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Abstract

Tourism development has become one of the key drivers of economic growth in many ASEAN countries, however, the adverse environmental impact of tourism and economic growth has raised significant concerns among the policymakers in region. This study investigates the role of tourism development in the context of Environmental Kuznets Curve (EKC) hypothesis across 10 ASEAN countries over a 25-year period from 1995 to 2019 via panel estimators robust to cross-sectional dependence. The findings reveal tourism contributes to environmental degradation significantly. On the EKC hypothesis, the evidence is mixed as only the Panel Corrected Standard Errors estimation indicates an inverted U-shaped relationship between emissions and GDP per capita. The threshold value of GDP per capita is estimated to be around USD 12,000 showing that the current economic development in ASEAN is still harmful to environment. Furthermore, renewable energy is found to be a strong mitigating factor. Population size, on the other hand, is a significant driver of both CO2 and GHG emissions. The findings of this study highlight the complex relationship between tourism development, economic growth, and environmental quality in the ASEAN region. Subsequently, several policy implications are discussed.

Keywords: CO2 emissions, Environmental Kuznets Curve, panel data econometrics, renewable energy, tourism development.

JEL code: O13, Q56, Z32

1. Introduction and background

The Association of Southeast Asian Nations (ASEAN) is a 10-country regional organization consisting of Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. ASEAN has experienced a substantial increase in economic activities and has managed to demonstrate positive economic development over the years. According to ASEAN Economic Integration Brief (2023), this positive economic growth has made ASEAN the world's fifth-

largest economy, with a GDP over 3.6 trillion US dollars in 2022. The region is expected to become the fourth-largest economy by 2030 following the United States, China, and India. As shown in Table 1 below, ASEAN achieved an average GDP per capita growth of 3.9% for a period of 25 years between 1995 and 2019, surpassing the global average of 1.8%.

Tourism development has become a key driver of economic growth in many ASEAN countries, as tourist arrivals have expanded by approximately 5-times from 30 million in 1995 to 148 million in 2019. However, rapid development and mass tourism often lead to the overexploitation of natural resources and various forms of pollution, particularly through transportation, accommodation, and other tourism-related activities. Between 1995 and 2019, the annual average growth rates of CO2 and GHG emissions in ASEAN were 4.8% and 3.3%, much higher than the global averages of 2.0% and 1.7%, respectively. ASEAN growth rates of CO2 and GHG emissions are expected to continue to exceed the world average, coinciding with the significant expansion in the region's tourism activities and economic growth.

Table 1: CO2 and GHG emissions growth, GDP per capita growth, and number of international tourist arrivals of ASEAN and World for year 1995-2019.

Year	Annual percentage change in CO2 emissions		Annual percentage change in GHG emissions		Annual percentage change in GDP per capita		Number of tourist arrivals per annum	
	ASEAN	**World**	**ASEAN**	**World**	**ASEAN**	**World**	**ASEAN**	**World**
1995	12.1	2.9	7.3	2.5	5.3	1.6	30,251,000	1,082,522,375
2000	2.9	3.2	2.3	2.6	5.3	3.1	39,291,000	1,332,379,079
2005	2.7	3.8	1.8	3.2	5.3	2.7	52,035,000	1,501,611,341
2010	8.2	6.1	5.2	5.2	6.2	3.3	75,344,985	1,755,720,046
2015	3.7	-0.6	2.2	-0.2	3.8	1.9	112,790,005	2,071,785,910
2019	7.3	-0.2	4.9	0.04	3.9	1.5	147,725,000	2,403,074,089
1995-2019 (average)	**4.8**	**2.0**	**3.3**	**1.8**	**3.9**	**1.8**	**71,427,174**	**1,661,275,303**

Source: Authors' own computation based on data collected from World Development Indicators (The World Bank, 2024).

The Environmental Kuznets Curve (EKC) hypothesis posits that as a country's income increases, environmental degradation initially rises but then declines after reaching a certain income level (Grossman & Krueger, 1995; Dinda, 2004). This inverted U-shaped relationship between economic development and environmental quality has been extensively studied in the context of ASEAN countries (Lean & Smyth, 2010; Saboori et al., 2012), but the findings are apparently mixed. Furthermore, the role of tourism within the EKC framework has received less attention despite its significant environmental impact (Katircioglu, 2014; Paramati et al., 2017).

Against this backdrop, this study aims to explore the role of tourism development in environmental degradation within the EKC framework for ASEAN from 1995 to 2019. This study makes three primary contributions. Firstly, as tourism and environmental quality are globally significant, understanding the relationship between tourism, economic growth, and environmental

quality is crucial for policymakers in promoting sustainable tourism practices in ASEAN countries. Secondly, this study revisits the role of tourism development within the EKC framework for an official regional association like ASEAN, where policies and tourism activities are highly interdependent, and seeks to address the mixed findings of previous studies on the tourism-economic growth-environment nexus in ASEAN countries. Lastly, this study employs Driscoll & Kraay (1998) fixed effects and Panel Corrected Standard Error (PCSE) estimators which are robust to cross-sectional dependence – crucial in the context of a regional bloc like ASEAN.

The study reveals that tourism development in ASEAN countries significantly increases CO2 and GHG emissions, consistent with many prior studies. However, support for the EKC hypothesis is mixed, as the inverted U-shaped relationship between economic growth and emissions is only statistically significant in the PCSE estimation. Renewable energy usage is a strong mitigating factor for emissions, whereas population size significantly drives both CO2 and GHG emissions. These findings suggest that despite the region's significant economic growth, current development practices in ASEAN remain environmentally detrimental, necessitating relevant policy implementation to address the adverse environmental effects of tourism and to promote sustainable tourism and climate action in ASEAN countries.

The paper proceeds as follows, Section 2 discusses the relevant empirical literature on tourism's environmental impact and the EKC hypothesis in the context of ASEAN countries. Section 3 discusses the materials and methods, followed by Section 4 with the results discussion of the baseline and robustness estimations. Section 5 finally concludes with several policy implications.

2. Literature review

2.1 Empirical studies on tourism development-environmental degradation nexus

In recent years, there is an increasing focus in the literature on the sustainability of tourism, particularly its relationship with environmental quality. While tourism development significantly boosts socio-economic growth, it often leads to environmental degradation (Azam et al., 2018). As the tourism sector expands, it escalates energy consumption, thereby deteriorating environmental quality through increased CO2 emissions (Katircioglu, 2014; Gedikli et al., 2022). Zhang & Gao (2016) identified tourism as a major contributor to greenhouse gas emissions, highlighting its substantial environmental pressure. Tourism's reliance on energy-intensive activities, such as transportation and infrastructure development, exacerbates environmental degradation (Ren et al., 2019; Zhang & Gao, 2016; Tian et al., 2021). The United Nations World Tourism Organization (UNWTO) attributes 5% of global CO2 emissions to tourism, with air transport responsible for about 40% of these emissions (Dubois & Ceron, 2006). Additionally, Tsagarakis et al. (2011) confirmed the link between energy consumption and accommodation, emphasizing tourism's impact on environmental degradation.

Nevertheless, as can be seen in the discussion below, previous empirical studies have mixed findings suggesting that the impact of tourism on emissions is complex and influenced by multiple factors, including region, study period, and methodological approach.

Katircioglu (2014) used autoregressive distributed lag (ARDL) estimates to explore tourism, energy consumption, and environmental degradation in Turkey, concluding that tourism development increases both energy consumption and climate change. Shakouri et al. (2017) similarly found that tourism development worsens environmental quality in Asia-Pacific countries. Zhang & Gao (2016) employed panel Granger-causality tests in China, discovering that tourism positively affects economic growth and CO2 emissions, with a feedback loop between economic growth and emissions. Gedikli et al. (2022) conducted a panel Granger-causality analysis in OECD countries, concluding that the negative environmental impact of international tourism outweighs its positive economic effects.

Conversely, some studies suggest that tourism can reduce emissions under certain conditions. Zhang & Liu (2019) found that non-renewable energy and tourism development harm the environment in Northeast and Southeast Asian countries, while renewable energy mitigates this damage. Khan et al. (2019) recommended promoting eco-friendly tourism through sustainable transportation in Asia and America, incorporating environmental awareness into education. Badulescu et al. (2021) found that, in the long term, CO2 emissions and GDP per capita negatively impact tourism development in the European Union, while energy consumption and squared GDP per capita positively influence tourism. Zafar et al. (2023) showed that tourism, trade, and growth factors negatively affect environmental sustainability, whereas ICT supports a sustainable environment in BRICS countries.

Other studies report mixed or region-specific findings on tourism's environmental impact. Tian et al. (2021) observed that tourism development and renewable energy consumption improve environmental quality in G20 economies, confirming the EKC hypothesis with an inverted U-shaped relationship between pollution and GDP in the long run. Ben Jebli et al. (2019) reported that tourism arrivals reduced CO2 emissions in the long term in Central and South American countries. Azam et al. (2018) and Ahmad et al. (2018) found both positive and negative environmental impacts of tourism depending on the region, with Azam et al. (2018) focusing on Malaysia, Thailand, and Singapore, and Ahmad et al. (2018) on five Chinese provinces. Sghaier et al. (2019) also reported differing impacts of tourism on environmental quality in Morocco, Tunisia, and Egypt.

2.2 Empirical studies on Environmental Kuznets Curve (EKC) hypothesis in ASEAN

Meanwhile, several related studies have focused on the EKC hypothesis in ASEAN countries, examining the relationship between CO2 emissions, energy consumption, and economic growth both collectively and individually. Similarly, their mixed results suggest that a common shortcoming of past studies might be the failure to account for cross-sectional dependence among ASEAN countries, potentially explaining the inconsistent findings. Furthermore, none of the studies below investigate the role of tourism development in the context of EKC hypothesis in the region.

Via Panel Smooth Transition Regression approach, and accounting for heterogeneity and time instability, Heidari et al. (2015) find nonlinearity relationship between energy consumption, CO2 emissions, and GDP in the ASEAN-5 with two threshold parameters, indicating that environmental degradation increased with economic growth in one regime, while it decreased in another. For Singapore, Tan et al. (2014) found that CO2 emissions and GDP increased together, with CO2 emissions negatively impacting Singapore's growth. Whereas, Ang (2008), in a study focused on Malaysia, found a long-run positive relationship between pollutant emissions growth, energy consumption growth, and output growth, with strong evidence that output growth influenced energy consumption growth in both the short and long run.

Several studies have investigated the EKC hypothesis for ASEAN countries but typically have not found support for a conventional EKC curve. Utilizing time-series methods to empirically investigates the impacts of economic growth, trade openness, energy consumption, and foreign direct investment on environmental degradation in six selected ASEAN countries for the period between 1971 to 2013, Chng (2019) finds the presence of EKC in Singapore, Thailand, and Vietnam, but no evidence of EKC in Malaysia, Philippines, and Indonesia. Saboori & Sulaiman (2013) also find that economic growth, CO2 emissions, and energy consumption were cointegrated in all five countries, but they find economic growth leading to less CO2 emissions in Singapore and Thailand, but more emissions in Indonesia and the Philippines. Chandran & Tang (2013) found no evidence for the EKC hypothesis for the ASEAN-5 collectively, while individual country studies also failed to support the EKC hypothesis. Lean & Smyth (2010) did not find evidence for Malaysia, Indonesia, Thailand, and Singapore; and Narayan & Narayan (2010) for Malaysia, Indonesia, and the Philippines.

In a more recent study by Ansari (2002) employing second generation unit root and cointegration tests that are robust to cross sectional dependence, the findings indicate that the EKC hypothesis is only valid in ASEAN when using footprint-based emissions, but not when using consumption-based CO2 emissions.

3. Materials and methods

3.1 Model and data:

The following linear models are proposed to investigate of the impact of tourism development on environmental quality and environmental Kuznets curve:

$$CO2_{it} = \beta_0 + \beta_1 TD_{it} + \beta_2 GDP_{it} + \beta_3 GDP_{it}^2 + X\beta + \gamma_i + \varepsilon_{it} \quad (1)$$

Where:

CO2 : total carbon dioxide emissions, for country i and time t, in kiloton, capturing the level of environmental quality.

TD : Total number of international tourist arrivals to ASEAN countries, for country i and time t, as a proxy for tourism development

GDP : Real GDP per capita constant at 2015 US dollars, for country i and time t.

GDP^2 : Squared term of Real GDP per capita.

X : Vector of control variables (see discussion for robustness check below)

γ_i : denotes unobserved country-specific effect.

ε_{it} : the iid error term.

The expected priori sign for TD is positive due to the earlier discussed proposition that tourism development is heavily linked with the higher demand for energy use and eventually leading to higher emissions. However, TD also can have negative sign as there were studies indicating tourism's positive impact on environmental quality by reducing emissions, especially in the context of sustainable tourism that relies on renewable energy. The inclusion of GDP and its squared term GDP^2 is meant to capture the EKC hypothesis in the model. To support the EKC hypothesis, GDP and GDP^2 are expected to have positive and negative signs, respectively, i.e. economic development is expected to raise environmental degradation during its initial stage, but after a specific development threshold, the degradation will fall.

Table 2: Summary statistics of the variables.

Variable		Mean	Std. dev.	Min	Max	No. of obs.
CO2	overall	106,594.80	127,709.70	674.95	605,290.60	N = 250
	between		124,861.30	4,750.68	385,954.60	n = 10
	within		47,139.04	-55,681.04	325,930.80	T = 25
GHG	overall	189,011.90	225,144.60	6,207.55	1,020,914.00	N = 250
	between		229,535.80	8,296.25	765,863.20	n = 10
	within		55,512.64	6,790.19	444,062.30	T = 25
TD	overall	7,142,717	7,761,535	194,000	39,900,000	N = 250
	between		6,449,181	1,398,320	18,200,000	n = 10
	within		4,760,079	-5,520,403	29,300,000	T = 25
GDP	overall	9,994.27	15,175.62	210.54	61,386.23	N = 250
	between		15,567.64	701.47	44,466.78	n = 10
	within		3,362.64	-4,092.61	26,913.72	T = 25
REN	overall	35.89	29.40	0.00	86.62	N = 250
	between		29.89	0.00	78.12	n = 10
	Within		7.58	13.11	57.34	T = 25
POPN	overall	57,600,000	67,700,000	299,097	270,000,000	N = 250
	between		70,700,000	375,123	235,000,000	n = 10
	within		8,369,565	20,900,000	92,300,000	T = 25
FDI	overall	5.47	5.68	-2.76	29.76	N = 250
	between		4.98	1.23	18.46	n = 10
	within		3.14	-6.34	16.77	T = 25

Table 3: Pairwise correlation coefficients of variables

Variable name	CO2	GHG	TD	GDP	REN	POPN	FDI
CO2	1.000						
GHG	0.968	1.000					
TD	0.543	0.380	1.000				
GDP	-0.232	-0.284	0.155	1.000			
REN	-0.274	-0.134	-0.511	-0.673	1.000		
POPN	0.830	0.929	0.083	-0.385	0.058	1.000	
FDI	-0.325	-0.355	0.072	0.650	-0.236	-0.403	1.000

A balanced panel dataset is used in this study, consisting of observations over a 25-year period from 1995 to 2019[1] for 10 ASEAN countries. All variables are obtained from The World Development Indicator (The World Bank, 2024), and they converted into natural logarithm in the analysis. Tables 2 and 3 above present the summary statistics and pairwise correlation coefficients of the variables, respectively. A closer look at the summary statistics reveals a unique finding where the standard deviations in the data are greater between countries than within countries (or across time periods), despite our dataset having greater number of years (25) compared to number of countries (10).

3.2 Estimation methods

The empirical analysis begins with the cross-sectional dependence (CSD) test among the ten ASEAN countries to determine the suitable estimation methods for the study. We expect a certain degree of dependence between these countries due to their close proximity and shared features, particularly as ASEAN is an official regional association comprising these ten countries. If this dependence is not accounted for by the estimation method, it is expected to violate the basic ordinary least squares (OLS) assumption of an independent and identically distributed error term. Furthermore, CSD can lead to omitted variable bias or endogeneity, resulting in inconsistent estimates (Pesaran, 2004). We utilize Pesaran (2004) test for CSD which can be applied to small and large panels, especially when $N > T$, whose null hypothesis of no CSD is expressed as:

$$CSD = \sqrt{2T/N(N-1)}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{i,k}\right) \quad (5)$$

Subsequently, the Driscoll & Kraay (1998) fixed effects within estimator is employed for both the baseline model and robustness check estimations. Driscoll & Kraay (1998) propose a non-parametric covariance matrix fixed effects estimator that produces standard errors which are not only heteroskedasticity- and autocorrelation-consistent but also robust to CSD. Although the fixed effects estimator may be less suitable for a long panel dataset (when $T > N$), we proceed with it due to unique

[1] Although data for tourist arrivals, CO2 emissions, and GHG emissions are available up until year 2020, we omit year 2020 data from the sample to eliminate the outlier effect due to the significant reduction in number of tourist arrivals and emission size as a result of movement control order following Covid-19 pandemic.

finding regarding the greater sources of variations between countries than within, as previously mentioned in the summary statistics discussion.

To complement this approach, we use the Beck & Katz (1995) Panel Corrected Standard Errors (PCSE) estimator. The PCSE estimator is capable of accounting for CSD, heteroskedasticity, and serial correlation in the residuals of panel time series models, and is more suitable for datasets where the number of cross-sectional units is less than the number of time periods ($N < T$). Beck & Katz (1995) demonstrate that the PCSE estimator, with its large-T asymptotics-based standard errors that correct for contemporaneous correlation between subjects, performs well in small panels. The PCSE method estimates the full $N \times N$ cross-sectional covariance matrix, and this estimate is precise if the ratio T / N is large.

Equation (1) above is estimated via both methods without the control variables to form the baseline estimation. For the first robustness check, we replace the dependent variable CO2 with GHG emissions (measured in kilotons of CO2 equivalent) and replicate the two estimation methods. For the second robustness check, three control variables are added to the baseline estimation to create a general model and re-estimated using the two methods. The three control variables are: REN, which is the level of renewable energy in the country; POPN, the total population size in the country; and FDI, the net inflow of foreign direct investment to the country. These three variables are frequently used as control variables in CO2 and GHG emissions models. In regions like ASEAN, where the use of non-renewable energy is prevalent and contributes to higher emissions, the inclusion of renewable energy would capture the mitigating effects of REN on tourism-induced emissions. The inclusion of POPN in the analysis of tourism-emissions helps isolate the environmental impact of tourism while accounting for population size. Similarly, since FDI has been shown to have detrimental effects on the environment despite its growth-promoting benefits, its inclusion helps differentiate the environmental impact of tourism from that of FDI. The control variables are also transformed into natural logarithms for estimation purposes.

4. Discussion of results

In Table 4, the results of Pesaran (2004) CD test for CSD are presented, and except for renewable energy, REN, all variables in the model are found to be cross-sectionally dependent, thereby justifying the choice of Driscoll & Kraay (1998) fixed effects and Panel Corrected Standard Error (PCSE) estimation methods.

Table 4: Pesaran (2004) cross-sectional dependence test results

Variables	CD statistics	p-value
CO2	27.967	0.000
GHG	30.095	0.000
TD	30.867	0.000
GDP	20.658	0.000
REN	1.278	0.201
POPN	33.380	0.000
FDI	3.999	0.000

Presented in Table 5 below are the results of the baseline model and the first robustness check, which include only tourism development, GDP per capita, and its squared term as determinants of CO2 and GHG emissions. The findings indicate that tourism development significantly increases CO2 emissions, with a 1% rise in tourist arrivals causing a 0.3-0.4% surge in emissions. This aligns with previous studies that have documented similar adverse environmental impacts of tourism development such as Gedikli et al. (2022), Shakouri et al. (2017), Zhang & Gao (2016), Katircioglu (2014), and others.

The evidence on the EKC hypothesis is mixed. The Panel-Corrected Standard Errors (PCSE) estimation supports the EKC, showing an inverted U-shaped relationship between economic growth and CO2 emissions, consistent with findings by Grossman & Krueger (1995) and Stern (2004), but the fixed effects estimation does not find the EKC relationship significant. The GDP per capita threshold value is computed to be approximately USD 6,200. Given that the average GDP per capita of ASEAN countries is around USD 10,000 (see summary statistics table), exceeding the estimated threshold, it can be implied that the current economic development in ASEAN is not detrimental to the environment. However, this result should be interpreted cautiously, pending further confirmation through subsequent robustness checks.

The first robustness check, using GHG emissions as the dependent variable, also finds that tourism development increases GHG emissions, though the impact is smaller. A 1% increase in tourist arrivals raises GHG emissions by approximately 0.2%. The EKC hypothesis is again supported by the PCSE estimation, with the GDP per capita threshold at about USD 2,200, significantly lower than the threshold for CO2 emissions.

The second robustness check, which includes additional control variables such as renewable energy (REN), population size (POPN), and net inflow of foreign direct investment (FDI), is detailed in Table 6 below. The adverse environmental impacts of tourism development are supported only by the fixed effects estimation, where a 1% increase in tourist arrivals raises CO2 and GHG emissions by about 3% and 1%, respectively. The PCSE estimations yield insignificant coefficients for tourism development, likely due to the inclusion of population size as a control variable. In line with the baseline estimation, the EKC hypothesis continues to be supported by the PCSE estimation but not by the fixed effects model. The GDP per capita threshold is higher than in the baseline estimation, now approximately USD 12,000 for CO2 emissions and USD 14,000 for GHG emissions. These thresholds

exceed the average GDP per capita for ASEAN countries, further supporting the premise that current economic development in ASEAN remains harmful to the environment.

Renewable energy is found to be a strong mitigating factor, with a 1% increase in renewable energy use reducing CO2 emissions by 0.6-0.9% and GHG emissions by about 0.4%, confirming findings from previous studies such as Tian et al. (2021), Ben Jebli et al. (2019), Zhang & Liu (2019), and others. Population size meanwhile is a significant driver of both CO2 and GHG emissions, with a 1% increase in population size raising CO2 emissions by about 10% and GHG emissions by 3-9%, corroborating results from Liddle (2013). FDI however is not a significant determinant of CO2 emissions, and its impact on GHG emissions is mixed, echoing the finding by Kivyiro & Arminen (2014) but contrasting with that of Ben Jebli et al. (2019), who found FDI significantly raising CO2 emissions.

Overall, the findings confirm the adverse environmental effects of tourism development in ASEAN countries. However, the evidence on the EKC hypothesis is partial, depending on the choice of estimation model and the emission indicator used.

Table 5: Driscoll & Kraay (1998) fixed effects and Panel Corrected Standard Error (PCSE) estimations – baseline and robustness check 1.

Dependent Variable	**Baseline estimation DV: CO2 emissions**		**Robustness check 1 DV: GHG emissions**	
Estimation method	Driscoll & Kraay (1998) fixed effects	Panel Corrected Standard Error (PCSE)	Driscoll & Kraay (1998) fixed effects	Panel Corrected Standard Error (PCSE)
	(1)	(2)	(3)	(4)
TD_{it}	**0.421*** ** (0.052)	**0.281*** ** (0.065)	**0.198*** ** (0.025)	**0.180*** ** (0.042)
GDP_{it}	0.410 (0.447)	**3.038*** ** (0.571)	-0.488*** (0.120)	**1.956*** ** (0.337)
GDP^2_{it}	0.006 (0.023)	**-0.174*** ** (0.033)	0.055*** (0.008)	**-0.127*** ** (0.019)
Constant	0.314 (1.799)	-6.374*** (2.117)	8.554*** (0.535)	1.792 (1.135)
R-squared	0.738	0.975	0.772	0.993
Wald statistics	-	106.90***	-	153.75***
GDP per capita threshold of EKC	-	6,185.02	84.47	2,210.09

Notes: Standard errors in parentheses. ***, **, * indicate significance level at 1%, 5% and 10% respectively. Number of observations are 250 and number of countries 10. Using the significant coefficients of GDP and GDP^2, the calculation of the threshold level of real GDP per capita is done by taking exponential of the absolute value of the ratio of coefficient of GDP to twice coefficient of GDP^2, i.e. $e^{\left|\frac{GDP}{2*GDPSQ}\right|}$. ^ indicates the maximum level of real GDP per capita threshold.

Table 6: Driscoll & Kraay (1998) fixed effects and Panel Corrected Standard Error (PCSE) estimations – robustness check 2.

Dependent variable	**CO2 emissions**		**GHG emissions**	
Estimation method	Driscoll & Kraay (1998) fixed effects	Panel Corrected Standard Error (PCSE)	Driscoll & Kraay (1998) fixed effects	Panel Corrected Standard Error (PCSE)
	(5)	(6)	(7)	(8)
TD_{it}	**0.342*** **	0.041	**0.117*** **	-0.011
	(0.074)	(0.048)	(0.027)	(0.024)
GDP_{it}	0.142	**2.177*** **	-0.491**	**0.860*** **
	(0.556)	(0.409)	(0.210)	(0.145)
GDP^2_{it}	0.015	**-0.116*** **	0.052***	**-0.045*** **
	(0.033)	(0.022)	(0.015)	(0.008)
REN_{it}	**-0.942*** **	**-0.636*** **	**-0.431*** **	**-0.369*** **
	(0.108)	(0.084)	(0.061)	(0.034)
$POPN_{it}$	-0.056	**0.971*** **	**0.342***	**0.926*** **
	(0.405)	(0.062)	(0.162)	(0.024)
FDI_{it}	0.002	0.001	-0.010**	-0.002
	(0.007)	(0.002)	(0.003)	(0.001)
Constant	6.743	-14.555***	5.552	-6.941***
	(8.279)	(1.793)	(3.330)	(0.589)
R-squared	0.797	0.989	0.840	0.999
Wald statistics	-	642.80***	-	3094.09***
GDP per capita threshold of EKC	-	11,892.00	112.30	14,122.94

Notes: Standard errors in parentheses. ***, **, * indicate significance level at 1%, 5%, and 10% respectively. See more notes in Table 5.

5. Concluding Remarks

This research delves into the intricate relationship between tourism development, renewable energy utilization, and environmental quality, proxied by total carbon dioxide (CO2) and greenhouse gas (GHG) emissions, across 10 ASEAN countries from 1995 to 2019. The findings of this study highlight the complex relationship between tourism development, economic growth, and environmental quality in the context of ASEAN countries.

While tourism development is found to have adverse impacts on CO2 and GHG emissions, the evidence on the Environmental Kuznets Curve (EKC) hypothesis is partial and dependent on the estimation method and emission indicator used. The results suggest that the current level of economic development in ASEAN countries, with a mean GDP per capita of around USD 10,000, may have already surpassed the threshold point where economic growth becomes beneficial for the environment. However, the threshold estimates of GDP per capita GDP vary widely, ranging from USD 2,200 to USD6,200 in the baseline model, and USD 12,000 to USD 14,000 in the general model, indicating the need for further research to establish a more robust threshold.

The study also underscores the importance of renewable energy and population size as key determinants of environmental quality. Increasing the use of renewable energy can significantly mitigate the adverse effects of tourism development and economic growth on CO2 and GHG emissions.

On the other hand, population growth is found to be a major driver of environmental degradation, highlighting the need for sustainable population management policies.

From a policy perspective, these findings suggest that ASEAN countries should adopt a balanced approach to tourism development and economic growth, prioritizing sustainable practices and investing in renewable energy infrastructure. Policymakers should also consider the potential trade-offs between economic development and environmental protection, and strive to find a balance that maximizes the benefits of tourism while minimizing its negative impacts. Furthermore, the study emphasizes the need for coordinated regional efforts to address environmental challenges in ASEAN. Given the transboundary nature of many environmental issues, such as air pollution and climate change, a collaborative approach among ASEAN member states is crucial for effective policy implementation and monitoring.

In summary, this study contributes to the growing body of literature on the environmental impacts of tourism development and economic growth in ASEAN countries. The findings provide valuable insights for policymakers and researchers interested in promoting sustainable development in the region. However, further research is needed to refine the estimates of the Environmental Kuznets Curve and explore the complex interplay between various socio-economic and environmental factors in ASEAN.

Abbreviations:
ASEAN: Association of South-East Asian Nations; CO2: Carbon dioxide; CSD: Cross-sectional Dependence; EKC: Environmental Kuznets Curve; GHG: Greenhouse gas; PCSE: Panel Corrected Standard Errors;

Declarations:

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Competing interests
The authors declare that they have no competing interests.

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Availability of data and materials
We use secondary data obtained from World Development Indicators (WDI) by the World Bank (2024). The datasets used and/or analysed during the study are available from the corresponding author on reasonable request.

Authors' contributions
YLT contributed to the introduction and background section, and JEC on the empirical literature review and overall formatting of the manuscript. MA was responsible for the methodology, estimations, and

results sections supported by MSM on overall results discussion. SAMZ meanwhile summarized the results and made the policy recommendations. All authors have thoroughly read, revised, and refined the manuscript, ultimately approved the final version.

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