International Economics and Business Conference (IECON)
E-ISSN: 3089-2066 | Vol. 3, no. 2, 2025 | pp. 1314–1323

GDP and CO_2 Emissions in ASEAN-5: Has the Turning Point Been Reached?

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ARTICLE INFO

Article History:
Received
May 2025

Accepted
July 2025

Keywords
Environmental Kuznets Curve, CO_2 emissions, Economic Growth

A B S T R A C T

Rapid economic growth and urbanization in Southeast Asia have increased environmental pressures, particularly through rising carbon dioxide (CO_2) emissions driven by fossil fuel–based activities. The Environmental Kuznets Curve (EKC) framework is commonly used to assess whether economic growth eventually leads to lower emissions after surpassing a certain income level. This model is particularly relevant for ASEAN countries—Indonesia, Malaysia, Thailand, the Philippines, and Vietnam—that are undergoing industrial transition.

This study examines the presence of the EKC in the ASEAN-5 from 1990 to 2021 and estimates the turning point for each country. Using unbalanced annual panel data, a quadratic regression model is applied through Pooled OLS, Fixed Effects, and Random Effects methods. Model selection follows Chow and Hausman tests, with robustness diagnostics including heteroskedasticity (Breusch-Pagan), residual normality (Jarque-Bera), and cross-sectional dependence (Pesaran CD and LM tests). Turning points are calculated when the GDP coefficient is positive and the squared GDP coefficient is negative and statistically significant, indicating an inverted-U relationship.

Results confirm that CO_2 = f (GDP, GDP^2) is a valid specification for the region, reflecting a general shift toward greener economies. However, only Malaysia and Thailand have passed their respective turning points; Indonesia, the Philippines, and Vietnam remain below. These findings highlight the varying stages of environmental transition among ASEAN countries and underscore the urgent need for energy reform and policy interventions in nations that have not yet reached the emissions-reducing phase of economic development

1. Introduction

1.1 Background

The study of the Environmental Kuznets Curve (EKC) has gained increasing relevance in the context of developing countries, especially in ASEAN nations that have experienced rapid economic growth since 1990. The non-linear relationship between GDP per capita and CO_2 emissions is a critical issue, as emissions tend to rise with economic development but are

expected to decline after reaching a certain income threshold [1,2]. The period from 1990 to 2021 is particularly significant as it covers key phases of industrialization, trade liberalization, and energy structure transformation in countries like Indonesia, Malaysia, and Thailand [3,4].

Moreover, using the most recent data up to 2021 allows for a timely empirical test of whether ASEAN countries have reached the EKC turning point. Previous research suggests that the turning point may vary depending on factors such as industrial composition, economic openness, and clean energy policy [5,6]. By utilizing extended panel data and incorporating models that account for heterogeneity and cross-sectional dependence, this study aims to fill gaps in the literature and inform data-driven environmental policymaking.

1.2 Problem Statement

Despite the growing number of studies on the Environmental Kuznets Curve (EKC), empirical evidence regarding its validity in ASEAN countries remains inconclusive and inconsistent across time, sectors, and methodologies. While the EKC hypothesis suggests that CO_2 emissions initially increase with GDP per capita before declining after a certain income threshold—forming an inverted-U shape [1,2]—recent research has shown that such a pattern is highly context-dependent and may shift into an N-shape in some cases [5]. Additionally, existing studies often focus on earlier periods and fail to incorporate more recent data or adequately control for heterogeneity and cross-sectional dependence across countries [3,6].

There is a lack of updated, comprehensive panel analyses that confirm the existence of the EKC in ASEAN-5 countries while also identifying each country's specific turning point and evaluating whether emission levels have begun to decline in line with economic development. This gap hinders the development of targeted, evidence-based environmental policies. Therefore, this study aims to empirically test the EKC hypothesis using unbalanced panel data from 1990–2021 and assess the turning point and emission trajectories of ASEAN-5 economies [4].

1.3 Objectives and Scope

The primary objective of this study is to empirically test the validity of the Environmental Kuznets Curve (EKC) hypothesis in five ASEAN countries—Indonesia, Malaysia, Thailand, the Philippines, and Vietnam—over the period 1990 to 2021. Specifically, the study aims to identify the turning point of GDP per capita at which CO_2 emissions begin to decline and to analyze whether each country has entered the decarbonization phase. The study also seeks to assess the cross-country differences in emission behavior and their implications for environmental policymaking.This research is limited in scope to CO_2 emissions from industrial combustion and economic indicators such as GDP per capita. It employs an unbalanced static panel data model due to variation in data availability across countries and years. Institutional quality, renewable energy composition, and sectoral breakdowns are acknowledged as important factors but fall outside the scope of this study.

2. Literature Review

2.1 Related Work

The relationship between economic growth and carbon emissions in developing countries remains a subject of considerable academic debate. One of the most widely used approaches to analyze this relationship is the Environmental Kuznets Curve (EKC), which posits a non-linear, inverted-U-shaped relationship between per capita income and environmental degradation [4,5,7–10]. Empirically, the EKC hypothesis is typically tested using a quadratic model in which

a positive coefficient for GDP and a negative coefficient for GDP^2 indicate the presence of a turning point where economic growth begins to reduce emissions.

Recent studies emphasize that the existence and shape of the EKC are highly contextual, varying across countries and sectors. For instance, Zhang et al. [4] confirmed the EKC pattern in ASEAN countries only when the share of renewable energy was accounted for, highlighting the importance of clean energy structure as a moderating variable. Ahmad et al. [3] applied a dynamic panel GMM approach and validated the EKC hypothesis in Indonesia, Malaysia, and Thailand, although the turning points were delayed in countries with high industrial intensity.

Other research has brought attention to methodological challenges, particularly the issue of cross-sectional dependence (CSD) in panel data analysis. Nasir et al. [6] argue that overlooking CSD may lead to serious inferential errors due to strong economic and policy linkages among ASEAN member states. As a result, more recent studies have increasingly adopted advanced econometric techniques such as Common Correlated Effects (CCE) and cross-sectionally weighted EGLS to mitigate this problem.

Additionally, studies like Yilanci et al. [5] observed that the EKC does not always follow the classic inverted-U form. In some cases, particularly in countries heavily reliant on emission-intensive exports, the pattern can shift to an N-shape. For example, in Vietnam and the Philippines, emission trends after the expected turning point remain inconsistent and are often influenced by external factors such as foreign direct investment (FDI) and weak energy policies [3,9,11].

Panel studies using fixed and random effects models also suggest that country- specific factors significantly explain variations in carbon emissions [3,5,12]. Consequently, statistical tests such as the Hausman and Lagrange Multiplier (LM) tests are essential for selecting the appropriate panel regression model. To ensure model robustness, diagnostic checks for heteroskedasticity, autocorrelation, and cross-sectional dependence—such as the Pesaran CD and Breusch-Pagan LM tests—are increasingly recommended.

2.2 Research Gap

While numerous studies have explored the Environmental Kuznets Curve (EKC) in the context of ASEAN countries, much of the existing literature remains limited in scope due to outdated datasets—typically ending before 2020—and a lack of methodological depth. Many of these studies utilize basic panel regression models without controlling for critical econometric issues such as heterogeneity among countries and cross-sectional dependence, both of which are particularly relevant in a region with high economic and policy interdependence. As noted by Nasir et al. [6] and Ahmad et al. [3] failure to address these issues can lead to biased results and unreliable policy implications. Moreover, few studies have rigorously applied fixed-effects panel approaches with robust diagnostics such as the Pesaran CD test, Breusch-Pagan LM test, and Jarque-Bera test to ensure the validity of their findings.

In addition, while the EKC hypothesis implies the existence of a turning point in the relationship between income and environmental degradation, most empirical work in the ASEAN context treats the region as a homogenous block, neglecting the significant differences in industrial structure, energy policy, and institutional capacity across countries. As a result, the identification and interpretation of turning points at the individual country level remain underexplored and inconsistent. For instance, the extent to which Indonesia or Vietnam has reached or surpassed the income threshold for CO_2 emission decline is still unclear in the current literature. This study addresses these gaps by using unbalanced panel data from 1990 to 2021 and focusing on country-specific turning points, thereby providing more granular insights that can

better inform national-level environmental policy design.

3. Methodology

3.1 Data Collection

This study employs annual static panel data from five ASEAN countries—Indonesia, Malaysia, Thailand, the Philippines, and Vietnam—covering the period from 1990 to 2021. The data were sourced from authoritative global databases, including the World Bank, International Monetary Fund (IMF), and International Energy Agency (IEA). The key variables include CO_2 emissions from industrial combustion (measured in metric tons per capita), GDP per capita in constant per-capita (USD PPP), and the squared term of GDP per capita to reflect the quadratic specification of the Environmental Kuznets Curve (EKC) hypothesis. The dataset was selected based on its consistency, comparability, and alignment with the study's objective of examining long-term emission trends in relation to economic growth in ASEAN-5 countries.

3.2 Analysis Techniques

The empirical analysis adopts a quadratic panel regression model to test the EKC hypothesis, expressed as:

$$O_{2t} = {}_0 + {}_1 D_t + {}_2 D2_t + {}_t$$

Where: i denotes country, t denotes year, β_{0i} captures country-specific fixed effects, and e_{it} is the error term, the quadratic form (GDP2) allows the identification of a turning point, calculated as:

$$unn\ ont = \frac{1}{2_2}$$

which indicates the income level at which emissions begin to decline with further economic growth.

Three static panel estimation methods are applied: Pooled Ordinary Least Squares (POLS), Fixed Effects Model (FEM), and Random Effects Model (REM). The appropriate model is selected based on the Chow test and the Hausman test, ensuring robustness in capturing heterogeneity across countries.

3.3 Validation

To ensure the reliability of the model, several diagnostic tests are conducted. Heteroskedasticity is assessed using the Breusch-Pagan test, where insignificance of the coefficients □1, □2 in the auxiliary regression indicates homoskedastic residuals.

$$_t \quad = + {}_1 D_t + D_t + {}_t$$

Residual normality is evaluated using the Jarque-Bera test, and in cases of non-normal distribution, logarithmic transformation (e.g., log-GDP) is applied to improve normality.

Additionally, cross-sectional dependence is tested using the Breusch-Pagan LM test, the Pesaran scaled LM test, and the Pesaran CD test. If dependence is detected across units, robust standard errors clustered by country are applied to correct for bias. These validation steps align with econometric best practices and enhance the credibility of findings, particularly given the regional interdependence within ASEAN.

4. Results and Discussion

4.1 Key Findings

Based on the Chow test (p-value = 0.000) and Hausman test (p-value = 0.000), the Fixed Effects Model (FEM) is deemed more appropriate than the Random Effects Model (REM), indicating that country-specific characteristics significantly influence the relationship between CO_2 emissions and GDP per capita. The regression coefficients of GDP and GDP squared are statistically significant at the 1% level, with values of 1.08E-05 and - 3.30E-10, respectively. These findings confirm the inverted-U shape of the Environmental Kuznets Curve (EKC), where CO_2 emissions increase in the early stages of economic growth but begin to decline after reaching a certain income level.

The turning point for the ASEAN-5 aggregate is identified at a GDP per capita of $16,364 (PPP 2021). This implies that these countries, as a group, are expected to start reducing emissions once this income threshold is surpassed. Table 1 presents the FEM estimation results, while Table 2 details the cross-sectional effects and individual turning points by country.

4.2 Interpretation of Results

The cross-sectional coefficients further underscore this variation. Malaysia shows a positive coefficient (+0.092858), reflecting higher-than-average emissions relative to the ASEAN-5 baseline—likely due to its earlier industrialization and historically carbon- intensive economy. Meanwhile, Indonesia and the Philippines have negative coefficients (- 0.029684 and -0.054067, respectively), indicating relatively lower emissions. These findings are consistent with the absence of cross-sectional dependence (Pesaran CD test p
= 0.654) and normal distribution of residuals (Jarque-Bera p = 0.122). However, the presence of heteroskedasticity (Breusch-Pagan $p < 0.05$) necessitates the use of robust standard errors to ensure model reliability (Table 1).

The results reveal considerable heterogeneity in CO_2 emission behavior across ASEAN-5 countries, both in historical patterns and projected trends. As shown in Table 2, Malaysia reached its EKC turning point as early as 1992 at a GDP per capita of $24,636, indicating its relative advancement in emission control.

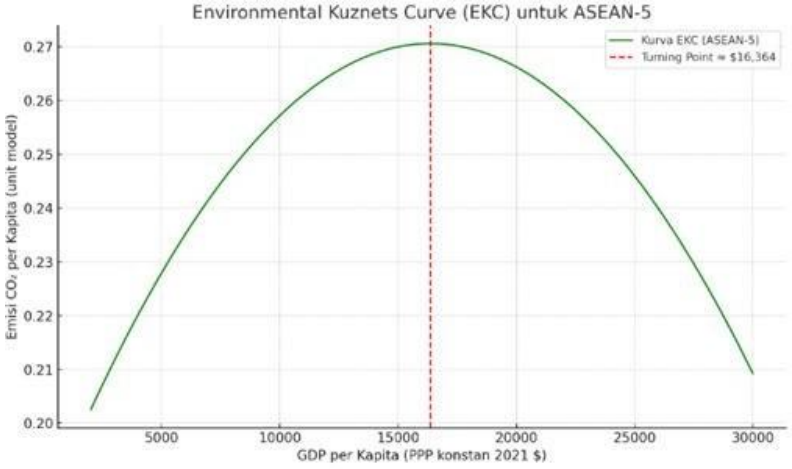
Table 2 Cross-Section Effect and Turning Points

COUNTRIES	CROSS-SECTION EFFECT	TURNING POINTS	TURNING POINT YEAR
		GDP per capita, PPP (constant 2021 international $)	
ASEAN-5		$16,364	
Indonesia	-0.029684	$ 12,757	2006
Malaysia	0.092858	$ 24,636	1992
Philipines	-0.054067	$ 6,787	1994
Thailand	-0.005479	$ 17,003	2006
Vietnam	-0.003628	$ 7,975 (Statistically insignificant)	1993

Indonesia and Thailand crossed their turning points in 2006 at $12,757 and $17,003 respectively, suggesting that they are now in the post-peak phase where emissions are expected to decline with further economic growth. In contrast, the Philippines and Vietnam remain below

their estimated thresholds, at $6,787 and $7,975 respectively. Notably, Vietnam's EKC result is statistically insignificant, implying that the model may not capture its emissions dynamics accurately, possibly due to structural or data limitations.

Figure 1: Environmental Kuznets Curve (EKC) for ASEAN-5 Based on the Fixed Effects Regression Model (FEM)

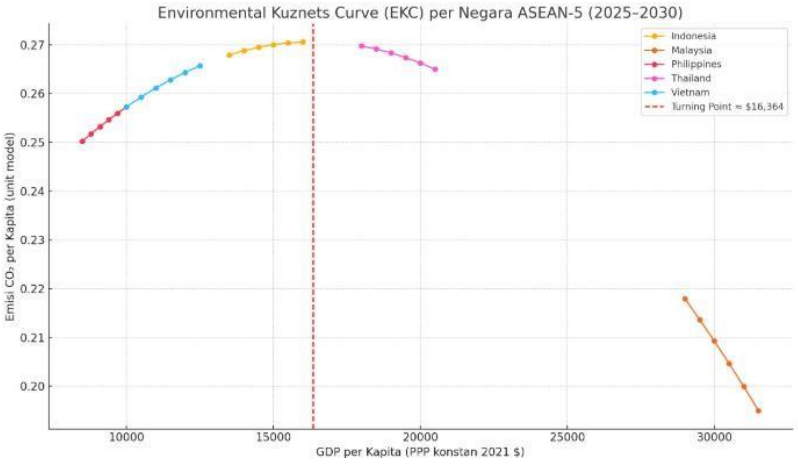


The EKC curve for ASEAN-5 (top right graph) clearly illustrates the inverted-U shape, with the regional turning point at $16,364 GDP per capita. Countries above this threshold—particularly Malaysia, and to a lesser extent Indonesia and Thailand—are now in a position to reduce CO_2 emissions without sacrificing economic growth. This is supported by the projected data in Table 3, which shows that by 2030, these three countries are expected to experience consistent economic growth with declining or stabilizing emissions. Malaysia, for example, is projected to achieve a GDP growth of 4.1% and a CO_2 reduction of -1.0% by 2030.

(Table3)

The bottom right graph, which presents individual EKC trajectories for each country from 2025 to 2030, highlights these trends visually. Malaysia continues on a clear downward emissions path, while Thailand and Indonesia approach a turning trajectory. In contrast, the Philippines and Vietnam remain below the turning point threshold and are projected to maintain positive emission growth through 2030. Vietnam's emissions, although slowing, still exhibit a slight upward trend (+0.1%), emphasizing the need for accelerated policy interventions, especially in clean energy development.

Figure 2: Environmental Kuznets Curve (EKC) by ASEAN-5 Country for the 2025–2030 Projection Period



These findings suggest that ASEAN-5 is in a transitional phase toward decarbonization. Countries that have already crossed the EKC turning point should focus on sustaining green growth through investments in clean technologies and energy efficiency. Meanwhile, nations that remain below the threshold must prioritize early-stage emission mitigation strategies to avoid future environmental and economic costs.

5. Discussion

5.1 Comparison with Prior Research

The findings of this study align with prior research supporting the Environmental Kuznets Curve (EKC) hypothesis in ASEAN countries, particularly in Indonesia, Malaysia, and Thailand. Ahmad et al. [3] confirmed the EKC using dynamic panel GMM models, noting that industrial intensity delays the turning point. Consistently, our fixed-effects regression model—with more recent data and diagnostic robustness—also identifies turning points for these countries, particularly in 2006 for Indonesia and Thailand, and even earlier for Malaysia. However, our results provide more recent empirical confirmation by extending the data through 2021 and controlling for cross-sectional dependence and heterogeneity, as advised by Nasir et al. [6]

Contrary to the classical inverted-U assumption, the results in the Philippines and Vietnam remain inconclusive or statistically insignificant—mirroring the mixed outcomes reported by Yilanci et al. [5] and Almeida et al. [13]. Their studies highlighted that EKC trajectories are highly sensitive to structural and institutional variables, especially in economies with weak environmental governance or insufficient renewable energy penetration. Our findings also support Zhang et al. [4] who emphasized the role of renewable energy development in sustaining the EKC, showing that Malaysia—having progressed furthest in renewable integration—demonstrates a consistent downward trend in emissions.

Additionally, this study advances the work of Anshari [11] who compared CO_2 emissions and ecological footprints, by providing a more precise identification of GDP-based turning points. Burki and Tahir [12] also stressed the influence of country-specific drivers such as trade, FDI, and industrial composition, all of which may explain why Vietnam and the Philippines lag behind. Unlike Almeida et al. [13] who used global cross-correlation analysis, our country-level panel approach provides localized insights more suitable for national policy design.

5.2 Limitations

One notable limitation is the statistical insignificance of Vietnam's results, which may stem from limited data or unobserved structural factors not captured by the model. This highlights the importance of adopting country-specific models rather than relying solely on regional aggregations. Furthermore, while the projection framework indicates future trends, actual outcomes may be influenced by unforeseen economic shocks or policy changes

5.3 Future Research

Future studies should incorporate broader environmental variables, such as renewable energy share, institutional quality, and technological innovation indicators. Extending the panel beyond 2021 and adopting dynamic or nonlinear models (e.g., threshold regressions or GMM-SYS) could yield deeper insights. More granular, sector-based analysis at the national level is also recommended to refine mitigation strategies.

6. Conclusion

This study confirms the existence of the Environmental Kuznets Curve in the ASEAN-5 region, albeit with significant variation across countries. By employing fixed-effects panel regression and controlling for key econometric issues, it identifies the turning point at which GDP per capita begins to reduce CO_2 emissions—found to be $16,364 (PPP 2021) in aggregate. The findings suggest that Indonesia, Malaysia, and Thailand are on a path toward decarbonization, while the Philippines and Vietnam require targeted policy interventions to transition toward cleaner growth. These insights contribute to the empirical validation of the EKC and offer valuable guidance for environmental policymaking in developing economies.

7. Recommendation

To achieve emission reductions while sustaining economic growth, policymakers in ASEAN should design country-specific mitigation strategies aligned with each nation's EKC trajectory. Investments in clean energy, energy efficiency technologies, and low-carbon infrastructure are essential, especially for countries nearing or yet to reach their EKC turning point. Regional collaboration in policy harmonization and knowledge sharing could further accelerate the transition to sustainable development across Southeast Asia.

Appendix

Table 1: Tabel 1: Result Model Fixed Effect: $CO2_{it} = \square_0 + \square_1(GDP)_{it} + \square_2 (GDP2)_{it} + \square_{it}$

MODEL	MODEL TESTING		$\square_0$	$\square_1$	$\square_2$
	CHOW	HAUSMAN			

FEM	36.2428 (0.000)	-	0.18225 (0.000)	1.08E-05 (0.000)	-3.30E-10 (0.000)
REM	-	16.942 (0.000)			
$CO2_{it}$ = 0.18255 + 1.08E-05 $(GDP)_{it}$ + -3.30E-10 $(GDP2)_{it}$ + $\square_{it}$					
R^2	0.752				
F test/prob	77.543 (0.000)				
Breusch-pagan (Heteroschedasticity)			0.000 (0.131)	6.34E-08 (0.370)	-2.30E-12 (0.253)
Pesaran CD (Cross-Section Dependence Test)	0.448(0.654)				
Jarque-Bera (Normality)	4.199 (0.122)				

Table 3: Projected Economic Growth and CO_2 Emissions, 2025–2030

Country	2025	2026	2027	2028	2029	2030
ASEAN-5	4.5 (0.3)	4.4 (0.2)	4.3 (0.2)	4.3 (0.1)	4.2 (0.0)	4.2 (-0.1)
Indonesia	5.1 (-0.2)	5.0 (-0.3)	4.9 (-0.4)	4.8 (-0.5)	4.8 (-0.6)	4.8 (-0.7)
Malaysia	4.4 (-0.5)	4.3 (-0.6)	4.2 (-0.7)	4.1 (-0.8)	4.1 (-0.9)	4.1 (-1.0)
Philippines	6.2 (0.5)	6.0 (0.5)	5.8 (0.4)	5.6 (0.3)	5.5 (0.2)	5.5 (0.1)
Thailand	3.1 (-0.1)	3.2 (-0.2)	3.3 (-0.3)	3.3 (-0.4)	3.3 (-0.4)	3.3 (-0.5)
Vietnam	6.0 (0.3)	6.1 (0.3)	6.2 (0.2)	6.2 (0.2)	6.1 (0.1)	6.1 (0.1)

Note: Figures in parentheses indicate emission growth

Acknowledgement

The authors gratefully acknowledge the financial and institutional support from the Faculty of Economics and Business, Universitas Muhammadiyah Semarang (UNIMUS). The authors also extend their appreciation to the Undergraduate Management Program for the time and opportunity granted in the preparation of this article.

REFERENCES

[1] Grossman G M and Krueger A B 1995 Economic Growth and the Environment *The Quaterly Journal of Economics* 110 353–77

[2] Stern D I 2004 The Rise and Fall of the Environmental Kuznets Curve *World Development* 32 1419–39

[3] Ahmad M, Zhao Z Y, Irfan M, Mukeshimana M C and Rjoub H 2021 Modeling the Dynamic Linkages between FDI, Industrialization and Carbon Emissions in the ASEAN Region *Environmental Science and Pollution Research* 28 23890–906

[4] Zhang D, Wang A Y and Zhou H 2022 Does Renewable Energy Development Mitigate CO2 Emissions? Evidence from ASEAN Countries *Renewable Energy* 181 1227–35

[5] Yilanci V, Aydin M and Pata U K 2022 Re-Examining the EKC Hypothesis in ASEAN-5 Countries: The Role of Energy Mix and Institutional Quality *Energy Reports* 9 5431–45

[6] Nasir M, Cahn N P and Thanh S D 2020 Environemtal Degradationand Role of Financialisation, Economic Development, Industrialisation and Trade Liberalisation: Evidence from ASEAN Econommies *Sustainable Development* 28 733–42

[7] Gill A R, Viswanathan K K and Hassan S 2017 Is Environmental Kuznets Curve Still

Relevant? 7
[8] Iskandar A 2019 ECONOMIC GROWTH AND CO2 EMISSIONS IN INDONESIA : INVESTIGATING THE ENVIRONMENTAL KUZNETS CURVE HYPOTHESIS EXISTENCE *JBPPK* 12 42–52
[9] Rahayuningrum S T 2024 Analysis of the Existence of Environmental Kuznets Curve (EKC) Hypothesis on CO2 Emission, Energy Consumption, and Economic Growth in Indonesia *JERSS* 8 38–52
[10] Wang Q, Li Y and Li R 2024 Rethinking the environmental Kuznets curve hypothesis across 214 countries: the impacts of 12 economic, institutional, technological, resource, and social factors *Humanit Soc Sci Commun* 11
[11] Anshari M A 2022 Re-visiting the Environmental Kuznets Curve for ASEAN: A Comparison between Ecological Footprint and Carbon Dioxide Emissions *Renewable and Sustainable Energy Reviewss* 168
[12] Burki U and Tahir M 2022 Determinants of Environmental Degradation: Evidenced-Based Insights from ASEAN Economies *Journal of Environmental Management* 306
[13] Almeida D, Carvalho L, Ferreira P, Dionísio A and Haq I U 2024 Global Dynamics of Environmental Kuznets Curve: A Cross-Correlation Analysis of Income and CO2 Emissions *Sustainability* 16 9089