JEEPO, 8(3), 28-37.

Journal of Energy & Environmental Policy Options

Financial Development, Energy Consumption, and Environmental Quality: Testing the EKC Hypothesis in ASEAN Countries

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Abstract

Using the examples of five ASEAN countries, namely, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam, from 2000 to 2024, this paper has an empirical analysis on the interaction between the perfectly correlated variables of governance, financial development, economic growth, energy consumption, and environmental quality. Environmental quality, using carbon dioxide emissions per capita as a proxy, is investigated under the context of the Environmental Kuznets Curve (EKC) hypothesis, in order to determine whether increasing income level eventually generates better environmental performance. Panel econometric techniques such as fixed effect, random effect, and robust least squares estimation are applied to the analysis of non-linear dynamics and linear dynamics. The results show that financial development is positively correlated with carbon dioxide emissions, which suggests that in the absence of specific green finance tools, financial deepening boosts resource-intensive and polluting industries. Governance, however, does not show statistically significant or strong effects, which underscores the little use of institutional enforcement to reduce environmental degradation within the region. Evidence of the Kuznets curve for the environment is realized in the random effects model, where emissions are decreased by economic growth in the short run, then increased after reaching a certain threshold, while this relationship is not robust across all estimations. This is also the case with energy consumption, where the findings are mixed as energy structure types and various ASEAN economies' differential dependence on fossil fuels reflect the high level of heterogeneity in the region. Overall, the results indicate that financial development and governance can affect environmental quality, but they only do so by strengthening institutional structures and more properly regulating capital flows towards green technologies and renewable energy in terms of scale and direction. These results point to the need for understanding the challenge for ASEAN countries to integrate environmental goals into the context of economic and governance reforms to ensure that economic growth leads toward sustainable ecopolitical advancements.

Keywords: *Environmental Quality, Financial Development, Governance, ASEAN Economies*

JEL Codes: *Q56, Q58, O44, C33*

Article's History
Received: 30th July 2025
Revised: 26th September 2025
Accepted: 28th September 2025
Published: 30th September 2025

Citation:
Tan, C., & Lee, E. (2025). Financial Development, Energy Consumption, and Environmental Quality: Testing the EKC Hypothesis in ASEAN Countries. *Journal of Energy and Environmental Policy Options*, 8(3), 28-37.

DOI:
https://doi.org/10.5281/zenodo.17315215

1. INTRODUCTION

Financial development represents one of the key drivers of national development, and requires growth and development of financial markets and financial institutions, in addition to efficiency, stability and inclusiveness of financial institutions and services. It is to increase mobilization of savings and investments giving it operating credit and help increase the power to introduce innovations improving it, hence stimulating the activities of industrial and commercial upload. However, in spite of the financial boom, heralded as a positive area of economic growth, an emerging literature about policy implications is putting attention to its complex relation with environmental impacts. In particular, scholars are increasingly interested in how financial deepening is sometimes coupled with ecological degradation in large part by the promotion of energy-intensive sectoral activity, encouraging consumption patterns at odds with sustainable functional appropriation of natural resources (Shahbaz et al., 2013; Tamazian et al., 2009; Sadiq et al., 2025). Second,

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more money means more money to be spent and finally invested again in more polluting industries or in the extraction of natural resources, thus concretizing environmental pressure and hastening the growth of carbon dioxide-MSIs emissions in the absence of the broader goals of sustainable development (Zaheer & Nasir, 2020; Ali et al., 2023).

In addition, environmental quality is one of the essential foundations of a sustainable socio-economic development in the long term. Mostly, it is measured in multiple dimensions in terms of air and water pollution, sustainable growth in natural resource management initiatives, and maintenance of ecological equilibrium (Grossman & Krueger, 1995; Stern, 2004; Senturk, 2023). Biodiversity loss, deforestation, water availability, or climate instability are only a few of how nature's degradation poses major risk factors for public health, agricultural output, and community resilience (Dasgupta et al., 2002; Imran et al., 2021; Iqbal & Noor, 2023). The destruction of ecological systems breeds food security and countries become prone to climate-related hazards, limits ability to ensure good and inclusive economic growth. These negative effects can be especially pronounced in developing countries such as Southeast Asia where the processes of rapid urbanization are happening together with those of industrialization, food production, and resource exploitation in conjunction with fragile environmental systems (Ali and al., 2019). Against the background, the interrelationship between the environment sustainability, financial development processes and the role of governance institutions emerge important line of inquiry which further review we will conduct (see Klaus and Pfamguarder, 2010; Iqbal, 2018; Habibullah, 2020; Ali et al., 2021; Hussain & Khan, 2022; Modibbo & Saidu, 2023). The reason is accentuated by the thought that it is necessary to have strong institutional of governing and including effective regulation and transparent environment policies to deal with thelection to ecological risk associated to expand finance (Levine, 2005; Frankel & Rose, 2005; Marc & Ali, 2017; Khan & Ali, 2019; Rossi, 2023). In an economics union like the Association of Southeast Asian Nations, where goal-regulated nations are on the way to realising conspicuous rates of economic transformation, the balancing the pace of financial and industrial development of the ecology is the prime issue. Green Growth: One of how finance can be targeted towards improving environmental care is by using "funny money" back into green technologies, renewable energy systems, and infrastructure which promotes human sustainability. The Association of South East Asian Nations (ASEAN) is a country that is endowed with natural resources, which were used by these countries as the foundation of economic development and industrial growth. However, rapid industrialization, urbanization, and constant economic growth have brought the area's environmental issues under huge pressure. The most noting problems are deforestation, pollution of air and pollution of water sources, plus over-exploitation of natural resources. The carbon dioxide emission has increased several-fold in the region as a result of increasing industries or transportation through vehicles, and household activities. In a similar vein, industrialization is often blamed for rising costs of greenhouse gas concentrations (mainly in developing economies), where industrial policies typically prioritize growth vs. ecology (Shahbaz et al., 2013; Stern, 2004; Bakht, 2020; Imran et al., 2024).

Deforestation has proven to be an incredible amount of emissions - especially in Indonesia and Malaysia, as large-scale clearing of forests for agricultural use, logging, and other human-induced fires have flushed massive amounts of the carbon locked up in the forest back to the atmosphere. Also, the overuse of fossil fuels for transportation and electricity generation has increased the stress on the environment, and energy-intensive industrial production systems have accelerated the increase of greenhouse gases (Ali et al., 2019; Gorus & Groeneveld, 2018; Desiree, 2019). These dynamics point to the struggle between economic hopes and managing the environment with respect. Literature has portrayed various perspectives of the relationship between energy consumption and environmental quality in the region. For instance, Mensah et al. (2018) reported inconsistent results on a per-individual Association of Southeast Asian Nations member, as economic growth is a driver to increase energy consumption, while the environmental impact is found to differ according to the resource constraints and rates of penetration of renewable energy. As has been reported in other Asian countries such as Malaysia, Thailand, Vietnam, and Indonesia, these countries experienced significant increases in energy demand, especially from non-renewable energy sources, which have increased the carbon dioxide emission rate exponentially and enhanced vulnerability to environmental impacts.

The relation between financial development and environmental performance is also controversial. According to some scholars, financial growth increases emissions by means of industrial growth and consumption based on carbon-intensive activities (Shahbaz et al, 2013; Mahmood, 2019). Others, on the other hand, argue that proper financial development can improve the state of the environment through concentration of resources, acting as a catalyst for investment in renewable energy (Tamazian et al., 2009; Emodi, 2019), and can promote ecologically-efficient reforms (Frankel and Rose, 2005). Moreover, financial development can promote the transmission of environmentally friendly technologies through international capital flows and cross-border collaborations, and consequently will play a role in promoting sustainable development (Frankel & Romer, 1999; Zenios, 2019; Kibritcioglu, 2023). Thus, for instance, the Association of Southeast Asian Nations must implement policy reform in the areas of energy transition and environmental governance in order to help structure the transition toward a more sustainable growth development model. Shifting towards renewable sources of energy like solar, hydro, and hydro power, and implementation of tougher environmental laws is a step in the right direction and can ensure the right balance between economic growth and a clean and green economy, while conserving the environment unnecessarily in the Indian state. Although financial development has played a key role in economic modernization in the region, the financial path-dependency is a fiercely contested outcome in the role of complex interaction with environmental consequences. This means that the financial development of Hasan's needs to be aggregated by schemes that are primarily oriented towards self-sustaining and long-lasting ecological base development. Even Grossman and Krueger (1995) also established the existence of an inverted-U-shaped relationship between financial development and resultant outputs from the fossil fuel, which has often been interpreted within the framework of the environmental Kuznets curve model. This model leads to the proposition that "during the early phase of financial and economic integration, environmental degradation is intensified due to the

increased industrialization and the usage of energy-intensive processes". But, exceeding a certain point, improvements in their financial systems, improving their regulatory practices could encourage investment in cleaner technologies, which will reduce the level of pollution over time.

Within the Association of Southeast Asian Nations (ASEAN), Malaysia is a formidable source for data entry due to a relatively developed financial infrastructure within the country. The country has a relatively stable legal system, and financial markets and business environment are well-favoring, which favor and attract more and more international capital flows. Malaysia has made drastic steps in a series of rationalisation policies over the last decade aimed at conceptualising the administration, financially sound institutions to encourage capital-intensive industries (Bank Negara Kuala Lumpur, 2016). Beyond the rationale of economic diversification, these policy designs are developed not only because they have the potential to regulate energy consumption path dependencies and environmental consequences, but also because the economic structure itself is getting diversified. Added to this, empirical studies have also furnished more evidence in favour of the financial development as a determinant of economic growth. For instance, Diallo and Masih (2017) observed that financial development has an important role in the long-run economic growth since it functions as a means of redirecting resources to productive sectors, releasing innovation, and increasing the productivity of the investment. At the same time, it is illustrated that the relationship among financial development, governance and environmental quality is highly non-immune as, under a weak regulatory institutions or poor enforcement of the law, there is a greater opportunity to couple financial development with economic development at the expense of the environment. Against this background, this paper tests the interaction effect of the cocktail of control variables between governance and financial development, economic growth and energy consumption in the context for measuring the environmental quality of selected Association of Southeast Asian Countries (ASEAN) economies. These are important institutional links to understand how institutional capacity and financial mechanisms can be developed to contribute to economic growth and environmental sustainability in the region.

2. LITERATURE REVIEW

Rasiah et al. (2018) have made a systematic analysis on the relationship among financial development, energy consumption and carbon dioxide emission in 5 members of Association of South East Asian Nation. Their analysis was comprehensive, in the short as well as the long term, and a valuable addition to this discourse of emission reduction and promotion of sustainable growth from a global perspective. Using the panel data collated for the period of 1970-2016, and econometric techniques such as pooled mean groups data estimation and fixed effects, they are conducting the study. Hausman specification tests that validated the efficiency of the pooled mean group estimate were used together with error correction ones that were used to assess the robust properties of the long-run relationship. Their results indicated that the explanatory variables in fact had a long-run correlation with carbon dioxide emissions. In particular, and contrary to a large segment of the empirical literature earlier, we found that financial development had no statistically significant impact on emissions. Based on their analysis, the authors proposed an improved regional cooperation among the Association of Southeast Asian Nations countries to fulfill sustainable development conditions in the entire natural environment.

In a study by Nosheen et al. (2019), they analyzed the interrelations of financial development with economic growth, detrimental deluging decisions, and power usage in Southeast Asian Temisia nations. Using annual time series data spanning the period 1980-2016, this research applied the autoregressive distributed lag bound testing for cointegration approach to analyze the short- and long-run dynamics. Another consequence of the analysis was that financial development also has a significant and negative impact on carbon dioxide emissions, and therefore, financial development can be engineered in order to enhance the quality of environmental assets in the long run. The parameters of openness of trade, economic growth, and energy consumption were demonstrated with a significant contribution to the chain of environmental degradation. Furthermore, the empirical finding of the positive relationship between economic growth and environmental quality has validated the existence of a positive inverted U-shaped relationship, which conforms with the outcome of the environmental Kuznets curve. Regarding the policy implications, the study distinguished some policy alternatives related to energy policies based on reductions in consumption and increased efficiency, fiscal reform policies based on constraining lending to polluting activities, and trade policies that reduce environmental pollution while fitting sustainable growth goals.

Similarly, Haseeb et al (2019) used the data from the World Bank to examine the correlation between market liberalization, political stability, economic growth, financial development, and carbon dioxide emission for the Association of Southeast Asian Nations countries. Emissions with a market-weight metric, kilotons, were used to test long-run equilibrium relationships applying the Johansen cointegration technique. The findings indicated that the political stability contributed to the rate of falling emissions, whereas the financial development had a significant effect on increasing the CO2 values. Importantly, the study highlighted the importance of economic and political freedoms as influencing environmental outcomes only indirectly through international mechanisms of regulation. Based on these interpretations, the authors recommended that policymakers should take action that affects carbon dioxide emissions and continues the movement toward sustainable practices by securing political stability and well-regulated markets. Rajpurohit and Sharma (2020) also examined the impact of the economic growth, energy usage, and financial growth on emissions in five Association of Southeast Asian Nations (ASEAN) countries over the period 1980 - 2014. Two well-known structural change tests, the pooled mean group (trend) estimation and long-run cointegration analysis, appropriate for heterogeneous panels, were conducted for the short-run and long-run dynamics, respectively. Their study accepted that CO2 emissions generally increase in early stages of economic development and then decrease when more development has been achieved, validating the environmental Kuznets curve hypothesis. Finally, financial

development was also found to positively contribute to emissions in the early stages, and reductions after economies began to mature. Emissions were strongly and positively correlated with energy use, in particular, fossil fuels. In regard to compounding of impact, the authors recommended that developing countries set out to pursue accelerated financial and economic development in order to generate the resources and institutional capacity that are required to implement environmentally sustainable technologies and practices. Le and Ozturk (2020) used the environmental Kuznets curve to examine the importance of globalization, financial development, government expenditure, and institutional quality on carbon such dioxide emissions. The period adopted is 1990 - 2014. By utilizing the leading panel econometric methods and controlling for the issues of cross-sectional dependence and stationarity, their research conducted based on only the placement mappers proved that there is existence of long-run relationship among these variables. The results revealed that government expenditure, energy, financial development and globalization had positive relationship with the level of carbon dioxide emissions by supporting the EKC hypothesis. Their policy recommendations related to the need for supporting green technologies and enhancing energy efficiency, promoting environmental governance, and making sure that the process of financial development and globalization incorporate aspects of sustainability.

Similarly, Chienwattanasook et al. (2021) investigated the impact of the economic growth rate, globalization and financial development on the amount of emissions in the Asia Pacific ASEAN region. Using panel data of World Development Indicators, KOF Globalization Index, and World Bank for the period of 2004 to 2018, they used a fixed-effect model with Driscoll-Kraay universal error standard. Their results revealed that an inefficient pattern of energy consumption leads economic growth, globalization, and financial development to be positively bacteria in safeguarding the environment from carbon dioxide emissions. The authors indicated that policymakers in the region should do more to cut emissions through increased energy efficiency while following the path to sustainable development. They also suggested that future research should include other explanatory variables and broader indicator measurements to provide a more substantial empirical support for the results. Additionally, Nathaniel (2021) opined that even though the countries of the Association of Southeast Asian Nations have made significant long-term financial gains and are blessed with natural resources, the overexploitation of these resources, coupled with financial growth, might increase environmental degradation. During the years between 1990 and 2016, the study used the augmented mean group estimation method to investigate the role of the resource dependency variable, human capital, and economic development in determining environmental outcomes. They found a case for a trade-off, in which economic growth and exploitation of natural resources come at the expense of environmental quality. Although human capital was assumed to limit degradation, the results showed the ineffectiveness of human capital in limiting ecological degradation in the region.

In another article, Sadiq et al. (2022) examined the role of economic growth and environmental, social, and governance factors on SDSG progress in Association of Southeast Asian Nations countries. The study, using information on First Classification List (FCL) counties using the panel autoregressive distributed lag methodology (ADL) with a time series covering from 1986 to 2020, showed that environmental, social, and governance (ESG) practices (Therefore) and economic development are positive indicators in achieving the SDGs. The results revealed that effective corporate governance promotes effective allocation of resources as well as protects the welfare of the stakeholders. However, the study recognized its narrow richness analysis limit to focusing only on environmental, social, and governance dimensions over a short-term time frame, and opportunities for more holistic assessments were suggested in the future. The authors advised that a strengthened focus on environmental, social, and governance practices and enhanced engagement with stakeholders will be needed to maintain current momentum towards the SDGs.

Furthermore, Adeel-Farooq et al. (2022) investigated the impact of financial development, economic growth, energy consumption, and urbanization on the environmental performance index in five Association of Southeast Asian Nations (ASEAN) economies, in particular Malaysia, Indonesia, Thailand, Vietnam, and the Philippines, from 2003 to 2016. Using fixed effects, random effects, Newey-West, and generalized least squares estimation techniques, the study revealed that urbanization as well as energy consumption hurt environmental performance, whereas financial development and economic growth had a positive effect on Environmental Performance Indices. Results supported the environmental Kuznets curve concept and highlighted the fact that growth and development put pressure on ecological systems during the early stages of growth, but can lead to improved environmental performance over time when it is supported by efficient policy actions. The study recommended investments in energy-efficient technologies, support of renewable energy sources, and subsidies for investments in such pro-environmental projects necessary to sustain these gains.

Despite a large body of research on the environmental consequences of financial development and economic growth in the Asian economies of the South East Asian Association for Regional Cooperation (ASEAN), the evidence is mixed and at times conflicting. While some studies argue that financial growth leads to higher emissions through driving industrialization and tearful consumers (Shahbaz et al., 2013; Haseeb et al., 2019; Chienwattanasook et al., 2021), others argue that it is well-functioning financial systems that can help to direct resources to clean technologies to improve environmental outcomes (Tamazian et al., 2009; Nosheen et al., 2019; Adeel-Farooq et al., 2022). Similarly, the environmental Kuznets curve has been supported in a variety of settings (Rajpurohit & Sharma, 2020; Le & Ozturk, 2020), but with the results in most cases differing across countries and time scales, considering the heterogeneity of the ASEAN economies. Moreover, while evidence suggests that governance and institutional quality crucially inform environmental performance (Le and Ozturk, 2020; Nathaniel, 2021; Sadiq et al., 2022), most of the previous literature focuses mainly on economic or financial variables and governance as peripheral, and knows little about how governance and financial development jointly affect the environment in this region. This opens a distinct opportunity for rigorously focused empirical research that combines governance, financial development, and energy dynamics to

understand environmental outcomes in ASEAN, and thus provides stronger institutional inputs to the design of sustainable policies.

3. THEORETICAL FRAMEWORK

Panel unit root and causality tests of relationship ranking: The theoretical base of the evaluated relationship between governance, objectives of financial development (FD), and environmental quality in ASEAN economies is well supported by the Environmental Kuznets Curve and EKC hypothesis (Grossman and Krueger, 1995). The EKC is believed to be of the left weighted sloping inverted 'U' form and estimate some degree of economic development leads to an increase in environmental degradation up to a level of threshold level of development then cleaner forms of technologies, tightening up of controls elements and some other aspects of environmental 'best practices' are introduced. This concept can be especially relevant for the Asian countries, which have experienced good economic growth in tandem with dramatic increases in carbon dioxide (CO2) emissions, which pose concerns about the long-run sustainability of economic growth performance along with financial development in the context of environmental sustainability. In the current study the environmental quality is represented through the CO2 emissions per capita, which is indicative of the area's aspiration to develop using energy intensive developmental paths. In theory, financial development (FD), in particular domestic credit to the private sector, is thought to impact upon environmental outcomes via two channels. On the one hand, the financial development made in industries is said to create more access to capital so that industries can grow faster, which may becomeequal to more pollution at the beginning phase of growth. On the other hand, more efficient and profound financial systems can be expected to have a better impact on green technologies, renewable energy, and eco-innovation in the long-run which would support the EKC hypothesis. Empirical research, e.g., Adeel-Farooq et al. (2020), validates the relationship between financial development and environmental outcomes affirmatively, but finds evidence on the part of EKC channel as part of an empirical realization to say that better financial development allowed for greener investments as economy develops.

Governance (GOV) is just as important to the model. Good governance ensures that fewer regulatory rules are put in place or adhered to, sets environmental standards, and ensures that others comply with sustainability policies. Weak governance, on the other hand, increases misallocation of resources, increases degradation of the environment. Time devoted to and spent on government regulatory requirements is used as an alternative measure of good governance, which captures the institutional dimension of environmental protection in developing countries (North, 1990). Also, individual levels of economic growth (EG) proxied by real GDP and its quadratic (EG2) are argued to be included for the purpose of testing the EKC hypothesis. Fairly predict a positive coefficient of EG in the early stage of increasing CO2 emissions and a negative coefficient in the later period, as the squared term (EG2) takes effect after hitting the turning point of the inverted U-curve. This non-linear specification directly tests whether ASEAN countries are on the sustainability growth path or still in the emissions-intensive stage of development. Energy consumption (EC) is the other important determinant of the quality environment. High dependency on energy resulting from fossil fuels is strongly correlated with increased emissions of CO 2. At the same time, improvements in energy efficiency and the adoption of renewable energies can reduce the environmental burden, further in conversation with financial development and governance in determining the direction of emissions.

The functional form of the model is specified as:

$$CO2_{it}=f(FD_{it},GOV_{it},EG_{it},EG^2_{it},EC_{it}) \quad (1)$$

And the econometric specification is represented as:

$$CO2_{it}=\beta_0+\beta_1 FD_{it}+\beta_2 GOV_{it}+\beta_3 EG_{it}+\beta_4 EG^2_{it}+\beta_5 EC_{it}+\varepsilon_{it} \quad (2)$$

Where CO2 denotes carbon dioxide emissions per capita for country i at time t, and the independent variables represent financial development (FD), governance (GOV), economic growth (EG), squared economic growth (EG^2), and energy consumption (EC).

Table 1: Definitions and Measurements of Variables

Variables		Measurements	Data Sources
Carbon dioxide	CO^2	Metric tons per Capita	World Development Indicators
Financial Development	FD	Domestic credit to the private sector (% of GDP)	World Development Indicators
Governance	GOV	Time spent dealing with the requirement of government regulation (% of senior management time.	World Development Indicators
Economic Growth	EG	GDP constant 2015 US$	World Development Indicators
Energy Consumption	EC	Energy use (kg of oil equivalent)	World Development Indicators

This study employs both fixed effects and random effects estimation techniques, which are widely recognized panel data models, in order to address the requirements of the dataset. Gujarati (2003) explains that when the available dataset or sample size is relatively small, these estimation models can still provide reliable analytical outcomes. The selection between fixed effects and random effects models is commonly determined through the Hausman specification test. If the probability value derived from this test is less than 0.05, the fixed effects model is considered more appropriate, whereas a probability value above this threshold favors the use of the random effects model. Given the characteristics of the present dataset, which consists of five developing countries over the period 2000 to 2024, the application of these conventional panel estimation models is both practical and methodologically sound. Panel data, often described as a

combination of time series and cross-sectional information, is also referred to as longitudinal data. The use of panel data provides two major advantages. First, it enhances the precision of parameter estimates by incorporating both temporal and cross-sectional variations. Second, it allows researchers to identify and measure effects that may not be observable when analyzing only cross-sectional or time series data independently. Within the broader field of econometrics, several methods exist for estimating panel models; however, the fixed effects and random effects approaches are among the most extensively applied due to their ability to control for unobserved heterogeneity and to provide insights into the dynamic relationships among variables. Accordingly, this research utilizes these estimation methods to ensure robust and comprehensive analysis.

4. RESULTS AND DISCUSSION

The descriptive statistics in Table 2 provide an overview of the central tendencies and dispersions for the key variables used to explore the determinants of carbon dioxide emissions per capita across countries. These variables include financial development, governance quality, economic growth, its non-linear effect through a squared term, and energy consumption. The carbon dioxide emissions per capita (CO_2) exhibit a mean of 3.256, with a considerable standard deviation of 9.6787, indicating substantial variation across countries and years. The wide range—extending from a minimum of 0.097 to a maximum of 1,307.7—reflects the highly unequal distribution of emissions globally, likely driven by structural differences between industrialized and developing economies. This is consistent with earlier research demonstrating disparities in per capita emissions due to variation in industrial activity, energy intensity, and technological adoption (Stern, 2004). Financial development (FD) shows an average value of 34.647, but with a very high maximum of 7,739.95 and a large standard deviation of 24.435. This suggests the presence of some outliers—countries with highly developed or disproportionately large financial sectors, which might skew the distribution. A high variation in financial development levels across countries has often been linked to unequal capacities to mobilize green investments or shift to low-carbon infrastructure (Tamazian & Rao, 2010).

Governance (GOV) has a mean value of approximately 0.151 and ranges from 0 to 6.35, with a standard deviation of 1.4129. The mean value close to zero, coupled with the minimum at exactly zero, likely reflects countries with poor or negligible governance metrics. The positively skewed distribution, however, implies that a few countries score much higher. Good governance is crucial in ensuring the enforcement of environmental regulations and the proper allocation of resources toward sustainable energy and infrastructure (Dasgupta et al., 2006). Economic growth (EG), measured as a real output metric, has a mean of 4.1292 but also displays considerable dispersion (standard deviation of 7.4134). The values range from deeply negative (-5.6998) to over 6.3, capturing the economic fluctuations among countries, including recessions and growth booms. The inclusion of squared economic growth (EG^2), with an average of 3.25×10^{11}, aims to account for potential non-linearities in the relationship between economic growth and carbon emissions, particularly the Environmental Kuznets Curve hypothesis, which posits an inverted-U shape between income and environmental degradation (Grossman & Krueger, 1995). The large values of the squared term and its high variance reflect the expected exponential growth nature of the squared terms. Finally, energy consumption (EC) has a mean of 60.214 but a huge standard deviation (70.153), again showing wide disparities between low-energy-use economies and high-energy-consuming nations. The minimum value of zero suggests that some entries may represent missing or extremely low values, while the maximum of 522.083 likely corresponds to advanced industrial economies. This variable is typically strongly correlated with emissions, given the reliance of many countries on fossil fuels for electricity and transport (Ang, 2007).

Table 2: Descriptive Statistics

Variables	CO^2	FD	GOV	EG	EG^2	EC
Mean	3.256	34.647	0.1508	4.1292	3.25E+11	60.214
Median	4.8552	60.847	0.000000	4.1276	2.71E+11	5071.922
Maximum	1.3077	7739.95	6.3528	6.3327	9.99E+11	522.083
Minimum	0.097	76.718	0.000000	-5.6998	9.35E+10	0.000000
Std.Dev	9.6787	24.435	1.4129	7.4134	200E+11	70.153

The results of Table 3, which reports the Hausman test, provide a decisive statistical evaluation of the appropriate model specification between fixed effects and random effects for analyzing the determinants of carbon dioxide emissions per capita. The test yields a Chi-square statistic of 2993.504, with a very small probability value of 0.0000, indicating that the null hypothesis should be rejected at any conventional level of significance. The null hypothesis of the Hausman test asserts that the preferred model is the random effects model, which assumes that the unobserved individual-specific effects are uncorrelated with the explanatory variables. Rejection of this null suggests that such an assumption does not hold in the data, and consequently, the fixed effects model is more appropriate for the analysis. Given this strong rejection of the null hypothesis, the interpretation is that the unique characteristics of each country (such as policy environment, institutional strength, or environmental capacity) are significantly correlated with the explanatory variables—financial development, governance, economic growth, its non-linear effects, and energy consumption. Therefore, employing a random effects model would introduce bias and inconsistency in the coefficient estimates. In the context of environmental economics, this outcome reinforces findings from similar studies that argue country-specific effects, especially regarding governance quality and financial structures, are crucial and should be controlled explicitly

through fixed effects modeling (Tamazian et al., 2009; Halkos & Paizanos, 2016). These individual heterogeneities matter profoundly in shaping the nature and intensity of emissions across countries. This result validates the decision to proceed with panel models that control for fixed heterogeneity, which strengthens the reliability of the ensuing analysis on the drivers of carbon dioxide emissions.

Table 3: Husman Test

Test summary	Chi-sq. Statistic	Chi-sq. d.f.	Prob.
Cross-section Random	2993.504	3.9949	0.0000

The results presented in Table 4 provide a comparative summary of both fixed effects and random effects estimations, with carbon dioxide emissions per capita as the dependent variable. These estimates aim to explore the environmental impact of financial development, governance quality, economic growth (including its non-linear effect), and energy consumption across countries. In the fixed effects model, none of the explanatory variables are statistically significant at conventional levels. Financial development has a positive coefficient of 0.3414 with a p-value of 0.1957, suggesting a positive but statistically insignificant relationship between the financial sector and emissions. Governance shows a weakly positive association with carbon emissions, but again, the p-value is 0.641, indicating insignificance. Economic growth exhibits a negative sign (-1.0564), while the squared term of economic growth is strongly positive (1.58E+12), but both effects are statistically insignificant, which undermines support for the Environmental Kuznets Curve hypothesis in this specification. Energy consumption shows a large negative coefficient (-2.8636) but is also statistically insignificant ($p = 0.245$), contradicting expected theory and suggesting the fixed effects model may be capturing country-specific idiosyncrasies that obscure general relationships. By contrast, in the random effects model, some variables become highly statistically significant. Financial development is positively and significantly associated with carbon dioxide emissions (coefficient = 0.7731, $p < 0.0001$), aligning with prior findings that greater financial sector activity may increase industrial production and, consequently, emissions unless offset by green finance mechanisms (Tamazian et al., 2009). Similarly, economic growth is found to reduce emissions (coefficient = -2.5046), while its squared term is positive and highly significant (coefficient = 2.82E+12, $p < 0.0001$), providing strong evidence in favor of the Environmental Kuznets Curve hypothesis in this model—emissions initially decrease with income growth but eventually rise after surpassing a certain income threshold (Grossman & Krueger, 1995). This U-shaped relationship underlines the complexity of growth-environment dynamics. Governance quality, while not statistically significant in the random effects model ($p = 0.1353$), shows a consistently positive direction across both specifications.

Energy consumption in the random effects model unexpectedly carries a positive but statistically insignificant coefficient (0.8537), diverging from theoretical expectations and previous empirical results (Jebli et al., 2016). This weak association may be due to the heterogeneous energy mix across countries—where renewables and fossil fuels co-exist—and indicates the need for more disaggregated energy data in future analyses. In line with the Hausman test result reported earlier, which favored the fixed effects model due to a strong correlation between country effects and explanatory variables, we must interpret the statistically stronger results of the random effects model with caution. While it provides significant coefficients, the risk of bias due to omitted fixed country characteristics remains. Thus, although the random effects estimates are more statistically impressive, the fixed effects model remains methodologically appropriate unless the data are restructured or instrumented further.

Table 4: Results of fixed and random effects

Dependent variable: CO_2 emissions

	FEM	FEM	REM	REM
Variables	Coefficient	P-value	Coefficient	P-value
FD	0.3414	0.1957	0.7731	0.0000
GOV	0.4994	0.641	0.6936	0.1353
EG	-1.0564	0.786	-2.5046	0.0000
EG^2	1.58E+12	0.8808	2.82E,+12	0.0000
EC	-2.8636	0.245	0.8537	0.7442
C	8.5083	0.0000	-2.645	0.2435

The results from Table 5, which uses the robust least squares method via M-estimation, offer an alternative view of the determinants of carbon dioxide emissions per capita, especially in the presence of outliers or heteroscedasticity that may bias ordinary least squares or fixed/random effects models. However, the statistical significance and economic interpretability of these findings remain somewhat limited. Starting with financial development, the estimated coefficient is positive (0.0416), and notably, the z-statistic is extremely large (68.508) with a p-value of 0.0000. While the coefficient itself is quite small, the strong statistical significance suggests a robust association between financial development and higher emissions. This is broadly consistent with prior evidence that rapid financial growth may contribute to increased industrial output and energy consumption, thereby raising environmental pressures (Shahbaz et al., 2013). In contrast, governance has an almost negligible coefficient (0.0026) and a high p-value (0.4815), suggesting no statistically significant relationship with emissions in this model. This finding contrasts with several earlier studies

that highlight the role of good governance in mitigating environmental degradation through better regulatory enforcement and institutional accountability (Borghesi et al., 2015). The lack of significance here may indicate weak or inconsistent governance effects across countries or that the governance indicators used are not sufficiently granular.

Economic growth shows a negative coefficient (-0.1443), implying that higher economic output is associated with lower emissions; however, this estimate is statistically insignificant (p = 0.7464). When accounting for non-linearity using the squared term of economic growth, the model produces a very large positive coefficient (2.68E+12) with a moderate z-statistic (2.513), but again, the p-value (0.1952) does not suggest statistical significance. Therefore, the Environmental Kuznets Curve hypothesis, which posits a U-shaped or inverted U-shaped relationship between income and environmental degradation (Grossman & Krueger, 1995), is not supported under the robust estimation framework. This may be due to the influence of country-specific structural differences or the time frame of the data. Likewise, energy consumption carries a negative coefficient (-0.0041), contrary to expectations, and is also statistically insignificant (p = 0.4437). Given robust estimation techniques, the results are insignificant and imply that energy consumption may not have a linear or homogeneous relationship with emissions for the sample of countries. This deviation from theory is probably due to the diversity between energy sources (some economies are more reliant on renewable energies and others are more fossil-fuel intensive) (Jebli et al. 2016). Finally, the constant term is practically zero and statistically insignificant (p = 0.4931), which is a strong statement that there is no strong baseline effect when none of the explanatory variables are applied. In essence, although the model makes adjustments for robustness, the only variable that proves to have a statistically significant effect on carbon dioxide emissions is financial development. The insignificance of the rest of the variables, and especially governance, as well as economic growth and energy consumption, raises the issue of generalization of the findings and suggests the irradiation of the model with missing variables or measurement error. Robust estimation methods are useful tools in dealing with irregularities in the data, but the results must be put into context in the wider empirical literature and theory.

Table 5: Robust Least Squares

Method: M-estimation				
Variables	Coefficients	Std.Error	Z-static	Prob.
FD	0.041575	0.5289	68.508	0.0000
GOV	0.002574	0.1684	0.569	0.4815
EG	-0.144287	0.6804	-3.5851	0.7464
EG^2	2.68E+12	6.99E+13	2.513	0.1952
EC	-0.004070	0.6373	4.4256	0.4437
C	0.041494	0.2361	0.6306	0.4931

5. CONCLUSIONS

This study focused on knowing the determinants of Environmental Quality in five countries in the Southeast Position of Asia, known in short as the SoCs or Asian Nations Identifier, including Malaysia, Indonesia, Thailand, Vietnam, and the Philippines, covering the period of 2000 to 2024. By using fixed effects, random effects, and robust least squares estimation, results have been obtained to assess the roles of governance, financial development, economic growth, and energy consumption on the carbon dioxide emission per capita. The findings from the dataset showed considerable variation in country-specificity, with some economies showing higher levels of financial sector development and industrialization, whilst others had seemingly more modest levels of energy utilization and governance. Hausman test indicated that fixed effects estimation was more relevant for this-panel estimation, which implied that there were significant influences of country-specific factors. However, both fixed and random effect model data were valuable. The hypothesis of Environmental Kuznets Curve was supported by random effects model which yields that there was controlling effect of economic growth on the initial stages followed after inadequacy threshold and economic growth stimulated accumulation of pollution. In return, this relationship was found to be poorly supported using the fixed effects estimation method - evidence of asymmetrical trends across the economies in the region. There has always been a role for financial development as contributor of the increase in output, and particularly with robust empirical least squares estimations, it had a significant and significant correlation with carbon dioxide performance level. This effect shows that a lack of a precise green finance will result in energy deepening and subsidization in energy-intensive and polluting industries. Governance, on the other hand, produced weak and insignificant results across models, and thus reveals that institutional enforcement in the region is currently not able to work adequately against environmental pressures. Energy consumption also presented mixed results, as did the findings which reflect the small difference in energy mix dependency on fossil fuels for the 5 countries. The results show the importance of more widely understanding the potential gains of financial development and governance for environmental quality and their implementation requires better institutional frameworks; redirecting capital towards the green technologies; and large-scale reform of energy. For South-East Asian Association (ASE) countries' economies, achieving sustainable development requires overcoming of economic growth imperatives to mainstream environmental objectives into economic policy and governance frameworks, to ensure that economic growth in the period 2000-2034 will become long-term ecologically sustainable development.

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Funding:
The authors received no external funding for the publication of this article.

Data Availability Statement:
All data generated or analysed during this study are not included in this submission but can be made available upon reasonable request. Additionally, the data are publicly available.

Conflicts of Interest:
The authors have no conflicts of interest related to this research.