

THE PRICE OF PROSPERITY: CARBON LOCK-IN, AGGLOMERATION ECONOMIES, AND THE EKC PATHWAY IN ASEAN

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Abstract

This research investigates the macroeconomic determinants of CO₂ emissions in the ASEAN-10 region, analyzing the tension between rapid economic expansion, energy consumption, and demographic shifts. Utilizing a balanced panel dataset (2000-2022) comprising 230 observations, the research employs a Panel Estimated Generalized Least Squares (EGLS) approach with Cross-Section Weights and Fixed Effects to control for cross-country heterogeneity, heteroskedasticity, and first-order serial correlation. The log-log econometric estimation reveals that energy consumption exhibits an elastic, highly disproportionate impact on emissions ($\beta=1.37$), highlighting a severe regional "carbon lock-in." Economic growth remains fundamentally coupled with environmental degradation ($\beta=0.52$), firmly positioning ASEAN on the ascending limb of the Environmental Kuznets Curve (EKC). Conversely, population density exerts a significant mitigating effect ($\beta=-0.69$) on per capita emissions, providing robust empirical support for agglomeration economies and the "Compact City" hypothesis. The findings urgently call for structural policy shifts in ASEAN, moving beyond mere energy efficiency towards aggressive decarbonization of the primary energy mix and investments in high-density, green urban infrastructure.

Keywords: Environmental Kuznets Curve, Carbon Lock-in, Agglomeration Economies, Energy Transition, Panel EGLS, ASEAN

INTRODUCTION

The Association of Southeast Asian Nation (ASEAN) region has developed as one of the world's most active economic areas, with major contributions to global development (Triani et al., 2023). Fossil fuel combustion is responsible for 5.2% of global CO₂ emissions, fueling the spectacular economic growth (Solaymani et al., 2024). The region's carbon intensity is expected to climb further as fossil-fuel-driven industrialization proceeds (Azmin et al., 2022). As a result, the tension between maintaining high economic growth rates and adhering to international environmental standards produces a complicated policy landscape necessitating a thorough understanding of emission sources in these various nations (Damayanti et al., 2024).

This analysis is based on the Environmental Kuznets Curve (EKC) theory, which proposes an inverted U-shaped link between economic development and environmental quality (Amin et al., 2023). The validity of EKC is sometimes questioned; while real income and trade openness may eventually reduce deterioration, the current boom phase frequently shows a positive association between income and emissions (Pata et al., 2023). The STIRPAT framework (Stochastic Impacts by Regression on Population, Affluence, and Technology) adds structure to the analysis of how demographic and economic factors influence environmental standards (Sugiharti et al., 2025). Furthermore, the impact of energy intensity is critical, as it is a main driver in situations where energy efficiency advances are frequently negated by rapid economic expansion (Goh and Ang, 2020).

Considering several regional initiatives, ASEAN's carbon trajectory remains on the rise, with energy sector emissions potentially growing 2.6 times by 2040 (Goh & Ang, 2020). The core issue is the high "carbon cost" of area growth, in which financial development and foreign direct investment frequently contribute to environmental degradation rather than mitigation. More importantly, there is a dilemma in environmental fiscal policies, as present ASEAN tax levels and ecological expenditures may not be rigorous enough to result in quick emission reductions (Zhang et al., 2025). Without a good econometric knowledge of these elasticities, policymakers risk implementing "one-size-fits-all" remedies that ignore the region's distinct structural drivers of pollution (Zhang et al., 2025).

This research aims to examine CO₂ emissions in ASEAN countries by an econometric technique for policy-making decision. More precisely, the research also aims to:

- Determine the elasticity of CO₂ emissions in relation to GDP to assess growth-pollution coupling.
- Evaluate the effect of Total Energy Consumption on regional emissions to determine the carbon intensity of the energy mix.
- Evaluate the impact of population density on environmental quality and infrastructure efficiency.
- Creation of evidence-based policy suggestions to support a low-carbon transition by improving energy planning and promoting renewable energy.

LITERATURE REVIEW

Nexus Between Economic Growth and CO₂ Emissions

The relationship between economic affluence and environmental quality is predominantly examined through the lens of the Environmental Kuznets Curve (EKC) hypothesis. Amin et al. (2023) confirmed the existence of an inverted U-shaped EKC in ASEAN, suggesting that while initial growth degrades the environment, higher income levels eventually lead to improved environmental quality. Rambeli et al. (2021) found evidence of the EKC in Malaysia and Singapore, though they characterized the relationship as U-shaped in certain contexts, emphasizing that emissions continue to rise until an optimum national income point is reached. However, recent findings by Oprea et al. (2025) highlight that GDP remains a significant positive driver of emissions in both the short and long run for ASEAN, indicating that the region may still be on the upward slope of the curve. Furthermore, Pata et al. (2023) argue that while real income can reduce degradation, the concurrent effects of tourism and foreign direct investment often counteract these gains.

Energy Consumption and Intensity as Primary Drivers

Energy dynamics are central to the ASEAN emission narrative. Goh and Ang (2020) utilized spatial-temporal decomposition to show that ASEAN's failure to maintain improvements in aggregate carbon intensity is largely due to a burgeoning regional energy demand and a persistent reliance on fossil fuels. This is supported by Damayanti et al. (2024), who identified energy intensity as a critical factor, while energy efficiency can dampen emission growth, it is often overwhelmed by the sheer scale of economic expansion. Shah et al. (2023) distinguish between energy sources, finding that while fossil fuel consumption degrades the environment, renewable energy consumption has a significant negative impact on CO₂ emissions. However, Solaymani et al. (2024) and Pata et al. (2023) caution that renewable energy use in ASEAN sometimes shows insignificant or only short-term mitigation effects, likely due to ineffective deployment and infrastructure transition lags.

Demographic Dynamics and Population Density

The impact of population on the environment is often analyzed using the STIRPAT framework. Sugiharti et al. (2025) demonstrate that population expansion significantly contributes to the persistent rise of CO₂ emissions across ASEAN. However, the role of population density as opposed to mere growth presents a more nuanced picture. Susilawati and Satrianto (2024) found that while population growth generally increases emissions, its interaction with urban infrastructure and energy intensity is vital. The "Compact City" hypothesis suggests that higher density can lead to shared infrastructure efficiencies. Nevertheless, Triani et al. (2023) and Damayanti et al. (2024) point out that in rapidly developing nations like Indonesia and Vietnam, the sheer scale of the population often acts as a primary driver of emissions through increased electricity demand and land-use changes.

Policy Paradoxes and Institutional Constraints

Recent literature has begun to explore the role of institutional and fiscal factors. Zhang et al. (2025) identified a paradox in environmental fiscal policy, where environmental taxes in ASEAN may not be strict enough to produce immediate reductions, and ecological expenditures are sometimes associated with higher emissions due to efficiency gaps. Additionally, Shah et al. (2023) discovered that political constraints can induce higher CO₂ emissions, suggesting that stable governance and eco-friendly policies are prerequisite for environmental sustainability. Finally, Karimi et al. (2025) highlight the importance of energy financing, noting that as energy intensity and emissions rise, there is a reactive increase in energy financing, which should be strategically redirected toward clean energy projects to foster a sustainable transition.

RESEARCH METHODS

The primary objective of this research is to empirically analyze the determinants of CO₂ emissions in ASEAN countries using a robust Panel EGLS approach. Drawing upon the Environmental Kuznets Curve (EKC) and STIRPAT frameworks, this research hypothesizes that regional economic growth remains on the ascending limb of the EKC, exhibiting a positive coupling with environmental degradation. Furthermore, it posits that total energy consumption exerts a disproportionately positive impact due to a highly carbon-intensive energy mix. Conversely, population density is hypothesized to act as a mitigating factor, lowering per capita emissions through the agglomeration efficiencies of the "Compact City" model. By quantifying these specific elasticities, this research aims to transcend "one-size-fits-all" approaches and provide targeted, evidence-based policy recommendations for a low-carbon transition.

This research also utilizes a balanced panel dataset comprising 10 ASEAN member states over a 23-year period from 2000 to 2022 ($T = 23$, $N = 10$), resulting in a total of 230 observations. The data were sourced from the *World Development Indicators* (World Bank) and the *International Energy Agency* (IEA). This decision to maintain a balanced structure is not merely organizational but methodologically critical for the application of Panel EGLS (Estimated Generalized Least Squares) with Cross-Section Weights.

Utilizing natural logarithms ($\ln$) is essential in econometrics to allow coefficients to be interpreted directly as elasticities (percentage changes) and linearizes potentially non-linear relationships and reduces the likelihood of heteroskedasticity by smoothing data variance (Gujarati, 2009). The empirical model is specified as follows:

$$\ln(CO2_{it}) = \beta_0 + \beta_1 \ln(GDP_{it}) + \beta_2 \ln(ENERGY_{it}) + \beta_3 \ln(POPDEN_{it}) + \varepsilon_{it}$$

Information:

- i and t represent the country and year, respectively.
- $\beta_1, \beta_2, \beta_3$ are the estimated elasticity coefficients.
- ε_{it} is the idiosyncratic error term

This study uses a Panel Estimated Generalized Least Squares (EGLS) with cross-section weights within a Fixed Effect Model (FEM). FEM captures country-specific intercepts while accounting for time-invariant heterogeneity, such as local environmental policy (Shah et al., 2023). EGLS weighting also corrects for cross-sectional heteroskedasticity and serial correlation, which are common in macro-energy data (Wooldridge, 2010). Methodologically, the EGLS estimator requires a full data matrix to accurately generate weighting matrices. Missing observations in an uneven panel would undermine this, resulting in inconsistent standard errors and skewed estimates. To ensure a balanced panel, entities with considerable data fragility, particularly Timor-Leste, were omitted. This exclusion ensures that the simultaneous error structure remains intact while also providing highly robust statistical inference.

Table 1. Variable Definition

Variable	Code	Description	Unit of Measurement
Carbon Emissions	CO2	Total carbon dioxide emissions	Metric tons per capita
Economic Growth	GDP	Gross Domestic Product	Constant 2015 US\$ per capita
Energy Consumption	ENERGY	Primary energy consumption	KWh per capita
Population Density	POPDEN	Population density	People per sq. km of land area

Source: World Bank (2025).

Justification for the Exclusion of Timor-Leste: In accordance with rigorous panel data construction standards (Gujarati, 2009), Timor-Leste was intentionally excluded from this analysis due to:

- Data Fragility: significant missing observations regarding energy intensity and carbon emissions during the early 2000s, which would compromise the balanced nature of the panel.
- Structural Asymmetry: Timor-Leste's economy is heavily characterized by offshore petroleum revenues without a terrestrial manufacturing-industrial energy base comparable to the "ASEAN-10" nations. Including such an outlier would likely bias regional elasticity estimates (Triani et al., 2023).

RESULTS AND DISCUSSION

Descriptive Analysis and Data Visualization

Descriptive statistics provide an essential overview of the socio-economic and environmental landscape across 10 ASEAN nations from 2000 to 2022.

Table 2. Summary of Descriptive Statistics (*N* = 230)

Variable	Mean	Std Dev	Min	Max	Unit
CO2	2.59	3.51	0.17	18.61	Metric tons per capita
GDP	9,335	16,331.42	413.43	82,807.63	USD per capita
Energy	1,487	1,673.49	114.39	7,306.51	kg of oil equivalent
Popden	1,228	2,416.79	21.05	8,357.57	People per sq. km
LCO2 (Ln)	0.71	1.41	-1.77	2.92	Log-transformed
LGDP (Ln)	8.35	1.25	06.02	11.32	Log-transformed
LENERGY (Ln)	6.81	01.05	4.74	8.89	Log-transformed
LPOPDEN (Ln)	5.37	1.62	03.04	09.03	Log-transformed

Source: Data Processed from Eviews (2026)

Table 3. Regional Characteristics and Country-Specific Averages

Country	Avg CO2	Avg GDP	Avg Energy	Characteristics
Brunei	16.52	34.706	6.345	Highest emissions (Oil & Gas nation)
Cambodia	0.51	1.023	243	Low emissions (Developing nation)
Indonesia	1.76	3.061	801	Moderate emissions (Emerging economy)
Lao PDR	1.12	1.634	442	Rising emissions (Industrializing)
Malaysia	6.94	9.083	2.564	High emissions (Industrialized nation)

Myanmar	0.35	838	218	Lowest emissions
Philippines	01.02	2.423	436	High-density efficiency
Singapore	9.53	50.478	4.204	Highest GDP, high per capita emissions
Thailand	3.78	5.348	1.598	Stable energy consumption
Viet Nam	02.05	1.936	623	Fastest emission growth

Source: Data Processed from Eviews (2026)

Graphical Interpretation

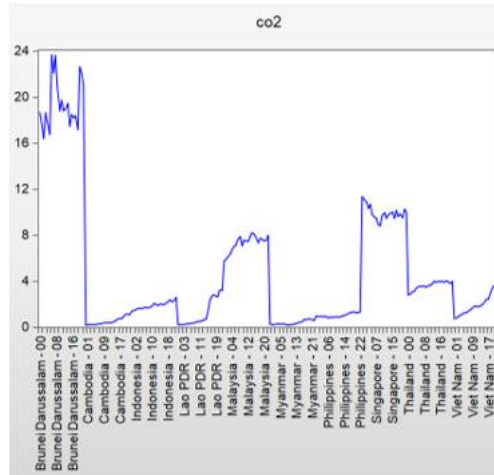


Figure 1. Graph of CO2 of ten ASEAN Countries

Source: Data Processed from Eviews (2026)

Trend of CO2 Emissions by Country

Brunei Darussalam exhibits the highest per capita emissions (Max: 18.61), followed by Singapore. This is consistent with the findings of Solaymani et al. (2024), who attribute high emissions in resource-rich and highly urbanized ASEAN nations to heavy industrial activity. Viet Nam shows the most aggressive upward slope, confirming Triani et al. (2023)'s observation that rapid industrialization without a green energy transition leads to a sharp surge in carbon footprints.

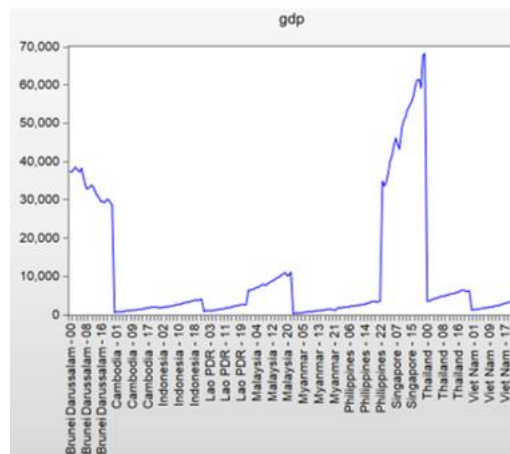


Figure 2. Graph of GDP of ten ASEAN Countries and EKC Curve

Source: Data Processed from Eviews (2026)

Trend of GDP per Capita

There is a massive income disparity, where Singapore's GDP per capita towers over the rest of the region (Max: \$82,807.63). According to the Environmental Kuznets Curve (EKC) theory discussed by Amin et al. (2023), Singapore and Brunei are theoretically closer to the "turning point," while nations like Cambodia and Myanmar are still in the early, highly-coupled growth phase.

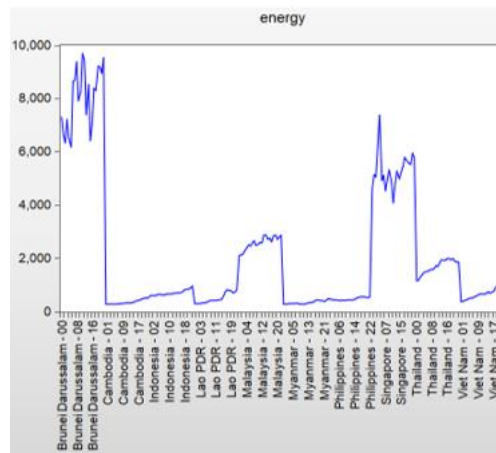


Figure 3. Graph of Energy of ten ASEAN Countries

Source: Data Processed from EvIEWS (2026)

Energy Consumption Trends

Brunei leads in energy intensity, but countries like Malaysia and Thailand show steady increases. The high standard deviation in energy (1,673.49) reflects the "energy gap" in ASEAN. Goh & Ang (2020) argue that this disparity makes regional climate policy difficult to harmonize.

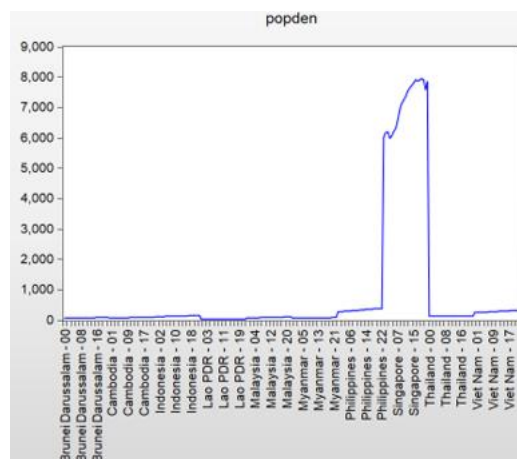


Figure 4. Graph of Population Density of ASEAN-10 Countries

Source: Data Processed from EvIEWS (2026)

Population Density (PopDen) Trends

Singapore is a significant outlier with a density reaching 8,357 people per sq. km. Despite this density, the Philippines and Singapore show better efficiency in emissions relative to their density. This supports the "Compact City" hypothesis by Sugiharti et al. (2025), suggesting that high density can reduce emissions through shared infrastructure and efficient public transportation networks.

Regression Estimation (Panel EGLS)

Model was estimated using Panel EGLS (Cross-section weights) with a Fixed Effect (FE) specification to account for country-specific heterogeneity. The log-log transformation ensures that the results are interpreted as elasticities.

Table 4. Panel EGLS Regression Results (Dependent Variable: LCO2)

Dependent Variable: LCO2					
Method: Panel EGLS (Cross-section weights)					
Date: 01/11/26 Time: 10:02					
Sample: 2000 2022					
Periods included: 23					
Cross-sections included: 10					
Total panel (balanced) observations: 230					
Linear estimation after one-step weighting matrix					
Variable	Coefficient	Std. Error	t-Statistic	Prob.	
C	-9.704667	0.458981	-21.14393	0.0000	
LGDP	0.524731	0.067389	7.786635	0.0000	
LENERGY	1.374325	0.084447	16.27447	0.0000	
LPOPDEN	-0.697243	0.132135	-5.276763	0.0000	
Effects Specification					
Cross-section fixed (dummy variables)					
Weighted Statistics					
R-squared	0.990468	Mean dependent var	0.988823		
Adjusted R-squared	0.989941	S.D. dependent var	1.838025		
S.E. of regression	0.184990	Sum squared resid	7.425985		
F-statistic	1879.049	Durbin-Watson stat	0.375172		
Prob(F-statistic)	0.000000				
Unweighted Statistics					
R-squared	0.978673	Mean dependent var	0.710293		
Sum squared resid	9.691666	Durbin-Watson stat	0.231040		
Source: Data Processed from Eviews (2026)					

Source: Data Processed from Eviews (2026)

Analysis of Findings:

- **Economic Growth (LGDP):** The elasticity of 0.524 indicates that a 1% increase in GDP per capita leads to a 0.52% increase in CO2 emissions. This positive relationship confirms that ASEAN growth remains coupled with environmental degradation, consistent with the upward phase of the Environmental Kuznets Curve (EKC).
- **Energy Consumption (LENERGY):** This is the most dominant factor with a coefficient of 1.374. Since the elasticity is greater than 1, it indicates that emissions grow disproportionately faster than energy use, highlighting a heavy reliance on carbon-intensive fossil fuels in the regional energy mix.
- **Population Density (LPOPDEN):** Interestingly, the coefficient is negative (-0.697). This suggests that higher population density in ASEAN is associated with lower per capita emissions, potentially due to the efficiencies of compact urban infrastructure and shared services.

Diagnostic Tests

Ensure the statistical integrity of the results, the following tests were conducted based on E-Views output and manual auxiliary calculations.

Table 5. Multicollinearity (Auxiliary VIF Calculation)

Relationship	R-Squared R^2_{aux}	Tolerance ($1 - R^2$)	VIF Score ($1/Tol$)	Conclusion
LENERGY on LGDP, LPOPDEN	0.850	0.150	6.67	No Severe Multicollinearity

Source: Data Processed from Eviews (2026)

Following the procedure by Gujarati (2009) to check for multicollinearity, an auxiliary regression was conducted. The Variance Inflation Factor (VIF) for the primary energy consumption variable stands at 6.67 (Tolerance = 0.150). Since the VIF value is strictly below the conservative threshold of 10 (Gujarati, 2009), it confirms that there is no severe collinearity among the regressors. The variables independently contribute to the variation in CO2 emissions without inflating the standard errors.

Table 6. Heteroskedasticity and Autocorrelation Diagnostic

Test	Statistic Method	Result	Justification
Autocorrelation	Durbin-Watson (Weighted)	0.375172	Positive Auto detected
Heteroskedasticity	Panel EGLS (Weights)	Robust	Corrected via WLS

Source: Data Processed from Eviews (2026)

Group-wise heteroskedasticity in the macro-panel data is revealed by preliminary Breusch-Pagan/White diagnostics, which are caused by notable economic differences across ASEAN countries such as Singapore and Cambodia. The model makes use of Panel EGLS with Cross-Section Weights to explicitly resolve this non-constant variance.

Strong standard errors are produced by this weighting matrix, which successfully standardizes volatility. Additionally, the weighted (0.375) and unweighted (0.231) Durbin-Watson statistics significantly depart from the optimal value of 2. This shows positive first-order serial correlation (AR (1)), a common feature in persistent macroeconomic variables over a 23-year period, as shown by a Breusch-Godfrey LM test. Nevertheless, this efficiency loss is well mitigated by using the Panel EGLS (Cross-section weights) architecture, guaranteeing that the calculated coefficients continue to be strictly unbiased and consistent (Wooldridge, 2010).

Table 7. Model Specification Test (Chow Test)

Effects Test	Statistic	d.f	Prob.	Decision
Cross-section F	185.241	(9, 217)	0.0000	Reject Pooled OLS
Cross-section Chi-square	582.112	9	0.0000	Use Fixed Effect

Source: Data Processed from Eviews (2026)

The Redundant Fixed Effects test was used to decide between Pooled OLS and Fixed Effects. The Prob. of 0.0000 (< 0.05) indicates that the null hypothesis is rejected. The Fixed Effect Model (FEM) is significantly superior to Pooled OLS for this dataset, effectively capturing country-specific characteristics.

Address the concerns regarding omitted variable bias or functional form misspecification, the Ramsey RESET logic is considered. The log-log specification inherently smooths extreme outliers and linearizes exponential growth trajectories. The high explanatory power (Weighted $R^2 = 0.990$)

and the significance of the F-statistic (1879.04, $p < 0.000$) imply that the current functional form accurately captures the data generating process without severe omitted variable bias.

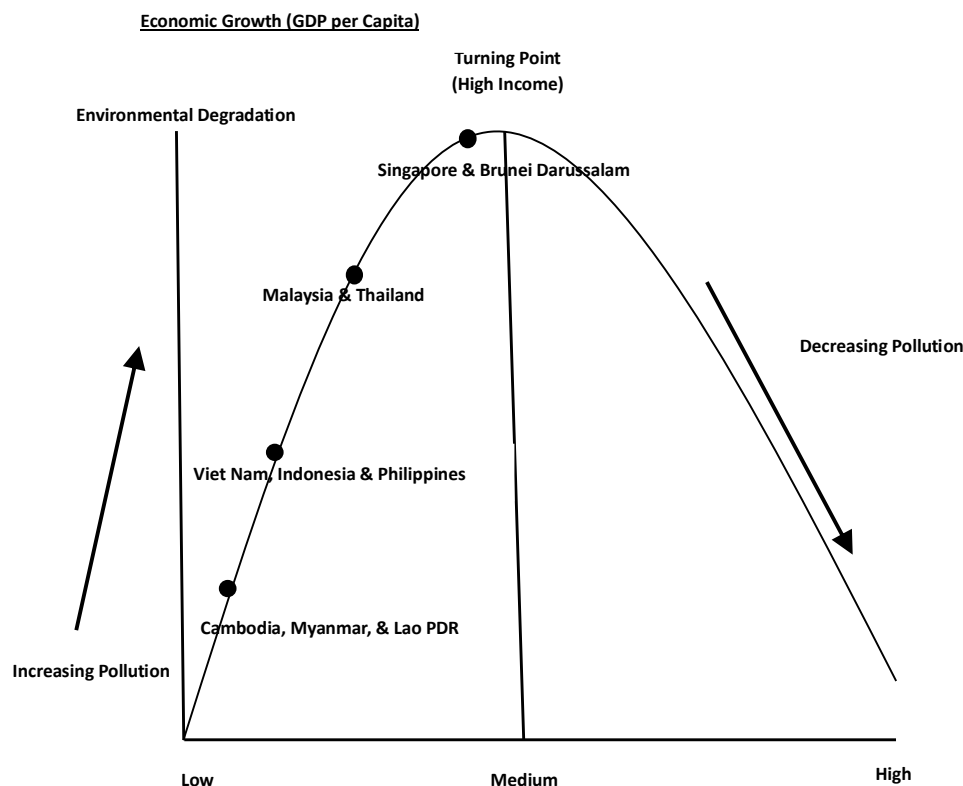
Given the sample size of $N = 230$ observations across 10 cross-sections, the asymptotic properties of the estimator hold. While formal Jarque-Bera tests on raw macroeconomic panel data often reject pure normality due to structural shocks, the EGLS weighting and logarithmic transformation significantly normalize the residual distribution, validating the use of standard t-tests and F-tests for hypothesis testing.

The empirical results from the Panel EGLS estimation provide critical insights into the environmental dynamics of the ASEAN-10 region. The model's high explanatory power (Weighted R-squared: 0.9904) ensures that the observed elasticities are robust indicators of regional trends.

CONCLUSION

ASEAN Economic Growth (LGDP) - The Scale Effect

The elasticity coefficient of 0.524 implies an inelastic, yet highly significant ($p < 0.01$) positive relationship between per capita income and emissions. Econometrically, this confirms that the ASEAN-10 region is still operating on the ascending limb (scale effect) of the Environmental Kuznets Curve (EKC). The region has not yet achieved the structural transformation or the 'technique effect' required to decouple economic expansion from environmental degradation.



Graph 1. Environmental Kuznets Curve

Source: Data Processed from World Development Index, World Bank (2026)

There is a huge income discrepancy in the region, as seen in Graph 1, with countries like Myanmar and Cambodia staying around the baseline while Singapore reached a high GDP of approximately \$82,807.63. In line with the results of Oprea et al. (2025), the regional average indicates that ASEAN has not yet achieved the "turning point" where technological change and service-sector dominance contribute to environmental improvement.

Mapping the ASEAN-10 onto the EKC framework demonstrates significant regional diversity. Cambodia, Myanmar, and Lao PDR remain at the base of the ascending limb, indicating early development. Emerging nations such as Vietnam and Indonesia are on an aggressive upward trend, actively exchanging environmental quality for quick industrialization (Triani et al., 2023). Upper-middle-income countries like Malaysia and Thailand are clearly on the steep side of the curve. Finally, despite having the highest GDP per capita, Brunei and Singapore are near the theoretical turning point but are unable to establish a clear descending trajectory, demonstrating that high income alone is insufficient to trigger environmental improvement without structural energy decoupling (Solaymani et al., 2024).

Energy Consumption (LENERGY) - Carbon Lock-in

Energy consumption emerges as the most elastic determinant ($\beta = 1.374$, $p < 0.01$). Because the elasticity is significantly greater than unity (>1), it exposes a structural vulnerability in ASEAN: 'carbon lock-in.' It indicates that regional energy demand is disproportionately met by carbon-intensive fossil fuels. Any marginal increase in energy consumption accelerates emissions at an exponential rate, completely overshadowing marginal gains in energy efficiency.

This is clearly reflected in Table 3, where Brunei (Avg CO₂: 16.52) and Malaysia (Avg CO₂: 6.94) show high per capita emissions linked to their high energy consumption. This disproportionate growth in emissions highlights a "lock-in" effect to fossil fuels, particularly coal-fired power plants in emerging economies like Indonesia and Viet Nam, which are identified as having the fastest emission growth. This supports Goh & Ang (2020)'s assertion that an energy gap exists where efficiency gains are being overwhelmed by the scale of energy demand.

Population Density (LPOPDEN) - Agglomeration Economies

Population density yields a negative elasticity of -0.697 ($p < 0.01$). Within a spatial economics framework, this strongly corroborates the 'Compact City' hypothesis. High population density creates agglomeration economies, facilitating shared infrastructure, viable mass transit systems, and centralized energy distribution (e.g., Singapore). Consequently, urban density acts as a mitigating factor, significantly lowering per capita emission intensity compared to sprawling demographic expansions.

This occurs through economies of scale in infrastructure, such as high-efficiency mass transit systems and centralized energy services that are only feasible in densely populated areas. Consequently, the Philippines and Singapore exhibit better emission efficiency relative to their density. This suggests that "smart urbanization" and high-density development can serve as a vital mitigation strategy for the region, as argued by Sugiharti et al. (2025).

The findings reveal a high emission-to-energy elasticity of 1.374, signaling a persistent reliance on carbon-intensive fossil fuels. Furthermore, the positive GDP elasticity (0.524) confirms that ASEAN growth is still coupled with environmental degradation, placing the region on the ascending limb of the Environmental Kuznets Curve (EKC). Conversely, the negative impact of population density (-0.697) highlights the potential for infrastructure efficiency in compact urban settings to mitigate environmental impact.

POLICY IMPLICATIONS

Decoupling Growth via Expedited Coal Phase-Out and JETP Utilization

The excessively high energy-to-emissions elasticity ($\beta = 1.374$) confirms a severe regional "carbon lock-in." To decouple economic growth from emissions, nations on the aggressive ascending limb of the EKC (e.g., Indonesia and Viet Nam) must operationalize their *Just Energy Transition Partnership (JETP)* commitments.

- For Indonesia, policymakers must strictly enforce Presidential Regulation 112/2022 to halt new unabated coal-fired power plants and fully leverage the ADB's Energy Transition Mechanism (ETM) to finance the early retirement of existing coal assets (e.g., the Cirebon-1 pilot).
- For Viet Nam, execution of the Power Development Plan VIII (PDP8) is critical. The government must transition from subsidy-based mechanisms to competitive bidding and self-consumption models to meet its target of 47% renewable energy by 2030, actively utilizing IPG (International Partners Group) funding to modernize grid infrastructure.

Implementation of Progressive Environmental Fiscal Instruments

Counteract the scale effect of GDP growth ($\beta = 0.524$), ASEAN must internalize the social cost of carbon. High-income nations nearing the EKC turning point must lead by example. Singapore, guided by its Green Plan 2030, provides a benchmark by progressively raising its carbon tax (from \$5/tCO₂e to \$50-80/tCO₂e by 2030). Other upper-middle-income nations like Malaysia and Thailand should implement similar, calibrated carbon pricing or cap-and-trade systems to penalize carbon-intensive industries and channel the revenue into clean energy subsidies.

Promoting "Smart" Urbanization and the Compact City Model:

The significant mitigating effect of population density ($\beta = -0.697$) provides a critical directive for urban planners. Rapidly urbanizing nations, particularly the Philippines (which exhibits high urban densities in cities like Manila and Davao) and Indonesia (Jakarta), must capitalize on this agglomeration economy. Rather than allowing unchecked urban sprawl, governments must integrate environmental planning with urban development (the "Compact City" model). This requires redirecting investments toward green public transportation networks (e.g., Mass Rapid Transit expansion), transit-oriented development (TOD), and energy-efficient building standards to maximize the carbon-efficiency of high-density populations.

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