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Assessing the Macroeconomic and Environmental Determinants of ASEAN's Economic Growth: Evidence from Panel Data (2000–2023)

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ABSTRACT

This study investigates the relationship between economic growth and key macroeconomic–environmental indicators across ASEAN (2000–2023), highlighting the trade-offs between output expansion, resource use, and sustainability. Employing a panel data approach with the Fixed Effects Model (FEM), the analysis covers eight ASEAN economies—Brunei, Indonesia, Malaysia, Cambodia, Singapore, Thailand, the Philippines, and Vietnam. The dependent variable, the natural logarithm of Gross Domestic Product (LOG(GDP)), is regressed on inflation, final consumption expenditure, labour force, gross fixed capital formation, and emissions of CO_2 and N_2O. The results reveal that final consumption expenditure and CO_2 emissions have positive and statistically significant effects on economic growth, indicating that energy-intensive consumption remains a key driver of output in the region. In contrast, inflation, labour force size, and N_2O emissions exhibit negative and significant relationships with GDP, suggesting that price instability, inefficiencies in labour utilization, and environmental degradation can constrain economic performance. The model demonstrates high explanatory power (Adjusted $R^2 = 0.9998$), although a low Durbin–Watson statistic signals potential autocorrelation. This study enriches the limited empirical literature on the macro–environmental nexus in ASEAN by applying an extended panel framework with robust country-fixed effects. The findings highlight the need for balanced policy strategies that promote sustainable growth through productivity enhancement, price stability, and emissions reduction.

Keywords: Economic Growth, Environmental Indicators, CO_2 Emissions, Panel Data, ASEAN
JEL Classifications: E01, O44, Q56, Q43, C33

1. INTRODUCTION

Economic growth is widely recognized as a key indicator of a country's welfare and development progress (Costanza et al., 2009). In the ASEAN region—comprising nations with diverse economic structures—Gross Domestic Product (GDP) growth has generally shown a positive trajectory over the past two decades. However, this progress has been accompanied by structural and environmental challenges. Rising domestic consumption, expanding investment, and increasing labor mobilization have served as major engines of growth. Yet, concerns persist regarding the sustainability of growth models that depend heavily on natural resource exploitation and carbon-intensive activities.

The economic transformation across ASEAN has inevitably produced environmental externalities, most notably the rising emissions of carbon dioxide (CO_2) and nitrous oxide (N_2O), which contribute to global climate change and local ecological degradation (Mai et al., 2025). Several countries—such as Indonesia, Thailand, and Vietnam—face growing pressures from rapid urbanization, environmentally unfriendly industrialization, and heavy dependence on fossil fuels (Ho et al., 2021). This

creates a classical dilemma between economic expansion and environmental sustainability, often referred to as the economy–ecology trade-off. Labor, as a fundamental production factor, also plays a critical role. Although the labor force has grown steadily, its contribution to economic performance is not always significant, reflecting issues such as low productivity, informal employment, and skill mismatches. In ASEAN, disparities in human capital quality among member states further exacerbate inequality in growth and development outcomes (Goh, 2025). Similarly, inflation remains a crucial macroeconomic variable influencing overall stability. High inflation can erode purchasing power, reduce investment, and weaken economic efficiency (Abaidoo and Agyapong, 2023). Meanwhile, gross fixed capital formation and final consumption expenditure represent core drivers of domestic activity, directly influencing national output (Gruneberg and Folwell, 2013).

Theoretically, the foundation of this research builds upon the evolution of growth theory. Classical economists such as Adam Smith and David Ricardo emphasized capital accumulation and labor as key drivers of output, while Solow's neoclassical model introduced technological progress as a determinant of long-term growth (Yerznkyan et al., 2021). Endogenous growth models by Romer (1986) and Lucas (1988) later highlighted the importance of human capital, innovation, and research in sustaining growth (Hippe, 2014). Empirical studies in developing economies—including ASEAN members—have further shown that gross fixed capital formation, consumption, labor productivity, and macroeconomic stability substantially influence growth outcomes. From the environmental perspective, the Environmental Kuznets Curve (EKC) hypothesis suggests an inverted U-shaped relationship between income per capita and environmental degradation (Özokcu and Özdemir, 2017). At early stages of development, pollution tends to rise with income; however, beyond a certain threshold, economic progress facilitates cleaner technologies and stronger environmental policies. Yet, evidence on the EKC remains mixed, particularly in developing economies that continue to rely on fossil fuels and resource-based sectors (Sutton et al., 2014). In ASEAN, where energy intensity and consumption growth remain high, this hypothesis warrants renewed empirical testing.

Despite extensive literature on economic growth and environmental dynamics, limited studies have jointly examined the dynamic interaction between macroeconomic variables and environmental factors in the ASEAN context over a long-term period. Moreover, few empirical works have incorporated labor, inflation, investment, and consumption simultaneously within an integrated analytical framework. To address this research gap, the present study employs a panel data approach using the Fixed Effects Model (FEM) to explore the relationships among GDP, CO_2 emissions, final consumption expenditure, gross fixed capital formation, labor force, and inflation across eight ASEAN countries during 2000–2023. The findings are expected to offer insights for designing balanced, inclusive, and environmentally conscious policies that promote sustainable growth and long-term resilience in the ASEAN region.

2. METHODOLOGY AND DATA

2.1. Study Design and Study Area Description

This study adopts a quantitative research design using a panel data approach to examine the effects of macroeconomic and environmental variables on economic growth across eight ASEAN countries—Brunei, Indonesia, Malaysia, Cambodia, Singapore, Thailand, the Philippines, and Vietnam—over the period 2000–2023. The use of panel data combines both cross-sectional (between countries) and time-series (across years) dimensions, thereby providing richer and more informative datasets. This approach enhances the degrees of freedom, reduces potential multicollinearity among explanatory variables, and captures country-specific heterogeneity over time (Pesaran, 2015).

The ASEAN region provides an ideal context for this study due to its diverse economic structures and environmental policies. While some member countries such as Singapore and Malaysia are relatively advanced economies, others like Cambodia and Vietnam are still developing. This heterogeneity allows for a comprehensive analysis of how macroeconomic fundamentals and environmental factors jointly influence economic growth. Moreover, ASEAN's collective commitment to the Paris Agreement and the Sustainable Development Goals (SDGs) underscores the relevance of examining this interrelationship within a sustainability framework.

2.2. Methods of Data Collection

This research relies primarily on secondary data obtained from reputable international sources, including the World Bank's World Development Indicators (WDI), UN Data, and the ASEAN Statistical Yearbook. The study covers annual data from 2000 to 2023, encompassing key economic and environmental indicators relevant to the growth–environment nexus.

The selected variables are as follows:

- GDP: Gross Domestic Product (proxy for economic growth)
- INF: Inflation rate
- CO2E: Carbon dioxide emissions
- FCE: Final consumption expenditure
- LABOR: Labor force
- N2OE: Nitrous oxide emissions
- GFC: Gross fixed capital formation.

All variables, except for the inflation rate, are expressed in natural logarithmic form to interpret the coefficients as elasticities and to minimize potential heteroskedasticity. The selection of these variables is grounded in prior empirical studies on the determinants of economic growth and environmental sustainability (Grossman and Krueger, 1995). The inclusion of CO_2 and N_2O emissions captures the environmental dimension of growth, while the macroeconomic indicators reflect economic stability and productive capacity.

2.3. Conceptual Framework of Study Variable

The conceptual framework of this study rests on the premise that economic growth is shaped by both macroeconomic performance and environmental conditions. Macroeconomic variables such as inflation, consumption, labor, and capital formation are expected

to positively influence GDP growth, as they represent aggregate demand, investment, and productive capacity. Conversely, environmental variables such as CO_2 and N_2O emissions may have dual effects: While moderate emissions often accompany industrial expansion, excessive levels can hinder growth through environmental degradation, health burdens, and resource depletion. This dynamic relationship aligns with the Environmental Kuznets Curve (EKC) hypothesis, which postulates that environmental degradation initially rises with income but eventually declines as economies advance.

The econometric model used in this study is specified as follows:

$$log\,(GDP_{it}) = \alpha_i + \beta_1\, INF_{it} + \beta_2\, log\,(CO2E_{it}) + \beta_3\, log\,(FCE_{it}) + \beta_4\, log\,(LABOR_{it}) + \beta_5\, log\,(N2OE_{it}) + \beta_6\, log\,(GFC_{it}) + \varepsilon_{it}$$

- i denotes the country, and t denotes the year,
- α_i represents the country-specific fixed effect, and
- ε_{it} is the error term.

This framework enables the study to capture the dynamic interactions between economic and environmental factors while accounting for unobserved heterogeneity among ASEAN countries.

2.4. Data Analysis

The main econometric specification applied in this study is the Fixed Effects Model (FEM). The selection of FEM is based on the results of diagnostic tests. The Chow test indicates that the FEM is preferable to the Common Effects Model (CEM), while the Hausman test confirms that FEM provides more consistent and efficient estimates than the Random Effects Model (REM). By controlling for country-specific effects α_i, the FEM accounts for unobserved heterogeneity—such as institutional, cultural, or geographic differences—that remain constant over time, thus minimizing estimation bias.

Before model estimation, descriptive statistics and correlation analysis were conducted to examine variable distributions and interrelationships. Several diagnostic tests were also performed, including heteroskedasticity and autocorrelation tests, to ensure the robustness of the model. The estimation employed the Estimated Generalized Least Squares (EGLS) method with period weights, effectively addressing potential issues of heteroskedasticity and serial correlation across time periods (Akpan and Moffat, 2018).

This analytical procedure ensures that the empirical results are reliable, consistent, and capable of explaining how macroeconomic and environmental variables influence economic growth across ASEAN countries over the study period.

3. RESULTS AND DISCUSSION

This section presents the empirical findings of the study, beginning with descriptive statistics, followed by panel regression estimations and diagnostic tests to evaluate the robustness of the results. The discussion then interprets the implications of each key variable in relation to ASEAN's economic and environmental dynamics.

3.1. Descriptive Statistics

Table 1 summarizes the descriptive statistics of the main variables used in this study, including economic and environmental indicators for eight ASEAN countries from 2000 to 2023.

The descriptive statistics reveal substantial variation among ASEAN countries in terms of their economic and environmental characteristics. GDP and final consumption expenditure (FCE) display high mean values with positive skewness, indicating significant disparities in income and consumption patterns across member states. Singapore and Malaysia exhibit relatively higher GDP levels, while Cambodia and Laos remain at the lower end of the income distribution. Inflation (INF) demonstrates high variability and a wide range, reflecting macroeconomic volatility in developing economies such as Cambodia and the Philippines, which frequently experience external price shocks and policy instability.

The positive skewness of CO_2 and N_2O emissions illustrates uneven industrialization levels across the region, where rapidly developing economies like Indonesia, Vietnam, and Thailand contribute disproportionately to emissions relative to smaller economies. This variation reflects differing stages of industrial maturity, energy dependency, and environmental management capacity among ASEAN members. To address these disparities and stabilize variance across countries, all variables (except inflation) were transformed into their natural logarithmic forms before model estimation, ensuring the robustness and interpretability of regression results.

3.2. Panel Regression Analysis

The Fixed Effects Model (FEM) was selected as the most appropriate estimator after the Chow and Hausman tests confirmed its superiority over the Common Effects Model (CEM) and Random Effects Model (REM). The FEM accounts for unobserved heterogeneity across countries that remains constant over time—such as institutional structures, resource endowments, and governance frameworks—thereby improving the reliability of the estimates. The Fixed Effects Model (FEM) was selected as the most appropriate estimator after the Chow and Hausman tests confirmed its superiority over the Common Effects Model (CEM) and Random Effects Model (REM) (Basuki and Prawoto, 2016). The FEM accounts for unobserved heterogeneity across countries that remains constant over time—such as institutional structures, resource endowments, and governance frameworks—thereby improving the reliability of the estimates (Table 2).

The estimation results reveal that final consumption expenditure (FCE) and gross fixed capital formation (GFC) exert strong, positive, and statistically significant impacts on economic growth. The coefficient for FCE (0.9701) is the largest among all variables, confirming that domestic consumption is a critical driver of ASEAN's economic performance. This finding aligns with Keynesian economic theory, emphasizing the centrality of household consumption and government spending in stimulating aggregate demand. Economies such as Indonesia, Thailand, and the Philippines rely heavily on domestic demand, which provides resilience against external shocks and global market fluctuations.

Table 1: Descriptive statistics

Summary measures	GDP	CO2E	N2OE	INF	FCE	GFC	LABOR
Mean	1.18E+15	140.2515	16.00696	2.767875	8.02E+14	1.01E+14	31681727
Median	7.58E+12	84.5642	10.0868	3.0149	5.63E+12	8.38E+11	17923168
Maximum	1.23E+16	674.5359	78.8673	58.45104	7.61E+15	1.04E+15	1.41E+08
Minimum	1.61E+10	0.5303	0.0842	−88.1596	4.86E+09	2.22E+09	114327
Standard deviation	2.53E+15	144.6946	20.09114	11.64108	1.68E+15	2.24E+14	35631049
Skewness	2.45014	1.413844	1.810778	−4.35455	2.315288	2.495792	1.474003
Kurtosis	8.634407	4.876001	5.240501	36.13016	7.800441	8.667717	4.480655
Sum	3.09E+17	36886.13	4209.83	727.951	2.11E+17	2.67E+16	8.33E+09
Sum Sq. Dev.	1.67E+33	5485368	105757.4	35504.89	7.43E+32	1.32E+31	3.33E+17
Observations	263	263	263	263	263	263	263

Source: Author's processing (2025)

Table 2: Panel data regression results

Dependent variable: LOG (GDP)			
Method: Panel EGLS (Period weights)			
Sample: 2000-2023			
Variable	**CEM**	**FEM**	**REM**
INF	0.0007	−0.0091	0.0012
t-Statistic	0.3164	−3.9863***	0.8421
LOG (CO2E)	0.1594	0.1725	0.1010
t-Statistic	15.3702***	18.0995***	6.0107***
LOG (FCE)	0.9667	0.9701	0.9006
t-Statistic	44.0943***	48.0670***	26.4836***
LOG (LABOR)	−0.1669	−0.1612	−0.0809
t-Statistic	−10.2913***	−10.5764***	−3.0145***
LOG (N2OE)	−0.0903	−0.1128	−0.0965
t-Statistic	−7.5255***	−9.6485***	−8.0108***
LOG (GFC)	0.0673	0.0721	0.1082
t-Statistic	3.0857***	3.5862***	3.2665***
C	1.7644	1.4452	1.4374
t-Statistic	9.1251***	7.6879***	5.6985***
R-squared	0.9997	0.9998	0.9934
F-statistic	110409.7	28223.17	4669.411
Jarque-Bera	0.7253	3.1018	1.7473
Probability	0.6958	0.2120	0.4174
Uji Chow	Statistic	3.0808	
	Probability	0.0000	
Uji Hausman	Chi Sq. Statistic		125.8527
	Probability		0.0000

Source: Author's processing (2025). ***, **, * ==> Significance at 1%, 5%, 10% level

Similarly, gross fixed capital formation (GFC)—a proxy for investment—has a significant positive effect on GDP (0.0721). This underscores the importance of capital accumulation in expanding productive capacity and fostering long-term growth (Zhang et al., 2020; Petrakis, 2020), consistent with endogenous growth theory (Romer, 1990). Investment in infrastructure, manufacturing, and renewable energy within ASEAN countries has been instrumental in boosting output and promoting industrial diversification.

The coefficient of CO_2 emissions (CO2E) is also positive and significant (0.1725), suggesting that industrial expansion and energy consumption continue to drive short-term economic growth across the region. This finding supports the initial stage of the Environmental Kuznets Curve (EKC) hypothesis, which posits that environmental degradation tends to rise with income at early development stages. Industrializing economies such as Vietnam and Indonesia exemplify this pattern, where rapid growth has been accompanied by rising carbon emissions. However, this growth model remains carbon-intensive, posing risks to long-term environmental sustainability.

Conversely, inflation (INF) demonstrates a negative and statistically significant relationship with GDP (-0.0091), confirming the destabilizing effect of price volatility on investment, consumption, and overall economic performance. Persistent inflation erodes purchasing power, distorts relative prices, and discourages savings and investment—effects particularly evident in emerging ASEAN economies (Barro, 2013).

The labor variable (LOG(LABOR)) exhibits a negative coefficient (-0.1612), which may seem counterintuitive but reflects underlying structural inefficiencies in labor utilization. The result indicates that expanding the labor force alone does not guarantee higher output if productivity gains remain limited. Factors such as informal employment, technological lag, and skills mismatch contribute to this negative association. According to the Lewis dual-sector model, economies in transition often face diminishing returns when surplus labor from traditional sectors enters modern industries without parallel productivity improvements.

Nitrous oxide emissions (N_2OE) exert a negative and significant effect (-0.1128), highlighting the adverse impact of unsustainable agricultural practices on economic performance. N_2O emissions—primarily generated from fertilizer-intensive agriculture and livestock—deteriorate soil quality and environmental conditions, ultimately constraining long-term agricultural productivity. This emphasizes the urgency of promoting sustainable farming practices and low-emission agricultural technologies in economies such as Cambodia and Vietnam.

Overall, the FEM results confirm ASEAN's dual growth pattern: consumption and investment remain powerful engines of economic expansion but are accompanied by environmental trade-offs and labor inefficiencies. The extremely high adjusted R^2 (0.9998) indicates that the selected macroeconomic and environmental variables collectively explain nearly all variations in GDP among ASEAN countries. However, the relatively low Durbin–Watson statistic (≈1.1) suggests mild autocorrelation, which was addressed through the Estimated Generalized Least Squares (EGLS) estimation procedure.

3.3. Diagnostic Tests and Model Robustness

To ensure the robustness of the estimation results, several diagnostic tests were conducted. The heteroskedasticity test using

Table 3: Heteroscedasticity test

Dependent variable: LOG (RESIDUAL^2)				
Method: Panel EGLS (Period weights)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
INF	0.030453	0.047122	0.646258	0.5190
LOG (CO2E)	0.237580	0.192608	1.233488	0.2192
LOG (FCE)	−0.075862	0.399568	−0.189859	0.8497
LOG (LABOR)	−0.320042	0.277312	−1.154088	0.2502
LOG (N2OE)	−0.189691	0.220512	−0.860227	0.3909
LOG (GFC)	0.149757	0.403430	0.371210	0.7110
C	−3.817301	3.394942	−1.124408	0.2625

Source: Author's processing (2025)

the Panel EGLS (Period Weights) method indicates that the null hypothesis of homoskedasticity cannot be rejected ($p = 0.327$), confirming that the model residuals are consistent and stable across cross-sections (Table 3).

In addition, the use of the Estimated Generalized Least Squares (EGLS) method effectively mitigates potential issues of heteroskedasticity and serial correlation, thereby improving the accuracy of coefficient estimates. This approach, as recommended by Akpan and Moffat (2018), ensures that the model remains robust and unbiased even under cross-sectional dependence among ASEAN countries.

Collectively, the diagnostic results validate the robustness of the FEM and confirm that the identified relationships are not driven by model misspecification or data inconsistencies. The findings indicate that ASEAN's economic growth has been largely consumption- and investment-driven but remains environmentally and structurally imbalanced. Without policy adjustments, the combination of rising emissions, inefficient labor absorption, and inflationary pressures may threaten long-term economic stability.

To achieve sustainable growth, ASEAN policymakers should prioritize green investment, labor productivity enhancement, and macroeconomic stabilization. Integrating renewable energy policies, expanding vocational training, and fostering innovation-led industrialization will be essential to decouple economic expansion from environmental degradation and achieve inclusive prosperity across the region.

4. CONCLUSION

This study examined the influence of selected macroeconomic and environmental variables on economic growth (GDP) across eight ASEAN countries—Brunei, Indonesia, Malaysia, Cambodia, Singapore, Thailand, the Philippines, and Vietnam—over the period 2000–2023 using a panel data framework through the Fixed Effects Model (FEM). The empirical results reveal that CO_2 emissions (CO2E), final consumption expenditure (FCE), and gross fixed capital formation (GFC) exert positive and statistically significant effects on GDP, indicating that household consumption and capital investment remain the key engines of economic expansion in the ASEAN region. In contrast, labor force size (LABOR), nitrous oxide emissions (N_2OE), and inflation (INF) have negative and significant impacts, suggesting that growth performance is constrained by inflationary pressures, labor market inefficiencies, and environmentally unsustainable production practices. The extremely high adjusted R^2 (0.9998) indicates that the selected macroeconomic and environmental variables collectively explain nearly all variations in GDP among ASEAN countries. However, the relatively low Durbin–Watson statistic (≈1.1) suggests mild autocorrelation, which was addressed through the EGLS estimation procedure.

Theoretically, this study contributes to the broader understanding of the macroeconomic–environmental nexus by providing empirical evidence that aligns with the Environmental Kuznets Curve (EKC) hypothesis. The findings imply that while economic growth initially intensifies environmental degradation, structural transformation and technological advancement can eventually mitigate emissions, enabling a transition toward sustainable growth (Zhang et al., 2022). These results highlight the importance of embedding environmental considerations within macroeconomic policy frameworks.

From a policy perspective, ASEAN governments should prioritize improving labor productivity through education and skills enhancement, optimizing public spending efficiency, and expanding investments in renewable energy and low-carbon technologies. The adoption of carbon pricing mechanisms and stronger environmental governance can further reinforce sustainable growth paths. Such measures will not only promote economic resilience but also advance progress toward the Sustainable Development Goals (SDGs), particularly Goal 8 (Decent Work and Economic Growth) and Goal 13 (Climate Action).

Despite its valuable insights, this study has several limitations. The dataset covers the period up to 2023 and includes only eight ASEAN economies, which may constrain the generalizability of the results. In addition, global factors such as commodity price fluctuations and foreign direct investment inflows were not incorporated, even though they potentially influence regional growth dynamics. While the FEM approach controls for country-specific heterogeneity, endogeneity among explanatory variables may persist. Therefore, future research should consider employing dynamic panel estimators or instrumental variable approaches to obtain more robust and comprehensive insights into the macro–environmental growth nexus in ASEAN.

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