Openness	percentage of GDP	World Bank Database (WDI, 2023)
FDI	Foreign Direct Investment	percentage of GDP	World Bank Database (WDI, 2023)

3.2. Empirical Model

The empirical model of this research strictly follow the model introduced by Ongan et al. (2022) and Işık, C. et al. (2021) which is derived from the combination of Armey curve and EKC curve. However, we slightly adjust it by adding three more variables which are population (lnPOP), foreign direct investment (FDI) and trade openness (TO). The reason behind this adjustment is that these variables are proved to have effects on both economic growth ((Ayad, Lefilef, & Ben-Salha (2023), Murshed, M. et al. (2018), Keho (2017), Raghutla (2020)) and environmental degradation ((Ayad, Lefilef, & Ben-Salha (2023), (Chng, Z. Y. (2019), Gorus & Aslan (2019)) in former researches.

Armey Curve model:

$$\boldsymbol{lnGDP_{it}} = \alpha + \boldsymbol{\beta_1\, lnGS_{it}} + \boldsymbol{\beta_2\, lnGS_{it}^2} + \boldsymbol{\beta_3\, lnEC_{it}} + \boldsymbol{\beta_4\, lnPOP_{it}} + \boldsymbol{\beta_5\, TO_{it}} + \boldsymbol{\beta_6\, FDI_{it}} + \boldsymbol{\varepsilon_{it}} \quad \textbf{(1)}$$

Environmental Kuznets Curve model:

$$\boldsymbol{lnCO2_{it}} = a + \boldsymbol{b_1\, lnGDP_{it}} + \boldsymbol{b_2\, lnGDP^2_{it}} + \boldsymbol{\beta_3\, lnEC_{it}} + \boldsymbol{\beta_4\, lnPOP_{it}} + \boldsymbol{\beta_5\, TO_{it}} + \boldsymbol{\beta_6 FDI_{it}} + \boldsymbol{u_{it}} \quad (2)$$

In the above equations, GDP, GS respectively denote GDP per capita, government spending; EC stands for energy consumption, measured as the electricity power from these sources in Terawatt hour (TWh); CO_2 represents carbon emissions; POP, TO, FDI respectively denote population, trade openness and foreign direct investment ε and u stands for error terms. The variables that are not in percentage form in this research, which are CO2, GDP, GDP^2, EC, POP, are written under the natural logarithm form in order to interpret the coefficient estimates as the elasticities of the response variables concerning the independent variables.

It is speculated that the relationship between GDP per capita and government spending and the relationship between CO_2 emissions and GDP per capita is positive. Therefore, $\boldsymbol{\beta_1}$ and b_1 are expected to have positive sign. In contrast, $\boldsymbol{\beta_2}$ amd b_2 should be negative if beyond a threshold, an addition in government spending (GDP per capita) would lead to a drop in GDP per capita (CO_2 emissions). The EKC curve will be verified when $\boldsymbol{\beta_1}$is positive and $\boldsymbol{\beta_2}$ is negative. Similarly, the AC curve will be valid when $b_1>0$ and $b_2 < 0$.

Replacing $\boldsymbol{lnGDP_{it}}$ in Eq.(2) by the Eq.(1), the composite model can be derived as follow:

$$\boldsymbol{lnCO2_{it}} = a + \boldsymbol{b_1(\alpha + \beta_1\, lnGS_{it} + \beta_2\, lnGS^2_{it} + \beta_3\, lnEC_{it} + \beta_4\, lnPOP_{it} + \beta_5\, TO_{it} + \beta_6\, FDI_{it})} + \boldsymbol{b_2\left(\alpha + \beta_1\, lnGS_{it} + \beta_2\, lnGS^2_{it} + \beta_3\, lnEC_{it} + \beta_4\, lnPOP_{it} + \beta_5\, TO_{it} + \beta_6\, FDI_{it} + \varepsilon_{it}\right)^2} + \boldsymbol{\beta_3\, lnEC_{it}} + \boldsymbol{\beta_4\, lnPOP_{it}} + \boldsymbol{\beta_5\, TO_{it}} + \boldsymbol{\beta_6\, FDI_{it}} \quad \textbf{(3)}$$

In the Eq.(3), the EKC hypothesis can be examined through the signs of b_1 and b_2. If $b_1>0$ and $b_2 <0$, the EKC hypothesis is valid since the shape would be inverted U-shaped (Figure 1). On the other hand, if $b_1 < 0$ and $b_2 > 0$ and indicating that the composite EKC curve is U-shape, EKC hypothesis is not supported by the Armey curve and therefore, invalid (Figure 2). In summary, EKC hypothesis are validated only when Armey curve and composite EKC curve are inverted U-shaped.

Armey CurveComposite EKC Curve

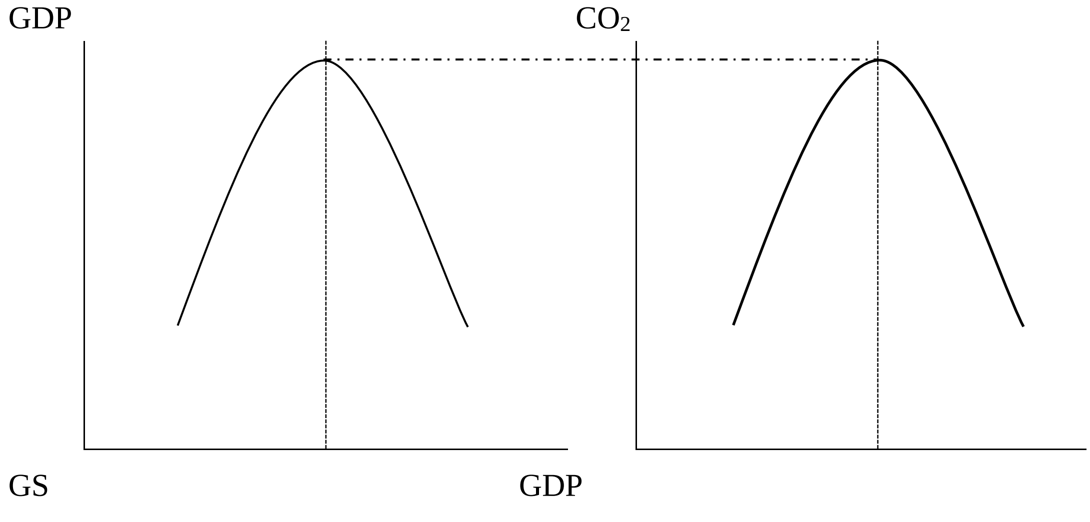

Figure 1: The inverted U-shaped composite model.

Source: Ongan et al. (2022), by Işık et al. (2022)

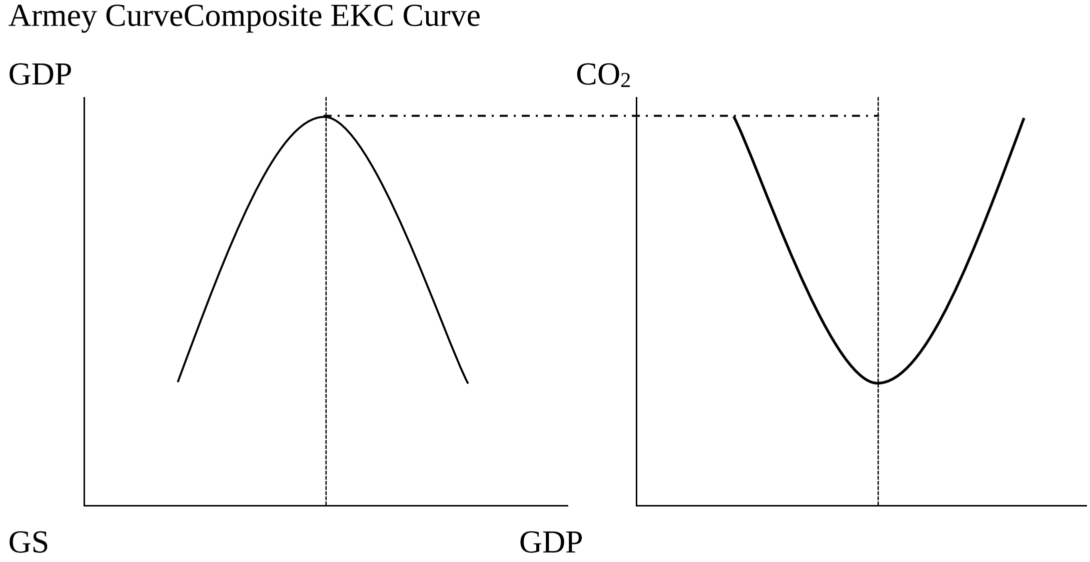

Figure 2. The U-shaped composite model.

Source: Ongan et al. (2022) and Işık et al. (2022)

Ongan et al. (2022) suggested two key insights explaining why testing the EKC model with the Armey curve is valuable. Firstly, both Armey curve and EKC model share the same mathematical structure which is nonlinear form with a upper turning point. This similarity allows them to be combined into a comprehensive model. The second driving force behind this combination is the dual role of the government spending. Public spending is widely recognized to stimulate economic growth, potentially leading to higher carbon emissions. Therefore, integrating the Armey curve into the EKC model accounts for this complex relationship, aiding in better understanding of the Environmental Kuznets Curve.

Interestingly, this methodology can also determine the threshold that government can control government spending and economic growth in order to achieve the sustainable goals. If the composite model has a concave shape, governments can determine the maximum government expenditure that effectively curtails CO_2 emissions. On the other hand, in case the composite model is convex, governments are able to establish higher GDP levels by utilizing maximum government expenditure to minimize CO_2 emissions. As proposed by by Işık et al. (2022), the optimal amount of government expenditure that maximize CO_2 emissions can be defined by following the steps below:

Firstly, by applying the first-order the optimization condition, specifically dlnGDP/dlnGDP to the Eq.(1), we can derive the level of government expenditure as follows:

$$\text{lnGS} = -\frac{\beta_1}{2\beta_2}$$

After that, we derive the optimal level for the composite EKC model in Eq.(3) from the first-order condition dCO_2/dGS:

$$\text{lnGS}_1 = -\frac{\beta_1}{2\beta_2}$$

$$\text{lnGS}_{2,3} = \frac{-\beta_1 \pm \sqrt{\beta_1^2 - 2\left(\frac{b_1}{b_2}\right)\beta_2 - 4\alpha\beta_2}}{2\beta_2}$$

The value of lnGS = $-\frac{\beta_1}{2\beta_2}$ will be the optimal value of CO_2 emission in Eq(3) Inserting lnGS = $-\frac{\beta_1}{2\beta_2}$ into $d^2CO_2/dlnGS^2 = 2b_1\beta_2 + 2b_2(\beta_1 + 2\beta_2 \text{lnGS})^2 + 4b_2\beta_2(\alpha + \beta_1 lnGS + \beta_2 lnGS^2)$, we can figure the following formula:

$d^2CO_2/dlnGS^2$ ($lnGS_1$) = $-b_2\beta_1^2 + 2b_1\beta_2 + 4b_1\alpha\beta_2$

According to by Işık et al. (2022), the optimal level of government spending that maximizes CO_2 emissions can be determined as $-\frac{\beta_1}{2\beta_2}$, provided that $\beta_2 < 0$ and $-b_2\beta_1^2 + 2b_1\beta_2 + 4b_1\alpha\beta_2 < 0$ which mean the shapes of both Armey curve and composite model are inverted U-shaped. Conversely, the optimal level of government spending that minimizes CO_2 emissions would be $-\frac{\beta_1}{2\beta_2}$ if $\beta_2 < 0$ and $-b_2\beta_1^2 + 2b_1\beta_2 + 4b_1\alpha\beta_2 > 0$, resulting in the inverted U-shaped for the Armey curve and the U-shape for the composite model.

4. Result and discussion

4.1. Results

Descriptive statistics

The descriptive statistics of variables for the dataset is demonstrated in Table 2.

Table 2: Descriptive statistics of variables

Variable	Obs	Mean	Std. dev	Min	Max
lnCO2	156	1.349	0.833	-0.854	2.367
lnGDP	156	8.255	1.319	5.639	11.11
$(lnGDP)^2$	156	69.879	22.603	31.796	123.432
lnGS	156	2.336	0.259	1.698	2.878
$(lnGS)^2$	156	5.523	1.191	2.885	8.289
$lnGS+(lnGS)^2$	156	7.858	1.449	4.583	11.167
$(lnGS+(lnGS)^2)^2$	156	63.84	22.806	21.004	124.714
lnEC	156	6.534	0.627	4.485	7.734
lnPOP	156	17.720	1.242	15.075	19.420
TO	156	150.175	103.709	32.972	437.327
FDI	156	5.511	6.671	-2.757	29.760

Source: the authors (2024)

Model testing

The results of the tests for cross-section dependence and slope heterogeneity in EKC model, AC model, and composite model are presented in Table 3.

Cross-section dependence test null hypothesis: No cross-section dependence in residuals

Slope heterogeneity test null hypothesis: Slope coefficients are homogenous.

Since the p-value of test statistics are below 1%, the null hypothesis of the two tests are rejected, indicating that there are significant cross-section dependence and slope heterogeneity.

Table 3: Cross-section dependence and slope heterogeneity test

	Panel A: EKC model		Panel B: AC model		Panel C: Composite model	
	Statistic	P.value	Statistic	P.value	Statistic	P.value
Cross-section dependence test						
Breusch-Pagan LM	82.862	0.000	160.812	0.000	59.178	0.000
Pesaran scaled LM	12.389	0.000	26.621	0.000	8.065	0.000
Pesaran CD	4.891	0.000	11.305	0.000	3.829	0.000
Slope heterogeneity test						
$\tilde{\Delta}$	8.971	0.000	9.098	0.000	9.674	0.000
$\tilde{\Delta}_{adj}$	10.781	0.000	10.935	0.000	11.626	0.000

Source: Authors (2024)

Table 4 demonstrates the results of second-generation CIPS unit root test. According to the table, the series are stationary at different level. While the variables of CO2, GDP and $(GDP)^2$ are stationary at level, the remaining variables are stationary at first difference. Since there are variables integrated of order one, a test for long run equilibrium relationship between these variables should be tested.

Table 4: Second-generation CIPS panel unit root test

Variables	**Test statistic**		**Result**
	I(0)	**I(1)**	
lnCO2	-2.760*	-4.685*	I(0)
lnGDPPC	-3.046*	-4.425*	I(0)
$(\ln GDP)^2$	-3.007*	-4.423*	I(0)
lnGS	-1.661	-4.687*	I(1)
$(\ln GS)^2$	-1.614	-4.635*	I(1)
$\ln GS+(\ln GS)^2$	-1.623	-4.648*	I(1)
$((\ln GS+(\ln GS)^2)^2$	-1.540	-4.498*	I(1)
lnEC	-1.630	-3.924*	I(1)
lnPOP	-2.098	-2.627*	I(1)
TO	-1.095	-4.257*	I(1)
FDI	-2.711*	-4.991*	I(0)

Note: indicate 10%, 5%, and 1% significance levels, respectively. Critical value at 10%, 5%, and 1% are -2.21, -2.33, -2.57 respectively.

Source: Authors (2024)

Cointegration test results are presented in Table 5. The null hypothesis that there are no cointegration is rejected by KAO test. Therefore, there are long run equilibrium relationship between dependent and independent variables.

Table 5: KAO cointegration test

Test statistic	Panel A: EKC model		Panel B: AC model		Panel C: Composite model	
	Statistic	**P.value**	**Statistic**	**P.value**	**Statistic**	**P.value**
Modified Dickey-Fuller t	-2.124	0.0167	-1.239	0.108	-1.641	0.050
Dickey-Fuller t	-1.489	0.068	-1.820	0.034	-1.330	0.091
Augmented Dickey-Fuller t	-1.293	0.098	-1.575	0.057	-1.371	0.085
Unadjusted modified Dickey-Fuller t	-2.823	0.002	-1.804	0.035	-2.270	0.011
Unadjusted Dickey-Fuller t	-1.761	0.039	-2.079	0.018	-1.601	0.054

Source: the authors (2024)

Regression results

Due to the exist of cointegration, significant cross-section dependence and slope heterogeneity, the Average Mean Group (AMG) estimation method is suitable for our models.

Table 6 show the results of AMG long run estimation for ARMEY Curve model, EKC model and composite model. Based on the results in Table 6, the shape of each model is presented in Table 7**.** The results indicate that ARMEY Curve is only validated in Vietnam since the coefficient of lnGS is above 0, the coefficient of $(\ln GS)^2$ is below 0 and both two value are statistically significant. Similarly considering, the composite model is also validated in Vietnam. Although the traditional EKC model is statistically insignificant, it is possible to test the validity of EKC in Vietnam through the proposed methodological approach since the ARMEY curve model is validated and composite model is statistically significant. As the shape of ARMEY curve and the composite curve is both inverted U-shaped, we can conclude that EKC theory does exist in Vietnam. Moreover, our research can also calculate the maximum government spending levels that will maximize CO2 emissions for Vietnam. The optimal government spending for Vietnam was calculated as 2.081% of Vietnamese real GDP per capital.

Table 6: AMG estimator test results

Variables	Indonesia	Malaysia	Philippine	Singapore	Thailand	Vietnam
ARMEY Curve Model						
lnGDP=F(lnGS, $(lnGS)^2$, lnEC, lnPOP, TO, FDI						
lnGS	-3.051	2.441	2.419***	8.588*	-6.807	3.081**
	(0.405)	(0.413)	(0.082)	(0.002)	(0.143)	(0.048)
$(lnGS)^2$	0.818	-0.449	-0.457	-1.866*	1.157	-0.740***
	(0.359)	(0.457)	(0.105)	(0.001)	(0.176)	(0.060)
lnEC	0.957*	0.764*	0.481*	-0.013	0.359***	-0.012
	(0.009)	(0.000)	(0.000)	(0.935)	(0.080)	(0.957)
lnPOP	-4.060*	-3.181*	-2.028*	-1.396*	-2.943**	4.217**
	(0.001)	(0.000)	(0.000)	(0.000)	(0.026)	(0.041)
TO	-0.010*	-0.000	-0.002**	-0.000	-0.003*	-0.002
	(0.000)	(0.383)	(0.010)	(0.916)	(0.000)	(0.260)
FDI	0.030*	-0.001	0.012	21.915*	0.005	-0.008
	(0.006)	(0.880)	(0.256)	(0.000)	(0.450)	(0.186)
EKC Model						
lnCO2=F(lnGDP, $(lnGDP)^2$, lnEC, lnPOP, TO,FDI)						
lnGDP	-1.242*	0.305	-3.162***	-3.523	1.557**	0.023
	(0.000)	(0.761)	(0.058)	(0.241)	(0.015)	(0.943)
$(lnGDP)^2$	0.083*	-0.009	0.218***	0.171	-0.092**	-0.012
	(0.000)	(0.863)	(0.060)	(0.234)	(0.019)	(0.612)
lnEC	0.576*	0.695*	0.177	0.199	0.848*	0.780*
	(0.000)	(0.000)	(0.333)	(0.490)	(0.000)	(0.001)
lnPOP	-1.028**	-1.331*	-1.916*	-1.829*	-3.930*	2.169
	(0.030)	(0.002)	(0.000)	(0.001)	(0.000)	(0.466)
TO	-0.002	0.000	0.001	-0.001**	-0.000	-0.001
	(0.109)	(0.252)	(0.580)	(0.035)	(0.669)	(0.519)
FDI	0.011***	0.002	-0.013	-0.001	0.007**	0.022***
	(0.078)	(0.714)	(0.297)	(0.476)	(0.055)	(0.051)
Composite Model						
lnCO2=F[(lnGS+$(lnGS)^2$), $(lnGS+(lnGS)^2)^2$, lnEC, lnPOP, TO, FDI						
lnGS+$(lnGS)^2$	-0.111	0.219	0.290***	0.408	0.002	0.298***

	(0.621)	(0.525)	(0.084)	(0.376)	(0.996)	(0.054)
$(\ln GS+(\ln GS)^2)^2$	0.004	-0.013	-0.017***	0.027	-0.001	-0.029**
	(0.821)	(0.523)	(0.064)	(0.365)	(0.977)	(0.025)
lnEC	0.493**	0.893*	0.377*	0.122	1.003*	0.787*
	(0.010)	(0.000)	(0.005)	(0.638)	(0.000)	(0.000)
lnPOP	-0.711	-1.739*	-2.062*	-1.761*	-5.165*	1.182
	(0.233)	(0.000)	(0.000)	(0.001)	(0.000)	(0.511)
TO	-0.001	0.000	0.001	-0.001*	0.001	-0.003**
	(0.275)	(0.635)	(0.122)	(0.000)	(0.181)	(0.040)
FDI	0.011***	0.006	-0.013	-0.001	0.005	0.017*
	(0.055)	(0.219)	(0.266)	(0.551)	(0.318)	(0.003)

*Note: *,**,*** indicate 10%, 5%, and 1% significance levels, respectively*

Source: the authors (2024)

Table 7: The curve shape of the ARMEY, EKC, and composite models

	ARMEY Curve model	Traditional EKC model	Composite EKC model
Indonesia	Insignificant	U-shaped	Insignificant
Malaysia	Insignificant	Insignificant	Insignificant
Philippine	Insignificant	U-shaped	Inverted U-shaped
Singapore	Inverted U-shaped	Insignificant	Insignificant
Thailand	Insignificant	Inverted U-shaped	Insignificant
Vietnam	Inverted U-shaped	Insignificant	Inverted U-shaped

Note: Curve shapes were obtained based on the results in Table 6.

4.2. Discussion

This paper comes to several conclusions that can be summarized as follows. First, as can be seen in Table 7, the AC and Composite models are inverted U-shaped in Vietnam and this means the composite model is capable of testing the EKC hypothesis in this country. The result also suggests an optimal government spending at 2.081% of GDP per capita which can maximize the amount of CO2 emissions. Energy consumption and foreign direct investment are found to be the key factors that contribute to ecological degradation in Vietnam as the increase in these two factors will lead to the increase in the level of CO2 emissions in the long run. However, while former researches about EKC hypothesis using the traditional EKC model suggest that there is a N-shaped (Shahbaz et al. 2019), or an inverted N-shaped (Nguyen et al. 2021) curve for EKC in Vietnam, our research using composite EKC model interpret that the curve for EKC in Vietnam is inverted U-shaped. Therefore, it is highly recommended to conduct more study on this hypothesis in the future so that we can determine the accurate shape for EKC in this country.

Regarding Singapore, although the EKC and Composite curve cannot be seen in this country, the presence of an inverted U-shaped curve for AC interpret that an upsurge in government spending initially increases real GDP per capita until a certain peak and then decrease it. Population and foreign direct investment are of the most significance in affecting the economic growth in this country according to the given result (population affect negatively and foreign direct investment affect positively).

Considering other countries, including Indonesia, Malaysia, Philippine and Thailand, the results of AMG reveal that the composite model cannot be used to determine the EKC shape in these countries according to the proposed theoretical frameworks. However, there is evidence of inverted U-shaped curve for the EKC hypothesis in Thailand and U-shaped curve for that hypothesis in Indonesia and Philippine, which can supports the theory that the economic development in these countries can affects the ecological degradation positively at first and eventually negatively in the long run or vice versa.

Based on this results, several recommendations can be interpreted. Firstly, according to the relationship between government spending and the CO2 emissions in Vietnam, Vietnamese government should prioritize sustainable development by integrating environmental considerations into its spending decisions. One key strategy lies in promoting energy efficiency across the nation by encouraging residents and institutions to adopt energy-saving technologies, ensuring the same benefits delivered with reduced energy consumption. Another approach that can be utilized is implementing energy efficiency measures in various sectors like lighting, heating, air conditioning, and shifting transportation towards cleaner alternatives. The outcome also gives an ideal maximum spending level (at 2.081%) that can help policymakers to decide whether the country should slow down or foster their economies with no more spending for compatible-sustainable economy and energy policies.

Although the EKC composite hypothesis is not verified in five remaining countries, policymakers can still use this composite model and the findings of this paper to take precaution measure when considering the sustainable development. One potential measure can be simultaneously pursuing environmental policies that reduce CO2 emissions by providing more green service fostering energy-saving practice in society. This measure can help the economy to become eco-friendlier and sustainable.

While providing some new insight, this paper still has its limitation that can be re-addressed in future research. For instance, as our sample is limited to only 6 ASIAN countries so it is recommended to retest or reinvestigate the model proposed by Işık et al. (2022) and Ongan et al. (2022) in other Asia countries and other parts of the world which exhibit diverse economic and environmental characteristics such as East Asia, West Asia and so on.

Conclusion

This research revisits the environmental Kuznets curve (EKC) hypothesis by employing the methodology proposed by Işık et al. (2022) and Ongan et al. (2022). There have not been any studies that employ this approach in Asia and this is the reason why we choose 6 ASIAN countries which have emerging economy with different level of income to reinvestigate EKC hypothesis using composite model. This model is also expected to allow policymakers in these countries to find out an optimal spending level that may maximize or minimize the CO2 emissions. For the purpose mentioned above, we utilize different tests to determine the appropriate regression method, including CD test, panel unit roots test, slope heterogeneity test, and panel cointegration test. As a result, we choose Augmented Mean Group (AMG) estimator to detect the attendance of an inverted U shape curve for ARMEY, EKC and the composite model.

The result of AMG estimator reveals that the composite EKC model is capable of testing EKC in Vietnam but not the other remaining countries. However, it can be interpreted from the results that all of these countries investigated should determine the optimal level of spending at which the economy development can endure a compatible relationship with the environment preservation.

REFERENCES

Al-Mulali, U. & Ozturk, I. (2016), "The investigation of environmental Kuznets curve hypothesis in the advanced economies: the role of energy prices", *Renewable and Sustainable Energy Reviews*, Vol. 54, pp. 1622-1631.

Al-Mulali, U. Weng-Wai, C. Sheau-Ting, L. & Mohammed, A. H. (2015), "Investigating the environmental Kuznets curve (EKC) hypothesis by utilizing the ecological footprint as an indicator of environmental degradation", *Ecological indicators*, Vol. 48, pp. 315-323.

Asiedu, B. A. (2022), "Economic Growth and Environmental Pollution; Testing the EKC Hypothesis in Brazil. In The Toxicity of Environmental Pollutants", *IntechOpen*.

Ayad, H. Lefilef, A. & Ben-Salha, O. (2023), "A revisit of the EKC hypothesis in top polluted African countries via combining the Armey curve into the Kuznets curve: A Fourier ARDL approach", *Environmental Science and Pollution Research*, Vol. 30 No. 33, pp.8 1151–81163.

Azam, M. & Khan, A. Q. (2016), "Testing the Environmental Kuznets Curve hypothesis: A comparative empirical study for low, lower middle, upper middle and high income countries", *Renewable and Sustainable Energy Reviews*, Vol. 63, pp. 556-567.

Aziz, N. Sharif, A. Raza, A. & Rong, K. (2020), "Revisiting the role of forestry, agriculture, and renewable energy in testing environment Kuznets curve in Pakistan: evidence from Quantile ARDL approach", *Environmental Science and Pollution Research*, Vol. 27, pp. 10115-10128.

Beşe, E. & Kalayci, S. (2021), "Environmental Kuznets curve (EKC): empirical relationship between economic growth, energy consumption, and CO2 emissions: evidence from 3 developed countries", *Panoeconomicus*, Vol. 68 No. 4, pp. 483-506.

Bozma, G. Başar, S. & Murat, E. R. E. N. (2019), "Investigating validation of Armey curve hypothesis for G7 countries using ARDL model", *Doğuş Üniversitesi Dergisi*, Vol. 20 No. 1, pp. 49-59.

Chng, Z. Y. (2019), "Environmental degradation and economics growth: Testing the Environmental Kuznets Curve Hypothesis (EKC) in six ASEAN countries", *Journal of Undergraduate Research at Minnesota State University*, Mankato, Vol. 19 No. 1.

Chow, G. C. & Li, J. (2014), "Environmental Kuznets curve: conclusive econometric evidence for CO2", *Pacific Economic Review*, Vol. 19, No. 1, pp. 1-7.

De Witte, K, Moesen, W. (2010), "Sizing the government", *Public Choice*, Vol. 145, No.1-2, pp. 39-55.

Fallahi, F. & Shoorkchali J. M. (2012), “Government size and economic growth in Greece: A smooth transition approach”, Available at: https://mpra.ub.uni-muenchen.de/74078/.

Gbatu, A. P., Wang, Z., Wesseh, P. K. & Sesay, V. A. (2019), “How do energy consumption, output, energy price, and population growth correlate with CO2 emissions in Liberia?”, *International Journal of Global Environmental Issues*, Vol. 18, No. 3, pp. 209-235.

Gorus, M. S. & Aslan, M. (2019), “Impacts of economic indicators on environmental degradation: Evidence from MENA countries”, *Renewable and Sustainable Energy Reviews*, Vol. 103, pp. 259–268.

Hasan, M. A., Nahiduzzaman, K. M., Aldosary, A. S., Hewage, K. & Sadiq, R. (2022), “Nexus of economic growth, energy consumption, FDI and emissions: A tale of Bangladesh”, *Environment, Development and Sustainability*, pp. 1-22.

Işık, C., Ongan, S., Bulut, U., Karakaya, S., Irfan, M., Alvarado, R., Ahmad, M. & Rehman, A. (2021), “Reinvestigating the environmental kuznets curve (EKC) hypothesis by a composite model constructed on the Armey curve hypothesis with government spending for the US states”, *Environmental Science and Pollution Research*, Vol. 29, No. 11, pp. 16472–16483.

Keho, Y. (2017), “The impact of trade openness on economic growth: The case of cote d’ivoire”, *Cogent Economics & Finance*, Vol. 5, No. 1, pp. 1332820.

Kyophilavong, P., Pommavong, P., Chanthasense, S., Manivong, K., Phengsavanh, S., Xangsayasane, S. & Volavong, T. (2020), “Environmental Kuznets Curve (EKC) Hypothesis in Lao PDR: The Role of Globalization and Financial Development”, *International Journal of Multidisciplinary in Management and Tourism*, Vol. 4, No. 1, pp. 11-27.

Martins S. & Veiga F. J. (2014), “Government size, composition of public expenditure, and economic development”, *International Tax and Public Finance*, Vol. 21, No. 4, pp. 578–597.

Murshed, M. et al. (2018), “An Empirical Assessment of Optimal Government Size and Economic Growth in light of the Armey Curve: A Panel Data Investigation”, *World Review of Business Research*, Vol. 8, No. 1, pp. 161–173.

Nasreen, S. & Anwar, S. (2015), “The impact of economic and financial development on environmental degradation: An empirical assessment of EKC hypothesis”, *Studies in Economics and Finance*, Vol. 32, No. 4, pp. 485-502.

Nguyen, A. T. Lu, S. H. & Nguyen, P.T.T. “Validating and Forecasting Carbon Emissions in the Framework of the Environmental Kuznets Curve: The Case of Vietnam”, *Energies 2021*, Vol. 14, pp. 3144.

Olaleye, S. O., Edun, F., Bello, H. T. & Taiwo, S. B. (2014), “Government expenditure and economic growth: An empirical analysis of the Armey Curve in Nigeria”, *Romanian Economic Journal*, Vol. 17, No. 51, pp. 47-66.

Ongan, S., Işık, C., Bulut, U., Karakaya, S., Alvarado, R. Irfan, M. … Hussain, I. (2022), “Retesting the EKC hypothesis through transmission of the armey curve model: An alternative composite model approach with theory and policy implications for NAFTA countries”, *Environmental Science and Pollution Research*, Vol. 29, No. 31, pp. 46587–46599.

Ozcan, B. & Ulucak, R. (2021), “An empirical investigation of nuclear energy consumption and carbon dioxide (CO2) emission in India: Bridging IPAT and EKC hypotheses”, *Nuclear Engineering and Technology*, Vol. 53, No. 6, pp. 2056-2065.

Özden, C. & Beşe, E. (2021), “Environmental Kuznets Curve (EKC) in Australia: Evidence from Nonlinear ARDL Model with a Structural Break”, *Polish Journal of Environmental Studies*, Vol. 30, No. 3.

Pirgaip, B., Bayrakdar, S. & Kaya, M. V. (2023), “The role of government spending within the environmental kuznets curve framework: Evidence from G7 countries”, *Environmental Science and Pollution Research*, Vol. 30, No. 34, pp. 81513–81530.

Raghutla, C. (2020), “The effect of trade openness on economic growth: Some empirical evidence from emerging market economies”, *Journal of Public Affairs*, Vol. 20, No. 3.

Shahbaz, M., Haouas, I. & Van Hoang, T. H. (2019), “Economic growth and environmental degradation in Vietnam: is the environmental Kuznets curve a complete picture?”, *Emerging Markets Review*, Vol. 38, pp. 197-218.

Shahbaz, M., Khraief, N. Uddin, G. S. & Ozturk, I. (2014), “Environmental Kuznets curve in an open economy: a bounds testing and causality analysis for Tunisia”, *Renewable and Sustainable Energy Reviews*, Vol. 34, pp. 325-336.

Shahbaz, M., Ozturk, I. Afza, T. & Ali, A. (2013), “Revisiting the environmental Kuznets curve in a global economy”, *Renewable and sustainable energy reviews*, Vol. 25, pp. 494-502.

Usama, A. M. Solarin, S. A. & Salahuddin, M. (2020), “The prominence of renewable and non-renewable electricity generation on the environmental Kuznets curve: a case study of Ethiopia”, *Energy*, Vol. 211, pp. 118665.