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From Prosperity to Sustainability: Exploring the Relationship between Financial Development, CO2 Emissions, and Government Effectiveness in ASEAN

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Abstract: The challenges posed by global climate change have intensified the urgency to reduce carbon emissions worldwide, particularly in rapidly developing regions. Within this context, this study investigates the validity of the Environmental Kuznets Curve (EKC) hypothesis, which proposes a nonlinear relationship between economic growth and environmental degradation. Focusing on the Association of Southeast Asian Nations (ASEAN), the paper examines how financial development and globalization influence carbon emissions while also evaluating the moderating role of government effectiveness. Using panel data from 2000 to 2022, a Fixed Effects model is employed to estimate these relationships. The purpose of this study is to determine whether financial development and globalization drive environmental degradation in ASEAN economies and whether government effectiveness alters the direction or strength of these effects. The novelty of this work lies in integrating governance as a moderating factor within the finance–globalization–environment framework using updated and comprehensive data. This approach provides new empirical insights into how institutional quality shapes the environmental outcomes of rapid

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financial and global integration. The study's significance stems from its ability to highlight the conditions under which economic expansion either worsens or alleviates environmental pressure in emerging regions. The empirical results show that financial development, energy consumption, and globalization significantly increase carbon emissions, suggesting that economic and financial growth initially intensifies environmental degradation. In contrast, GDP squared exhibits a negative effect, offering evidence for the EKC hypothesis in the ASEAN context. Moreover, the interaction terms involving government effectiveness with financial development and globalization display strong positive associations with emissions, underscoring the complex role of governance in shaping the finance–environment nexus in ASEAN economies.

Keywords: Carbon Emissions; Financial Development; Globalization; Government Effectiveness; ASEAN Region.

从繁荣到可持续：探讨东南亚国家联盟中金融发展、二氧化碳排放与政府效能的关系

摘要：全球气候变化带来的挑战加剧了世界各国减少碳排放的紧迫性，特别是在快速发展的地区。在此背景下，本研究旨在检验环境库兹涅茨曲线假说的有效性该假说认为经济增长与环境退化之间存在非线性关系。本文以东南亚国家联盟为研究对象，考察金融发展和全球化如何影响碳排放，同时评估政府效能的调节作用。研究采用2000**年至**2022**年的面板数据**，通**过固定效应模型进行实证分析。本研究旨在确定：在东盟地区，金融发展和全球化是否会推动环境退化，以及政府效能是否会改变这些影响的方向或强度。本研究的创新之处在于将治理质量作为调节变量纳入金融**全球化**环境分析框架，并采用最新全面数据，为制度质量如何影响快速金融与全球整合的环境后果提供了新的实证依据。研究意义在于揭示新兴地区经济扩张加剧或缓解环境压力的边界条件。实证结果表明：金融发展、能源消费和全球化显著推高碳排放，说明经济和金融增长在初期会加剧环境退化；而经济增长平方项呈现负向影响，为环境库兹涅茨曲线假说在东盟语境下的成立提供了证据。值得注意的是，政府效能与金融发展/**全球化的交互**项均与碳排放呈现显著正相关，这凸显了治理水平在塑造东盟地区金融-环境关系时发挥的复杂作用。

关键词：碳排放；**金融**发展；全球化；政府效能；东南亚国家联盟地区

1. Introduction

Global warming has been recognised as a pressing global challenge over the past few decades, given its profound adverse effects on ecosystems and on economies at all stages of development [56, 4]. The deterioration of environmental quality poses a substantial threat to future generations, heightening the risk of deep economic and social crises, including rising unemployment, widening inequality, and persistent poverty [25, 4, 44, 70, 3]. In response, researchers have increasingly acknowledged the need to safeguard the environment and have sought to identify and quantify the drivers of environmental degradation (ED).

A broad consensus has emerged that elevated greenhouse gas (GHG) concentrations, and CO_2 emissions in particular, are central to anthropogenic climate change. CO_2 emissions constitute the single largest contributor to the intensification of global warming [40, 53]. Consequently, a large body of empirical work has examined the determinants of carbon emissions with the aim of informing more effective environmental protection strategies. Early studies attributed rising environmental degradation primarily to the expansion of economic activity and the continued reliance on conventional, carbon-intensive energy sources [37, 5, 64, 32], both of which contribute to higher atmospheric CO_2 concentrations. The Intergovernmental Panel on Climate Change (IPCC)

underscored the pivotal role of CO_2 in overall GHG emissions in its Fifth Assessment Report [30]. It is estimated that approximately 76.7% of total GHG emissions are accounted for by CO_2, with a substantial share originating from emerging economies seeking to accelerate economic growth and increase national output [30, 46].

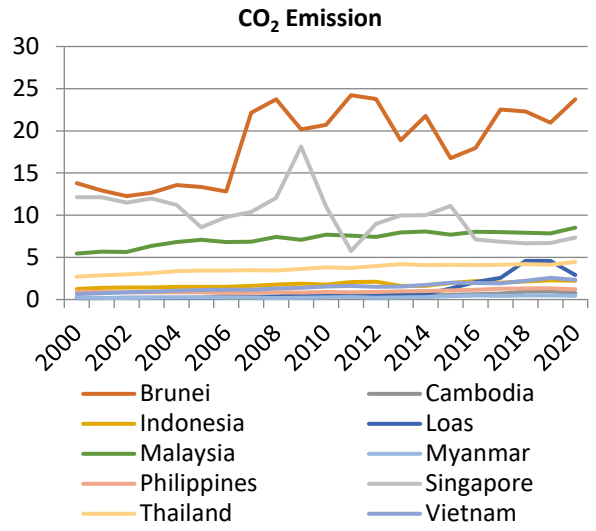

Figure 1. Trend of CO_2 Emissions in the ASEAN Region

Figure 1 presents CO_2 emission trends for ASEAN member states Cambodia, Brunei, Indonesia, Thailand, Myanmar, Vietnam, Malaysia, Laos, the Philippines, and Singapore over the period 2000–2020. The series exhibit a persistent upward trajectory, indicative of a rapid and largely uninterrupted increase in emissions. World Bank statistics show that Brunei recorded the highest per capita CO_2 emissions at 23.69 tons, followed by Malaysia (7.10 tons) and Singapore (6.39 tons), whereas Myanmar, Cambodia, and Laos reported substantially lower levels at 0.23, 0.33, and 0.30 tons, respectively [68].

The Environmental Kuznets Curve (EKC) hypothesis has been widely investigated in the ASEAN context as scholars have sought to understand the joint dynamics of CO_2 emissions, economic growth, and energy consumption. Tang and Tan [60] provide evidence in favour of the EKC hypothesis for Vietnam over 1976–2009. By contrast, Al-Mulali et al. [6] and Ozturk and Al-Mulali [41] find no support for an inverted U-shaped relationship in selected ASEAN economies, with the latter documenting a U-shaped pattern for Cambodia. For Malaysia, Saboori et al. [47] report mixed evidence, suggesting only partial support for the EKC.

Financial development occupies a central position in theories of economic progress, as it reduces transaction costs, relaxes credit constraints, and improves the efficiency of financial intermediation [29, 57]. Well-functioning financial systems mobilise savings, allocate capital more effectively, foster innovation, and thereby underpin sustainable long-run growth. They enhance stock market performance, attract domestic and foreign investment, and strengthen the nexus between financial structures and real economic activity [49]. Empirical evidence further indicates that countries with more advanced financial systems tend to exhibit better environmental performance relative to those with weaker financial sectors [15]. Financial deepening can support environmental quality by facilitating cross-border investment and research that promote cleaner technologies [59]. Foreign direct investment (FDI), when accompanied by appropriate regulations, accelerates technology transfer, enabling firms to upgrade production processes and reduce emissions [20, 10]. Financial institutions can also shape environmental outcomes directly by conditioning access to finance on compliance with environmental standards [11].

At the same time, financial liberalisation is not unambiguously beneficial from an environmental perspective. Easier access to credit may fuel rapid industrial expansion, greater energy consumption, and, in the absence of stringent regulation, higher CO_2 emissions [48]. Consequently, the environmental implications of financial development are theoretically ambiguous and empirically contingent.

The relationship between financial development and CO_2 emissions has therefore attracted considerable scholarly attention [53, 19, 17, 34, 16]. The emerging literature suggests that the sign and magnitude of this relationship depend critically on governance quality, regulatory frameworks, and the pace of technology adoption. The EKC hypothesis articulated by Grossman and Krueger [22] posits a nonlinear link between income and environmental degradation, with pollution rising in the early stages of development and declining once economies attain higher income levels and can invest in cleaner technologies and stronger institutions.

Within this broader debate, the ASEAN region one of the most dynamic and fastest-growing economic blocs globally faces a dual imperative: sustaining robust economic growth while mitigating climate-related risks. ASEAN provides an analytically fruitful setting because its member states exhibit rapid financial deepening, intensifying global integration, rising energy demand, and marked heterogeneity in governance and institutional quality. These features make the region well suited for examining how financial development and governance interact to shape environmental outcomes. Moreover, ASEAN economies account for an increasingly significant share of global CO_2 emissions, yet remain relatively underrepresented in empirical work compared with other regions.

Drawing on panel data for 2000–2022, this study analyses how financial development, population dynamics, GDP growth, and energy use jointly influence CO_2 emissions in ASEAN, employing a Fixed Effects

Model (FEM) to capture unobserved country-specific heterogeneity. The analysis further incorporates the moderating roles of Government Effectiveness and the KOF Globalisation Index which synthesises economic, political, and social dimensions of integration [35, 23].

The underlying premise is that strong governance can attenuate the adverse environmental consequences of financial expansion, whereas weak institutional arrangements are likely to amplify them.

By focusing on ASEAN economies undergoing rapid structural transformation, the study seeks to assess whether and under what conditions effective governance can reconcile financial development with environmental protection, thereby offering policy-relevant insights for the pursuit of sustainable, low-carbon growth trajectories.

2. Literature Review

A substantial body of empirical research documents robust positive associations between financial development, energy consumption, and CO_2 emissions, frequently revealing patterns consistent with the Environmental Kuznets Curve (EKC) hypothesis across diverse country groups [36]. Although financial deepening tends, on balance, to intensify CO_2 emissions, several studies indicate that globalization may partially offset these effects by facilitating technology transfer and the diffusion of cleaner production methods. For example, Tahir et al. [58] show that GDP, globalization, and financial progress exhibit a unidirectional causal relationship with CO_2 emissions in South Asia, and argue that governments in the region should leverage globalization to attract green technologies and improve environmental quality. Shahbaz et al. [54] report a strong linkage between transport infrastructure and emissions, with transport-related CO_2 remaining persistently high since 2009, while Mujtaba et al. [39] find that, in middle-income economies over 1985–2014, energy consumption, population growth, and CO_2 emissions move together positively, whereas financial development and trade openness contribute to emission reductions. In the Gulf Cooperation Council (GCC) countries, Zmami and Salha [71] identify a reversed U-shaped association between economic growth and emissions, thereby confirming both the EKC and the Population Halo Hypothesis (PHH). Shaheen et al. [55] underscore that GDP and energy use are key drivers of CO_2 emissions, while urbanization and agricultural expansion raise NO_2 levels. In a similar vein, Adebayo et al. [2] show that energy use and urbanization exert positive effects on CO_2 emissions, whereas trade openness exerts a mitigating influence in the long run.

Other multi-country analyses further highlight the central role of energy variables. Majeed and Luni [38], using data for 166 countries, report the somewhat paradoxical result that renewable energy use is associated with higher CO_2 emissions, while water withdrawal exacerbates environmental degradation, findings that nonetheless remain broadly consistent with the EKC framework. For ASEAN economies, Phong [43] confirms that economic growth, energy consumption, and urbanization significantly increase emissions, and related evidence for OECD countries (e.g. Zafar et al., 2019) points in the same direction, reinforcing the view that energy consumption is a principal determinant of environmental pressure.

Country-specific studies offer additional nuance. In Pakistan, Rasool et al. [45] find that higher oil prices and efficiency improvements in the transport sector help reduce CO_2 emissions, although financial development and GDP growth continue to exert upward pressure on emissions. Ganda [21] shows that FDI inflows are positively associated with CO_2 emissions in BRICS economies, providing only partial support for the EKC. Anwar et al. [7] report that, in low-income economies, globalization, urbanization, and even renewable energy use can aggravate environmental degradation in the short to medium term, despite the longer-run mitigation potential of renewable technologies. Dong et al. [18] demonstrate that, at the global level, population growth, GDP, and both renewable and non-renewable energy consumption are positively related to CO_2 emissions, while Ali et al. [5] document that urbanization over 1972–2014 has significantly elevated long-run emissions in Pakistan. In the Chinese context, Shahbaz et al. [54] show that FDI contributes to reducing CO_2 emissions, exports increase them, and the GDP–emissions relationship follows a U-shaped pattern, thereby confirming the EKC. Yuelan et al. [69] emphasise the pivotal role of fiscal policy through government expenditure and taxation in shaping environmental outcomes, and identify energy use as the primary driver of pollution. They also find that democracy marginally worsens environmental quality, whereas globalization has a beneficial effect. Usman et al. [63] validate the EKC for South Africa and show that energy use is a key driver of environmental degradation, while Waqih et al. [67] report comparable evidence for SAARC countries. Similarly, Cosmas et al. [13] confirm the EKC in Nigeria, where industrialization, GDP growth, and energy consumption intensify emissions, even as globalization exerts a mitigating influence. For Vietnam, Van et al. [65] arrive at analogous conclusions: globalization reduces emissions, whereas economic growth and industrialisation increase them.

Evidence from sub-Saharan Africa and other regional blocs is broadly consistent with these findings. Wang and Dong [66] show that energy use, economic expansion, and urbanisation significantly increase the ecological footprint in sub-Saharan African economies. Jugurnath and Emrith [33] find that FDI does not contribute to emission reductions in Small Island Developing States (SIDS), suggesting that capital inflows alone are insufficient to guarantee

environmentally sustainable trajectories. In BRICS countries, Haseeb et al. [26] demonstrate that financial development and energy consumption raise emissions, while globalization has only a limited effect, though the EKC is confirmed in several cases.

For MENA economies, Charfeddine and Kahia [12] report that renewable energy use and financial development have modest environmental impacts relative to the dominant influence of overall energy consumption, which remains the chief source of pollution.

In China, trade and exchange rate fluctuations have been shown to affect emissions, with FDI contributing positively to CO_2 and supporting the EKC pattern. Within the European Union, Park et al. [42] conclude that increased internet usage amplifies CO_2 emissions via its effects on GDP, energy demand, and electricity consumption. Twerefou et al. [62] find that GDP growth raises CO_2 emissions in sub-Saharan Africa, whereas globalization reduces them, again aligning with EKC dynamics.

At the global level, Balogh and Jámbor [9] observe that both nuclear and renewable energy can be associated with higher emissions, while coal energy predictably worsens environmental quality; they also identify industrial expansion and international tourism as major contributors to global CO_2 emissions.

Taken together, this literature consistently identifies energy consumption, urbanisation, and under many conditions financial development as primary drivers of CO_2 emissions, while the environmental consequences of globalization and renewable energy adoption are decidedly mixed.

The sign and magnitude of these effects appear to depend critically on governance quality, the effectiveness of regulatory frameworks, and the pace and direction of technological diffusion. Globalization can catalyse the deployment of clean technologies and foster international environmental cooperation, but it can also incentivise the relocation of pollution-intensive activities to jurisdictions with laxer regulations. Against this backdrop, the EKC remains a central organising framework, positing that environmental degradation initially rises with income but can decline once countries attain higher levels of development, institutional capacity, and technological sophistication. These insights underscore the urgency of implementing sustainable financial reforms, accelerating the adoption of energy-efficient and low-carbon technologies, and strengthening governance architectures.

For rapidly growing ASEAN economies in particular, designing policies that reconcile economic expansion with environmental stewardship is crucial for achieving long-term climate resilience and sustainable development.

3. Data and Methodology

3.1. Theoretical Framework

Saud et al. [51] report that, for Central and Eastern European countries, the financial development index and per capita income are negatively associated with CO_2 emissions, while energy use is the principal driver of environmental degradation. Their results further indicate that greater urbanization and trade openness are linked to lower CO_2 emissions, thereby improving environmental quality and providing empirical support for the Environmental Kuznets Curve (EKC) hypothesis in the region. Urbanization, financial development, and GDP emerge as key determinants of environmental outcomes in their framework.

Using a GMM approach for 26 African economies, Adams and Klobodu [1] similarly find a positive relationship between GDP and environmental damage, underscoring the growth–emissions trade-off in lower- and middle-income contexts. Hafeez et al. [24] document that financial development significantly increases CO_2 emissions in OBOR countries and uncover bidirectional causality between financial development and emissions, concluding their analysis by examining the validity of the EKC across 52 participating economies.

In the MENA region, Awan et al. [8] show that globalization and financial development exert a statistically significant negative effect on CO_2 emissions, while income has a strong positive association with emissions, financial development exhibits a negative association, and urbanization contributes to emission reductions. By contrast, Saidi and Mbarek [50] reject the presence of an EKC pattern in 19 emerging economies, even though income, trade, urbanization, and financial development are all found to be closely related to CO_2 emissions.

For a set of South Asian countries, Jamel and Derbali [31] demonstrate that financial development and energy consumption both exert strong positive effects on CO_2 emissions. Their results suggest that, although financial development has a substantial impact on emissions, per capita energy use and urbanization are even more influential, while the trade ratio has a small but negative effect.

In the case of India, Sehrawat et al. [52] provide additional support for the EKC hypothesis, confirming that the income–environment relationship follows a nonlinear trajectory in which environmental degradation initially rises with economic growth before declining at higher income levels.

3.1.1. Hypothesis of the Study

H0: Impact of financial development on CO2 emissions in ASEAN nations.

H1: Effect of KOF globalization on CO2 emissions in ASEAN countries.

H2: Interaction effect of Government Effectiveness between financial development and CO2 emissions.

H3: Moderating role of Government Effectiveness between KOF globalization and CO2 emissions.

H4: Existence of Environment Kuznets hypothesis.

3.2. Methodological Framework

The fixed effect model is that the intercept is estimated as a cross-section group and the intercept would be noted independently for each cross-section. The presence of a dummy variable in each group or constant is why it is often referred to as the least square dummy variable (LSDV). This model elucidates the fixed effect estimating technique in panel data format.

$$Pit = ai + \beta 1Qit + \ldots\ldots\ldots\ldots \beta kQkit + uit$$

$$P = da + Q\beta' + u$$

Group dummy variables are utilized to measure the various intercepts for each cross-section.

The standard F-test is applied to compare the fixed effects model with the traditional constant OLS model. When the calculated F-statistic is greater than the critical F value, the null hypothesis of cross-sectional homogeneity is rejected. Under these circumstances, the standard constant technique will be discarded in favor of the fixed effect method.

$$F = (RFE\ 2\text{-}RCC\ 2)/(N\text{-}1)\ (1\text{-}RFE\ 2)/(NT\text{-}N\text{-}K) \sim F\ (N\text{-}1, NT\text{-}N\text{-}K)$$

In the empirical results, RFE2 reports the coefficient of determination for the fixed-effects specification, whereas R2CC denotes the corresponding coefficient of determination for the common-constant (random-effects) model. If the null hypothesis of no systematic difference between the estimators cannot be rejected in the Hausman specification test, the common-constant specification is retained as the preferred model [28].

3.3. Conceptual Framework

Figure 2 presents the conceptual framework guiding this study. The core objective is to assess how financial development and key macroeconomic variables shape CO_2 emissions in ASEAN economies. The framework captures the relationship between financial development and environmental degradation across ten ASEAN member states Malaysia, Brunei, Indonesia, Thailand, Myanmar, Vietnam, Laos, Cambodia, the Philippines, and Singapore using a balanced panel spanning 2000–2022.

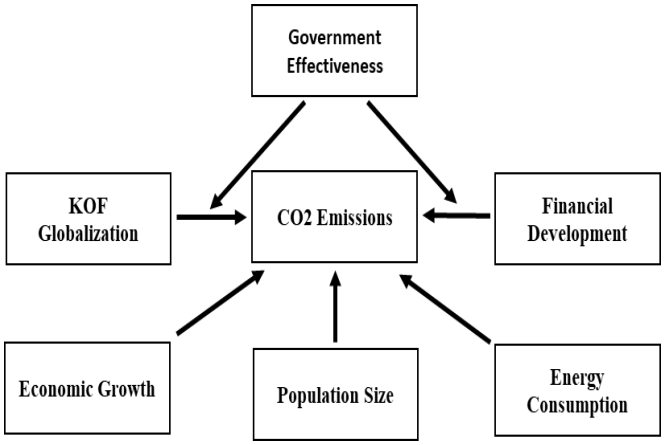

Figure 2: Framework of the Model

CO_2 emissions per capita, employed as the primary indicator of environmental degradation, are drawn from Our World in Data [46]. Financial development is measured by a composite index (0–100) obtained from the IMF Financial Development Database [57]. The KOF Globalisation Index (0–100), reflecting economic, social, and political integration, is sourced from the KOF Swiss Economic Institute [23]. Population, GDP per capita, and energy use per capita are taken from the World Development Indicators [68].

To test the Environmental Kuznets Curve (EKC) hypothesis, the model incorporates the squared term of GDP per capita, allowing for a nonlinear relationship between income growth and environmental pressure [22]. Government effectiveness, derived from the Worldwide Governance Indicators [35], enters the framework as a moderating variable that conditions the impact of financial development and globalisation on environmental outcomes. In doing so, the model explicitly integrates institutional quality into the analysis, recognising that governance capacity may either amplify or attenuate the environmental consequences of financial deepening and increasing global integration across ASEAN economies.

3.4. The Econometric Models

Model 1:

$$CO_{2it}=\alpha_0+\beta_1 FD_{it}+\beta_2 KOF_{it}+\beta_3 PS_{it}+\beta_4 GDP_{it}+\beta_5 GDP^2_{it}+\beta_6 EC_{it}+\beta_7 GE_{it}+\mu_{it}$$

Model 2:

$$CO_{2it}=\alpha_0+\beta_1 FD_{it}+\beta_2 KOF_{it}+\beta_3 PS_{it}+\beta_4 GDP_{it}+\beta_5 GDP^2_{it}+\beta_6 EC_{it}+\beta_7 KOF*GE_{it}+\mu_{it}$$

Model 3:

$$CO_{2it}=\alpha_0+\beta_1 FD_{it}+\beta_2 KOF_{it}+\beta_3 PS_{it}+\beta_4 GDP_{it}+\beta_5 GDP^2_{it}+\beta_6 EC_{it}+\beta_7 FD*GE_{it}+\mu_{it}$$

In the equations (4), (5), (6) α_0 shows intercept, β_1, β_2…, β_7 illustrations the value of coefficient, μ shows error term, and it shows the panel data.

Table 1: Description of Indicators

Sign	Description	Units	Source
CO_2	Carbon Emissions	Per Capita Metric tons	OWD
FD	Financial Development	0-100 Index	IMF
KOF	KOF Globalization Index	0-100 Index	KOF-SEI
PS	Population Size	Millions	WDI
GDP	Gross Domestic Product	Per Capita	WDI
EC	Energy Consumption	Per Capita	SRWE
GE	Government Effectiveness	E-2.50-2.50	WGI

Table 1 represents the measurement and data source of variables. CO2 Emission measure as per capita metric tons, financial development in index from 0-100, KOF globalization in the form of index (0-100), Population size in millions, GDP and energy consumption in per capita, government effectiveness also in index from -2.50-2.50. all the data collected from various sources, Our World in Data (OWD), International Monetary fund (IMF), World Development Indicator (WDI), KOF Swiss Economic Institute (KOF-SEI), Statistical Review of World Economy (SRWE) and World Governance Indicator (WGI).

4. Results and Interpretation

4.1. Formulas/Equations/Theorem Proofs

To examine the descriptive summary will be presented as follows:

Table 2: Descriptive Summary of Variables and Pair-Wise Correlation Matrix (2000-2022)

Panel A: Descriptive Statistics

	Mean	Maxi	Mini	Std. Dev.	Obs.
CO_2	4.541	24.22	0.162	5.816	230
FD	0.373	0.796	0.038	0.215	230
KOF	59.79	84.69	29.64	14.68	230
PS	59545039	271000008	333165	69613501	230
GDP	8.228	16.78	0.219	3.118	230
EC	117.94	662.29	2.516	181.61	230
GE	2.108	4.44	0.38	1.005	230

Panel B: Pair-Wise Correlation Matrix

	CO_2	FD	KOF	PS	GDP	EC	GE
CO_2	1						
FD	0.410	1					
KOF	0.425	0.698	1				
PS	-0.373	-0.022	0.040	1			
GDP	-0.591	-0.365	-0.455	0.061	1		
EC	0.776	0.550	0.533	-0.399	-0.421	1	
GE	0.706	0.852	0.863	-0.219	-0.523	0.628	1

Source: Author's Calculation

Table 2 displays the summary of descriptive statistics along with the pair-wise correlation matrix of the variables. Panel A reports the descriptive statistics, including the mean, median, standard deviation, and the minimum and maximum values for each indicator. The standard deviation for some variables indicates significant variation from the mean, suggesting potential anomalies in the data. The wide range between minimum and maximum values for certain variables implies that central tendency measures, such as the mean, may not fully represent the dataset's distribution. This suggests that some variables may not follow a normal distribution. The dataset consists of 230 observations for each variable, covering the period from 2000 to 2022. In Panel B, the pair-wise correlation matrix is used to assess the relationships and potential multicollinearity between variables. The results show no signs of multicollinearity, as there is no strong correlation observed among the variables.

4.2. Multicollinearity

To examine the multicollinearity will be presented as follows:

Table 3: Variance Inflation Factor

Variable	Centered VIF
FD	6.5621
KOF	8.8654
PS	1.3802
GDPPC	4.1180
$GDPPC^2$	3.9702
ECPR	6.3389
GE	8.4476
C	NA

The variance inflation factor (VIF) was employed to test for multicollinearity in the dataset. Since the centered VIF values were all below 10, the results indicate that multicollinearity is not present in the data.

4.3. Autocorrelation

To examine the autocorrelation will be presented as follows:

Table 4: Breusch-Godfrey Serial Correlation LM Test:

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	103.70	Prob. F (2,200)	0.000

The probability value of autocorrelation is less than the significant value of 0.05. This means that autocorrelation in this data. This problem is tackled by taking the lag of the dependent variable.

4.4. Heteroskedasticity

To examine the heteroskedasticity will be presented as follows:

Table 5: Heteroskedasticity was examined using the Breusch-Pagan-Godfrey test

Heteroskedasticity Breusch-Pagan-Godfrey test			
F-statistic	12.318	Prob. F (7,202)	0.000

The probability value for heteroskedasticity was found to be less than 5%, indicating the presence of heteroskedasticity in the dataset. This issue was corrected using the White test.

4.5. Redundant Fixed Effects Test

To examine Redundant Fixed Effects Tests will be presented as follows:

Table 6: Redundant Fixed Effects Tests

Redundant Fixed Effects Tests			
Effects Test	Statistic	d.f.	Prob.
Cross-section F	56.918	-9,193	0.000
Cross-section Chi-square	272.13	9	0.000

To examine the suitability of common versus random effects, a redundant fixed effects test was applied. The findings suggest that the fixed effects model is appropriate.

4.6. Redundant Fixed Effects Test

Table 7: Hausman Test

	Coefficients (b) Fe	(B) Re	(b-B) Difference	S. E.
FD	3.083	-0.741	3.824	1.719
KOF	0.104	0.079	0.025	0.017
PS	-1.671	-1.442	-2.321	1.753
GDP	-0.268	-0.332	0.064	0.021
GDP^2	0.028	0.030	-0.002	0.001
EC	0.004	0.008	-0.004	0.001
GE	1.242	1.577	-0.335	0.468
Test: H0: Difference in coefficients not systematic Prob>chi2 = 0.0210**				

Note: *** p<.01, ** p<.05, * p<.1 respectively.
Source: Author's Calculation

Table 7 presents the results of the Hausman test, which is applied to identify the more suitable method between the random effects and fixed effects models. When the probability value is greater than 5%, the random effects model is preferred, whereas a value below 5% favors the fixed effects model. Since the Hausman test produced a probability value under 5%, this study adopted the fixed effects approach.

4.7. Results of Baseline Regression Analysis

The Fixed effect technique is utilized to analyze the association between financial development and environment pollution in the ASEAN region using panel data from 2000 to 2022.

Table 8: Fixed Effect Regression Analyses

Variables	Model 1	Model 2	Model 3
FD	2.283**	-1.229**	
	(2.709)	(5.682)	
KOF	0.005**		-0.016***
	(0.030)		(0.044)
GE	0.754	0.312**	-0.051*
	(0.690)	(0.844)	(1.380)
FD*GE		1.483**	
		(2.110)	
KOF*GE			0.015**
			(0.022)
PS	-6.10	-6.45	-7.84
	(1.50)	(1.30)	(1.61)
GDP	0.156**	-0.146*	-0.148**
	(0.065)	(0.086)	(0.066)
GDP^2	-0.007**	0.006	6.03
	(0.006)	(0.006)	(6.72)
ECPR	0.005*	0.005**	0.004
	(0.002)	(0.002)	(0.003)
_cons	-0.198	0.298	0.955
	(1.502)	(1.406)	(2.279)
R-Square	0.959	0.949	0.952
Prob (F-Statistics)	0.000***	0.000***	0.000***

Note: Values in Parenthesis represent the Std. Dev. *** p<.01, ** p<.05, * p<.1 respectively.
Source: Author's Calculation

The coefficient of financial development (FD) in Table 8 reveals a significant positive relationship with CO2 emissions, the dependent variable. Empirical findings suggest that for every unit increase in financial development, carbon emissions rise by 2.283 units, thereby supporting Hypothesis H0. Likewise, the KOF Globalization Index shows a positive and statistically significant association with environmental degradation, where a one-unit rise in the index corresponds to a 0.005-unit increase in environmental harm, confirming Hypothesis H1. CO_2 emissions are also positively and significantly linked to GDP, with a one-unit increase in GDP contributing to a 0.156% rise in emissions. In contrast, GDP squared exerts a negative influence on CO_2 emissions in ASEAN countries, as a one-unit increase in GDP squared reduces emissions by 0.007 units. The coefficient of Energy Consumption Per Capita (ECPR) shows a significant positive correlation with CO2 emissions. Specifically, a one-unit increase in energy consumption per capita leads to a 0.005-unit rise in CO2 emissions. Population size and government effectiveness, however, do not exhibit statistically significant relationships with CO2 emissions, indicating no measurable effect on carbon emissions. Nonetheless, the interaction between the KOF globalization index and government effectiveness positively influences CO2

emissions, where a one-unit increase in both results in a 0.015447-unit rise in emissions, confirming Hypothesis H2. Furthermore, the interaction term between financial development and government effectiveness shows significant positive effects on CO2 emissions, supporting Hypothesis H3. A one-unit increase in financial development and government effectiveness together leads to a 1.483375-unit increase in CO2 emissions. Lastly, the findings also provide evidence supporting the Environmental Kuznets Curve hypothesis, indicating that as GDP increases, environmental degradation initially rises before declining.

Table 9: Endogeneity Test using 2SLS Regression

Variable	Coefficient	Std. Error	z-statistic
FD	0.10601*	0.0598	1.79
KOF	0.23738** *	0.0487	5.97
Control Variables	Yes	Yes	Yes
Countries	Yes	Yes	Yes
Years	Yes	Yes	Yes

Table 9 presents the results of the endogeneity test using the Two-Stage Least Squares (2SLS) regression model. The analysis addresses potential endogeneity between financial development (FD), globalization (KOF), and the dependent variable by employing instrumental variables and controlling for country- and year-specific effects. The estimated coefficient for financial development (FD) is 0.10601, which is statistically significant at the 10% level. This suggests that FD exerts a modest but positive influence on the dependent variable, implying that improvements in financial systems and capital availability contribute slightly to the enhancement of economic or environmental outcomes. In contrast, globalization (KOF) demonstrates a much stronger effect, with a coefficient of 0.23738, significant at the 1% level, indicating that increased integration into global markets exerts a substantial and robust positive influence on the dependent variable. The inclusion of control variables, as well as country and year fixed effects, ensures that unobserved heterogeneity and temporal variations are properly accounted for, strengthening the robustness of the results. The consistency of the 2SLS estimates with the earlier fixed effect findings further validates the model, suggesting that endogeneity does not materially distort the estimates.

5. Discussion

The empirical results of this study are broadly consonant with prior evidence. The positive effect of financial development on CO_2 emissions is in line with the findings of Khan et al., Ahmed et al., Tsimisaraka et al., Danish et al., and Kihombo et al., all of whom show that financial deepening tends to intensify environmental pressure, particularly in rapidly industrialising economies [36, 4, 61, 14, 37].

This convergence of results reinforces support for Hypothesis H_0, namely that financial development in ASEAN currently contributes to higher emission levels. The confirmed nonlinear income–emissions relationship likewise supports Hypothesis H_1 and is consistent with the EKC pattern reported by Ahmed et al., whereby rising income initially exacerbates pollution before technological upgrading and stricter regulation eventually curb emissions [4]. The strong role of energy consumption documented here mirrors the conclusions of Kihombo et al., who emphasise that energy-intensive production structures remain a core driver of environmental degradation in developing regions [37]. Furthermore, the positive association between globalisation and CO_2 emissions accords with evidence from Hassan et al. and Kihombo et al., who argue that deeper global integration through higher investment, trade, and industrial activity tends to raise emissions in the absence of robust environmental governance [27, 37]. The moderating influence of government effectiveness identified in this study also echoes Danish et al., who underscore the centrality of institutional quality in shaping the environmental consequences of economic and financial expansion [14].

From a theoretical perspective, these results extend the literature on the environmental implications of financial development and globalisation [44-57; 69-71]by demonstrating that governance quality is a pivotal moderating mechanism in emerging economies. The study enriches the EKC framework by showing that institutional effectiveness not only conditions the income–environment nexus, but also mediates how financial deepening and global integration are transmitted into environmental pressures. This supports the view that environmental outcomes in developing regions cannot be adequately explained without explicitly incorporating governance into the analytical architecture. In practical terms, the evidence yields several policy-relevant insights. The positive linkage between financial development, globalisation, and emissions implies that ASEAN economies must embed environmental safeguards into financial sector regulation and strategies of outward and inward integration. Strengthening regulatory enforcement, scaling up green finance instruments, and accelerating the shift towards cleaner energy systems emerge as critical levers for emission reduction. At the same time, the findings suggest that improvements in government effectiveness will have only limited impact unless they are accompanied by explicit environmental targets, tighter standards, and well-designed mitigation policies. Collectively, these implications provide a basis for

ASEAN policymakers to design more balanced, sustainability-oriented development trajectories.

6. Conclusions and Polices

The central aim of this research was to examine how globalization influences environmental degradation within ASEAN nations. Using panel data from 2000 to 2022 for Malaysia, Brunei, Indonesia, Thailand, Myanmar, Vietnam, Laos, Cambodia, the Philippines, and Singapore, the study employed a Fixed Effects model selected through the Hausman Test. Descriptive statistics and VIF results confirmed the absence of multicollinearity, ensuring the reliability of the estimations. The empirical analysis yields several important insights. Globalization, financial development, and energy consumption are found to exacerbate CO_2 emissions across ASEAN countries, suggesting that increased openness and financial expansion are not yet aligned with environmentally sustainable pathways. GDP exhibits a positive relationship with emissions, while the squared term of GDP per capita demonstrates a negative link, indicating that although early economic growth intensifies environmental degradation, higher income levels eventually help mitigate emissions in line with the Environmental Kuznets Curve hypothesis. Furthermore, the interaction terms between globalization and government effectiveness, as well as between financial development and government effectiveness, both reveal positive effects on CO_2 emissions. These results imply that weak regulatory effectiveness within ASEAN governments is a central factor contributing to rising environmental damage, as institutions may lack the capacity or commitment to enforce environmental standards. This study contributes to the environmental economics literature by integrating government effectiveness as a moderating factor in the globalization–environment and finance–environment relationships, an area largely overlooked in previous ASEAN-focused research. Unlike earlier studies that examine these determinants independently, this work offers a unified analytical framework that captures how institutional quality shapes the environmental consequences of financial development and globalization. By employing updated panel data (2000–2022) and interaction-based modeling, the study provides novel empirical evidence on the institutional conditions under which globalization and financial expansion either intensify or alleviate CO_2 emissions.

The findings of this study generate several important policy implications for ASEAN nations. Governments must strengthen environmental governance by enforcing regulations that compel industries to improve energy efficiency, adopt cleaner technologies, and transition toward renewable energy sources. Given that energy infrastructure development must support both energy security and environmental protection, policymakers should allocate financial resources toward green investments, including energy-efficient production systems and low-carbon technologies. Because globalization and financial development exacerbate CO_2 emissions in the presence of weak institutions, ASEAN governments should implement institutional reforms that enhance transparency, strengthen anti-corruption mechanisms, and modernize legal and regulatory frameworks. These measures can help ensure that globalization and financial expansion contribute to, rather than undermine, environmental sustainability. The study also suggests several policy recommendations: integrating environmental standards into trade and investment policies, promoting green financial instruments such as green bonds and sustainability-linked loans, and increasing incentives for renewable energy adoption. Finally, future research should examine sector-specific emissions, incorporate nonlinear or dynamic modeling approaches, and explore additional institutional factors such as regulatory quality or political stability. Comparative studies across regions or analyses using disaggregated dimensions of globalization would also provide deeper insight into how institutional contexts shape the environmental outcomes of economic integration.

Declarations

Author Contributions

MKB: writing-original draft, formal analysis, methodology, writing-review, and conceptualization; UA: writing methodology and visualization; SWA: supervision and conceptualization; AD: data collection and arranging the data.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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Institutional Review Board Statement

Rigorous ethical guidelines were adhered to throughout the study to ensure participant privacy and data confidentiality in compliance with institutional and national research standards.

Informed Consent Statement

Participation in the study was voluntary, and informed consent was obtained from all participants prior to their involvement.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this manuscript.

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