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Economic and Environmental Dynamics in Southeast Asia: The Impact of Tourism, Gross Domestic Product, Foreign Direct Investment, and Trade Openness on Carbon Dioxide Emissions

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Abstract

This research explores the influence of tourism activities, economic output, international investment inflows, and openness to trade on emissions of carbon dioxide within seven key tourist destinations of the Association of Southeast Asian Nations from 2000 to 2020. The methodologies employed include the autoregressive distributed lag approach and panel data-based Granger causality tests. According to the findings, a notable correlation among studied factors is identified, as the empirical evidence confirms that economic growth, openness to trade, and tourism activity positively impact carbon dioxide emissions. Consequently, increases in these elements are associated with a rise in pollution levels. Conversely, foreign direct investments display a significant inverse relationship with carbon dioxide emissions, indicating that growth in international investments may reduce emissions. Furthermore, the long-term analysis validates the robustness of associations among tourism, trade openness, foreign direct investments, and carbon emissions. Comprehensive interpretations of the obtained results are provided, alongside essential policy directions and suggested avenues for future investigations into the connections among economic advancement, the tourism sector's growth, global investment patterns, and ecological sustainability.

Keywords: *Tourism, Gross Domestic Product, Foreign Direct Investment, Trade Openness, Carbon Dioxide Emissions*
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1. INTRODUCTION

Global warming, though still a critical issue, is no longer the sole environmental concern as it was perceived in the previous century. While historical events such as continental drift, which took place approximately 4.5 billion years ago, have led to significant geographical transformations, contemporary challenges extend far beyond this natural phenomenon. Present-day global concerns revolve around rising inequality, excessive resource consumption, and widespread environmental degradation, all of which pose severe threats to sustainability (Koeberl, 2006; Pata et al., 2023; Huang et al., 2024; Marc et al., 2024; Roussel & Audi, 2024). These interconnected issues could potentially trigger a sharp rise in the average global temperature, estimated at 3°C, leading to disastrous consequences. If left unchecked, such climatic changes could severely impact ecosystems, accelerating the frequency of natural disasters such as droughts, food shortages, declining agricultural productivity, and the rapid melting of glaciers and ice caps. The potential long-term damage would be beyond repair, underscoring the urgent need for a globally integrated and systematic plan of action (Nwezeaku, 2018; Mongo et al., 2021; Wei & Lihua, 2023). A substantial share of global emissions is attributable to human activities, which intensify the release of harmful gases—especially carbon dioxide. This particular emission is widely recognized as the chief contributor to the rise in global temperatures, significantly impacting both natural ecosystems and human communities. The repercussions of increasing carbon dioxide levels are particularly severe in climate-sensitive regions, where they contribute to extreme weather patterns, habitat loss, and declining biodiversity (Marc, 2022; Amjad et al., 2022; Wei & Lihua, 2023; Ali, 2023; Marc & Ali, 2023; Song et al., 2024).

Tourism is emerging as one of the fastest-growing sectors in the global economy, which has connections with climate and environmental dynamics (Roy & Madheswaran, 2020; Sadashiv, 2023; Audi, 2024). The rapid growth in tourism becomes the mechanism for increasing demands for the infrastructure, electricity, and transport that further build up carbon emission levels in tourism. Most of the energy used to supply tourism activities related to transportation or leisure

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activities comes from nonrenewable sources such as fossil fuels, coal, oil, and natural gas, which hasten energy depletion for millions of years besides increasing the levels of carbon dioxide emissions (Zahid, 2018; Ahmed, 2019; Huang et al., 2020; Kilyachkov & Chaldaeva, 2021; Huang et al., 2021; Wang & Wu, 2022; Audi et al., 2025). Further, a lot of the developing tourism destinations have poor infrastructure with regards to logistics, and it intensifies fossil fuel consumption. All the above notwithstanding, tourism contributes a great deal to the economic development of countries through urbanization and industrialization. However, the nexus between tourism and global warming will have to be scrutinized against other forms of environmental pollution, as they are more complicated than simply focussing on tourism. A substantial number of studies have been conducted to show the negative effect on the environment made by tourism-related activities including accommodation, transport, and commercial development (Akadiri et al., 2020; Akim, 2020; Osei & Acheampong, 2021; Ali et al., 2021; Pata et al., 2023; Awan et al., 2023). The tourism burden environment if not properly handled is likely to bring about some long-run economic problems such as resource depletion, biodiversity loss, and low resilience of ecosystems. Hence, some of the management practices on sustainable tourism policies must be initiated to curb these effects and ensure that economic benefits will not be achieved at the cost of environmental sustainability (Nwezeaku, 2018; Altaf & Shahzad, 2021; Ali et al., 2021; Ehsanullah et al., 2021; Li et al., 2022; Wang & Wu, 2022; Baydur, 2024).

Financial investments, particularly domestic savings and foreign direct investment (FDI), play a critical role in driving economic development and achieving sustainable environmental goals. When internal savings fall short of funding vital investments, countries often depend on FDI as an important catalyst for economic growth (Ahiawodzi, 2019; Cooper, 2022; Chen, 2022; Abdul-Mumuni et al., 2023; Ullah et al., 2023). Foreign direct investment can substantially reshape host economies through the stimulation of industrial growth, the transfer of advanced technologies, and job creation. Nonetheless, it is essential to rigorously assess the environmental impacts associated with FDI to ensure economic advantages do not inadvertently result in environmental harm. Although FDI contributes positively to economic prosperity, it can simultaneously accelerate environmental degradation, especially where environmental regulations are inadequate or poorly enforced. Industrial growth spurred by FDI frequently triggers higher carbon emissions, increased levels of pollution, and excessive resource depletion. In such contexts, environmental systems absorb the real cost of economic advancement, emphasizing the necessity for robust environmental legislation and investments aligned with sustainable development principles (Zhu et al., 2016; Bashir & Rashid, 2019; Urban & Radas, 2021; Ang, 2022).

Balancing the interplay among economic expansion, the growth of the tourism sector, and ecological sustainability is a pivotal contemporary challenge. While foreign direct investments and economic development are crucial to progress, they must be integrated with environmental priorities to ensure lasting sustainability. Therefore, policymakers must design and implement policies that encourage sustainable investments, enhance energy conservation, and promote eco-friendly tourism activities to reduce environmental impacts resulting from economic growth. Addressing these intricate challenges demands concerted efforts at both national and international levels, ensuring that economic successes do not compromise ecological integrity. In the longer perspective, economies driven predominantly by FDI cannot automatically ensure environmental protection. Instead, proactive policy formulation and strategic interventions become necessary to realize true sustainability. The elevated carbon emissions frequently linked with FDI have the potential to diminish economic advantages derived from foreign capital inflows, underscoring the need for effective environmental governance (Kilyachkov & Chaldaeva, 2021; Zahra et al., 2023). Consequently, when assessing the ecological consequences of economic growth propelled by foreign direct investment, it is crucial to recognize potential trade-offs, as environmental costs may, at times, eclipse the economic benefits gained (Osei & Acheampong, 2021; Shahbaz et al., 2018; Zahid, 2018; Perveez, 2019).

The relationship between carbon emissions and FDI has been widely analyzed in empirical studies, consistently highlighting its complexity and multidimensional nature (Hwang & Lee, 2019; Chang, 2015; Nasir, 2022; Gao et al., 2022; Koçak & Şarkgüneşi, 2018; Minh, 2020; Ochoa-Mor, 2020; Rossi, 2023; Audi, 2024). According to the pollution haven hypothesis, multinational corporations tend to invest in nations with relatively lenient environmental rules to reduce compliance costs, promoting industrial growth at the expense of environmental standards. Consequently, FDI inflows often lead to increased industrial operations, heightened carbon emissions, and various detrimental ecological impacts (Luna & Luna, 2018; Abdul-Mumuni et al., 2023; Hussain & Khan, 2022; Huang et al., 2022; Mustapha, 2022). Numerous countries, especially within the ASEAN bloc, have confronted challenges associated with aligning environmental sustainability and foreign investments. Their rapid economic progress relies heavily on intensive energy consumption patterns, predominantly driven by fossil fuels. This substantial energy dependence contributes directly to increased greenhouse gas emissions, intensifying climate-related vulnerabilities and environmental risks. Thus, addressing fossil fuel dependency is essential for mitigating greenhouse gas emissions and reducing potential environmental threats resulting from accelerating climate change.

Environmental impacts have been raised concerns pertaining to rapid growth in the economy at the cost of an excessive energy consumption. Unrestrained growth in industries in the region can significantly accelerate climate change along with its associated challenges (ASEAN Centre for Energy, 2015). As with the ever-rising demand for energy in supporting an industrialized economy, the use of fossil fuels increases; thus high greenhouse gas emissions coupled with several other undesirable environmental impacts like degraded air quality, altered weather patterns, among other disturbances, have become evident. Such issues create the urgency of viable development strategies that balance economic growth with environmental care so that progress does not destroy ecological stability in the long run. By 2060 the World Bank projects that between six to nine millions harness additional deaths caused by pollution and economic loss equivalent to approximately one percent of the global gross domestic product (Javaid et al., 2023). Alarmingly, 92% of these deaths are expected to take place in emerging and developing nations, where weak environmental policies and inadequate infrastructure heighten vulnerability to pollution-related illnesses. Environmental pollution and rising carbon dioxide emissions also have significant economic consequences. Countries with poor environmental planning face increased risks of pollution-induced health crises, leading to reduced workforce productivity in both the industrial and service sectors. This productivity loss has been estimated to reduce a country's annual gross domestic product by approximately 2% (Landrigan et al., 2018). If left unchecked, worsening environmental conditions could have long-term implications for economic stability, human health, and social well-being (Beck & Mahony, 2018; Achy & Lakhnati, 2019; Weber, 2022; Liu et al., 2023). A casual approach to environmental regulation could lead to severe consequences, ultimately threatening long-term development by allowing unchecked ecological degradation.

The growing awareness of the link between environmental degradation and economic growth has made the study of ecological sustainability a focal point of contemporary research. Many studies have examined the relationship between ecological deterioration and gross domestic product per capita, highlighting the need for sustainable economic policies (Bakhsh et al., 2017; Kosyak & Popov, 2020). Advanced economies continue to grapple with the environmental costs of industrialization, making it imperative to find solutions that balance economic prosperity with ecological preservation (Awan & Azam, 2022). The need for a shift toward sustainable growth is further reinforced by Raworth (2017), who argues that environmental concerns must be integrated into economic planning to ensure long-term resilience. Foreign direct investment and economic growth must be strategically managed to prevent environmental degradation. While foreign direct investment contributes to economic expansion, it must be accompanied by stringent environmental policies to mitigate its adverse effects. ASEAN economies, in particular, must address their reliance on fossil fuels and implement sustainable energy solutions to curb carbon emissions. Policymakers must take immediate action to integrate environmental regulations into economic frameworks, ensuring that industrial expansion does not come at the cost of long-term ecological and economic stability.

Empirical research focusing on Indonesia between the years 1976 and 2014 demonstrates that increased trade openness significantly elevated carbon dioxide emissions. This rise in emissions largely stemmed from growing external demand coupled with expanded international trading activities. Two competing hypotheses are central to explaining this relationship. First, according to the race-to-the-bottom hypothesis, nations seeking rapid economic benefits may relax environmental regulations, potentially sacrificing environmental standards in pursuit of greater economic competitiveness. This prioritization inevitably increases pollution and environmental degradation. Alternatively, trade openness can also foster environmental benefits if it aligns with sustainable production practices and technological advancements (Managi, 2004). Indeed, trade liberalization exerts complex environmental impacts that can simultaneously be positive and negative, typically classified into three distinct channels: the scale, technique, and composition effects.

The composition effect involves changes in a country's industrial structure resulting from trade integration. Conversely, the technique effect represents technological enhancements within industries that improve production efficiency and lower pollution. Finally, the scale effect describes the increase in economic output—and hence environmental impact—as a consequence of expanded trade activities (Hassan & Salha, 2020; Habibullah & Kamal, 2024). These distinct effects collectively shape how trade impacts the environment. The commitments articulated during COP26 on November 13, 2021, within the Glasgow Climate Pact, reaffirmed those agreed upon in the Paris Agreement. Specifically, it underscored the importance of considering scale, technique, and composition effects as determining factors influencing trade's environmental consequences, especially under scenarios limiting global temperature increases to 1.5°C. This global trade-driven economic expansion has motivated numerous countries to pursue carbon neutrality objectives. Consequently, trade openness increasingly finds itself under scrutiny concerning its relationship with carbon emissions and sustainability efforts. These developments emphasize the growing necessity for coherent policy integration addressing trade openness and environmental mitigation (Khan & Hassan, 2019; Roussel & Audi, 2024). Furthermore, balancing international trade activities and sustainable environmental outcomes has become imperative for policymakers worldwide, given the heightened environmental awareness resulting from recent climate summits.

The present research examines how economic performance, openness to international trade, overall trade activities, and foreign direct investments influence carbon dioxide emissions, employing contemporary econometric methods. While earlier studies primarily utilized conventional econometric approaches, this research employs advanced panel autoregressive distributed lag (ARDL) techniques, enabling an extensive analysis of both short-term and long-term relationships. The advantage of applying panel ARDL lies in its ability to evaluate symmetric and asymmetric relationships, providing deeper insights into how economic and trade-related factors affect carbon emissions across ASEAN economies. The use of recent and updated datasets further strengthens the accuracy and relevance of the findings. These insights could significantly benefit ASEAN countries confronting severe pollution levels and other environmental pressures. Understanding the relationship between economic growth, trade liberalization, and ecological sustainability is essential for designing policy frameworks that effectively balance economic development and environmental conservation. Structurally, the paper comprises four main sections: first, a comprehensive literature review summarizing existing research; second, a detailed explanation of the dataset and econometric techniques employed; third, an empirical results section highlighting key findings; and finally, a discussion and policy recommendations section that contextualizes empirical results within a practical policy outlook. The concluding portion highlights critical outcomes, emphasizing implications for both future academic inquiries and practical policymaking. Ultimately, this study aims to equip policymakers and researchers with clearer insights into environmental challenges linked to trade liberalization and foreign investment flows, supporting ASEAN countries in pursuing sustainable economic policies.

2. LITERATURE REVIEW

Tourism, along with its burgeoning global growth, has become an important subject of consideration vis-a-vis environment. The importance of examining the growing demand for tourism and associated increases in CO_2 emissions in newly industrializing countries. In a related analysis, Khoula et al. investigated the environmental effects of tourism in Brazil from 1990 to 2019 using advanced econometric methods, including fully modified ordinary least squares (FMOLS), dynamic ordinary least squares (DOLS), and canonical cointegration regression (CCR). Their findings indicate ongoing debates regarding tourism’s net environmental impact. While scholars like Selvanathan et al. (2021) and Wei and Lihua (2023) assert that tourism contributes significantly to environmental harm, other research contends that tourism might enhance environmental quality, especially in economically advanced nations. For instance, Tiwari et al. (2013) discovered tourism's beneficial role in improving environmental conditions within OECD countries. Likewise, studies by Abbasi et al. (2021) and Ozturk (2016) confirmed enduring connections between tourism activities and environmental outcomes across a diverse panel of 34 nations.

Country-level analyses further illustrate the complexity inherent in tourism's environmental impacts. Dawood et al. (2023) demonstrated that, within Turkey, factors such as energy consumption, economic growth, and tourism activities jointly increase carbon emissions, despite rising awareness among travelers encouraging environmentally sustainable practices. A study conducted on Cyprus by Katircioglu et al. (2014) found an inelastic yet statistically significant link between tourism and emissions, with tourism-related emissions adjusting towards equilibrium at an annual convergence rate of approximately 95.4%. Additionally, literature addressing foreign direct investment (FDI) and its environmental consequences yields mixed results. Several scholars identify a U-shaped pattern, implying that initial inflows of FDI elevate emissions, whereas emissions gradually decrease beyond a certain economic threshold (Desiree, 2019; Chenran et al., 2019; Christoforidis & Katrakilidis, 2021; Shahbaz et al., 2019; Khan & Hassan, 2019; Bakht, 2020).

Investigations specifically focusing on Vietnam suggest that foreign direct investment exerts negative ecological impacts, thus supporting existing concerns about environmental deterioration linked to FDI (Willy, 2018; Chenran et al., 2019; Skhirtladze & Nurboja, 2019). Similarly, Shahbaz et al. (2019) confirm that FDI substantially boosts carbon emissions during early investment stages, extending well into higher developmental phases. Two primary mechanisms characterize the connection between economic development, FDI, and pollution: firstly, FDI inflows stimulate greater economic output and thereby intensify environmental harm, reinforcing the pollution haven hypothesis. This hypothesis posits that corporations relocate polluting activities to regions with lax regulatory controls, exacerbating environmental issues. Conversely, FDI can also encourage cleaner production techniques through technological transfers, progressively mitigating emissions and pollution (Lau et al., 2014; Ahmed & Alvi, 2024).

Despite extensive scholarly discourse, consensus on the environmental consequences of FDI remains elusive. Rahaman et al. (2022) highlight FDI’s potential to aggravate environmental harm, thus lending credence to the pollution haven theory. In contrast, Zhang et al. (2022) propose alternative perspectives, suggesting FDI promotes positive environmental outcomes by encouraging technological innovation and improved industrial efficiencies. Haug and Ucal (2019), employing nonlinear autoregressive distributed lag (NARDL) modeling, evaluated FDI’s complex effects on per capita carbon emissions and trade. Their findings indicate limited long-term influence of FDI on environmental quality; declining exports correlate with reduced emissions, yet increases in exports show ambiguous environmental impacts.

Regional variations further compound the relationship between FDI and emissions. Zhang and Zhou’s (2016) examination of spatial differences in China revealed that FDI notably contributed to reducing emissions, particularly indicating decreasing emission patterns from western to eastern and central regions. Such findings align with the pollution halo hypothesis, which suggests that FDI improves ecological conditions through technological advancements and higher efficiency standards (Toth & Paskal, 2019; Shahid et al., 2024; Wang & Li, 2024). Nonetheless, empirical results remain conflicting. Some studies highlight negative environmental effects from FDI, while others emphasize its potential to accelerate environmentally beneficial technological advancements. Thus, recognizing the environmental implications of FDI requires careful consideration of country-specific characteristics, including regulatory institutions, economic conditions, and technological advancement. Policymakers seeking sustainable development must acknowledge this complexity.

Significant reductions in carbon emissions intensity relative to GDP are critical to limiting global warming to a maximum of 2°C. Achieving this goal necessitates annual reductions exceeding 3% in emissions intensity, with carbon dioxide emissions expected to peak and subsequently decline, even as global GDP continues to grow around 3% annually. To maintain downward emission trajectories past 2030, annual reduction rates must accelerate to more than 4% by 2030, subsequently reaching 6–7% each year thereafter, thus supporting economic growth while holding global temperatures below a 2°C increase (He et al., 2018). The economic growth-emissions nexus has been widely explored globally. Alper and Onur (2016) examined China’s economic growth-emissions dynamics from 1977 to 2013, employing fully modified ordinary least squares methodologies; their results indicated limitations in applying the Environmental Kuznets Curve (EKC) model for explaining Chinese emission patterns. Similarly, Barış-Tüzemen et al. (2020), examining Turkey from 1980 to 2017, evaluated whether an N-shaped EKC exists using quantile regression and ARDL techniques, finding no convincing evidence supporting this form of EKC in Turkey’s emissions trajectory.

It was Magazzino (2016) who further investigated the net effects among carbon dioxide emissions, real GDP, and energy consumption for six Gulf Cooperation Council countries based on annual data for 1960-2013. This research addresses the complexities and multifaceted interrelations of economic growth, foreign direct investment, and environmental sustainability, demanding distinctive policies tailored to the regions and structures that make up climate action and sustainable development. The study revealed that whereas all the variables had unit roots, the long-run relationship had a different pattern in countries, with Oman having an entirely different relationship. Granger causality tests indicated that energy consumption was a key determinant of all real gross domestic production in the three countries of Kuwait, Oman, and Qatar; thus reinforcing the view that economic activities in these economies are heavily dependent on fossil fuel consumption (James, 2020; Zulfiqar et al., 2022; Yan & Sriboonchitta, 2024). The further gap left to understanding economic growth as a direct effect on carbon dioxide is filled through advancements in computational modeling. According to Marjanović et al. (2016), an extreme learning machine model was developed to predict gross domestic product against carbon dioxide emissions. Their study compared artificial neural networks, genetic programming, and extreme learning machine techniques, demonstrating the reliability of computational models in predicting economic trends. The coefficients of determination for the artificial neural networks, genetic programming, and extreme learning machine models were found to be 0.4475, 0.8756, and 0.9271, respectively, indicating that machine learning techniques offer a robust framework for analyzing the complex interactions between economic activity and environmental sustainability.

Recent research indicates that the relationship between economic growth and environmental outcomes varies considerably across nations. While some nations exhibit a clear relationship between economic expansion and reductions in carbon emissions intensity, others do not follow this pattern, suggesting the critical need for tailored, country-specific policy strategies. Effective policies must simultaneously encourage economic prosperity and sharply reduce carbon dioxide emission intensity. Going forward, combining regulatory interventions, innovative technologies, and sustainable energy initiatives will become essential for balancing stable economic conditions with the pressing global imperative of mitigating climate change impacts. An extensive and continually expanding literature base has investigated the connection between international trade openness and environmental sustainability. For instance, studies suggest trade openness significantly impacts carbon dioxide emissions. Shahbaz et al. (2017) demonstrated empirically that a 1% increase in trade openness led to carbon dioxide emissions rising by 0.247% in Pakistan over the long term and 0.122% in the short term. Nonetheless, this positive relationship gradually becomes linear in the long run when squared and cubic terms for trade openness are introduced, whereas in the short run, the relationship remains distinctly nonlinear. Similarly, Al-Mulali and Sheau-Ting (2014) found that trade openness and carbon dioxide emissions have a significantly positive connection characterized by long-term linearity, with clear evidence of causation running from trade openness toward increased emissions. Additionally, broader economic factors such as wealth and economic advancement further mediate this relationship (Chen et al., 2021; Jamel & Zhang, 2024).

Zhang et al. (2017) analyzed trade openness's environmental impacts across ten newly industrializing economies and concluded that trade openness indeed contributes to reducing emissions, especially if accompanied by economic growth. Thus, they recommended pursuing policies encouraging trade openness alongside sustained economic expansion to achieve environmental goals. Nonetheless, empirical results are mixed. For instance, Mutascu (2018), utilizing wavelet techniques, assessed trade openness and carbon dioxide emissions in France between 1960 and 2013 and found no substantial long-term relationship, validating a neutral hypothesis. However, other frequency scales indicated nuanced and insignificant interactions between openness and emissions. Such contrasting outcomes underscore ongoing debates. Some studies assert a clear positive connection, indicating trade openness exacerbates emissions. Conversely, other research argues openness enhances environmental outcomes by promoting advanced technological standards and practices. Overall, these diverse findings illustrate the critical but ambiguous role trade openness plays concerning carbon dioxide emissions. Differences emerge due to varying stages of economic development, technological sophistication, environmental governance structures, and energy consumption behaviors unique to each nation. Recognizing these distinctions is critical for formulating effective policies that balance trade openness and carbon emissions reduction, while ensuring sustained and sustainable economic growth.

3. METHODOLOGY

This study investigates how tourism, foreign direct investment, economic growth (GDP), and trade openness influence carbon dioxide emissions across selected ASEAN economies, specifically including Brunei Darussalam, Thailand, Vietnam, Singapore, the Philippines, Malaysia, and Indonesia, during the years 2000–2022. The dataset utilized for analysis was sourced from the International Monetary Fund (IMF) databases and World Development Indicators (WDI) provided by the World Bank (2020). Carbon dioxide emissions were quantified in kilotons (Kt), while foreign direct investment was represented by net inflows as a percentage of GDP. Tourism was measured through total tourist arrivals, economic growth was captured by GDP per capita at constant 2015 US dollar values, and trade openness was calculated as total imports and exports of goods and services relative to GDP. For econometric analysis, all variables were converted into their natural logarithmic forms.

The model specification is:

$CO2 = f($ FDI, GDP, TOU, TOP)

After adding the parameters, the equation form is

$$CO2 = \alpha_0 + \beta_1\, FDI + \beta_2\, GDP + \beta_3\, TOU + \beta_4\, TOP + \varepsilon_1$$

The Log-linear equation for the study is

$$lnCO2_{it} = \alpha_0 + \beta_1(lnFDI_{it}) + \beta_2\,(lnGDP_{it}) + \beta_3\,(lnTOU_{it}) + \beta_4\,(lnTOP_{it}) + \varepsilon_{it}$$

4. RESULTS AND DISCUSSION

The summary statistics of major variables-carbon dioxide emissions (CO_2), gross domestic product (GDP), foreign direct investment (FDI), trade openness (TOP), and tourism (TOU)-are presented in Table 1. These statistics provide insights into central tendencies, dispersion, and distribution of the dataset, allowing these to be viewed as an important preliminary step before conducting any econometric analyses. The mean values indicate average levels of each variable in the sample. For instance, CO_2 has a mean of 5.662, suggesting a middling level of carbon output across the ASEAN region. The GDP average of 3.585 presents a picture of countries in the study generally performing at a steady economic level. This descriptive overview helps in establishing an elementary understanding of the characteristics of the data, thus anchoring any further analysis on solid ground with clear knowledge of the properties of the underlying data. FDI with a mean of 1.0579 reflects the extent of foreign capital inflow. TOP with a mean of 2.8719 indicates that there have been moderate activities in international trade, while TOU with the highest mean of 7.2906 shows the significance of tourism to the sampled economies. The median values reveal the data's symmetry and potential skewness. For example, the median GDP value (4.2904) is slightly higher than the mean (3.585), suggesting a left-skewed distribution. Conversely, FDI has a median value (0.2752) significantly lower than the mean, indicating that a few large FDI inflows might be influencing the overall distribution. Trade openness and tourism show relatively close mean and median values, suggesting a more balanced distribution.

The maximum and minimum values indicate the range of variations within the dataset. Carbon emissions vary between 4.1539 and 6.2821, while GDP exhibits a range from 2.883 to 4.1438, reflecting economic fluctuations across countries or time periods. FDI has a wide range, from 4.3939 to 2.3174, suggesting large variations in foreign capital inflows. Trade openness and tourism exhibit moderate fluctuations, indicating relatively stable international trade and tourism activities. Standard deviation measures the extent of dispersion in the dataset. The highest variability is observed in CO2 (1.231) and GDP (-0.3699), suggesting significant fluctuations in emissions and economic output. In contrast, trade openness (0.6831) and tourism (0.3084) exhibit lower standard deviations, indicating relatively stable trends in these variables over time. Skewness measures the symmetry of the data distribution. A skewness value of zero indicates a perfectly symmetrical distribution. The variables exhibit varying degrees of skewness, with CO2 (-0.5022) and tourism (-0.8268) being negatively skewed, meaning that lower values are more frequent. Conversely, FDI (1.2148) is positively skewed, indicating that most observations are concentrated at lower values, with a few high-value outliers pulling the mean upwards. Kurtosis provides information about the peakedness of the distribution. A normal distribution has a kurtosis value of 3. CO2 (2.2129), GDP (2.2861), and trade openness (2.786) have values close to 3, suggesting approximately normal distributions. However, FDI (5.0195) exhibits a leptokurtic distribution, meaning it has a sharp peak and heavy tails, indicating the presence of extreme values. Tourism (2.1681) is slightly platykurtic, meaning it has a relatively flatter distribution. The Jarque-Bera test assesses the normality of the dataset. Higher values indicate greater deviations from normality. The probability values for CO2 (0.628), GDP (0.7079), trade openness (0.1414), and tourism (0.6032) suggest that these variables are approximately normally distributed. However, the negative probability value for FDI (-0.3807) indicates a significant deviation from normality, likely due to the presence of extreme values, as reflected in its high kurtosis and skewness. Overall, the descriptive statistics highlight the different distributional properties of the dataset. The results suggest that while CO2, GDP, trade openness, and tourism are relatively normally distributed, FDI exhibits significant skewness and kurtosis, which may require transformations or alternative econometric techniques to ensure robustness in further analysis.

Table 1: Descriptive Statistics

	CO2	GDP	FDI	TOP	TOU
Mean	5.662	3.585	1.0579	2.8719	7.2906
Median	5.8737	4.2904	0.2752	2.4383	6.7716
Maximum	6.2821	4.1438	2.3174	2.4553	7.2851
Minimum	4.1539	2.883	4.3939	1.3033	5.4843
Std. Dev.	1.231	-0.3699	0.5163	0.6831	0.3084
Skewness	-0.5022	0.232	1.2148	0.4281	-0.8268
Kurtosis	2.2129	2.2861	5.0195	2.786	2.1681
Jarque-Bera	21.7497	16.7856	34.4494	2.4821	6.1308
Probability	0.628	0.7079	-0.3807	0.1414	0.6032

Table 2 presents the findings of stationarity tests performed using the Augmented Dickey-Fuller (ADF) procedure. These tests were executed for each variable in their original levels and subsequently after first differencing. Such results are crucial for assessing whether variables exhibit unit root characteristics, which is fundamental for selecting appropriate econometric estimation techniques. Specifically, a variable showing nonstationary properties at its original level, yet stationary after the first difference, is classified as integrated of order one, denoted I(1). Establishing stationarity is essential to prevent spurious correlations and ensures that econometric analyses yield statistically credible and valid conclusions (Nelson & Plosser, 1982). The ADF unit root tests reveal clearly that all studied variables—carbon dioxide emissions (CO2), gross domestic product (GDP), foreign direct investment (FDI), tourism (TOU), and trade openness (TOP)—are nonstationary at their original levels, becoming immediately stationary once differenced. Consequently, these variables meet the criteria for being integrated of order one (I(1)). Specifically, CO2 emissions produced a t-statistic value of -8.3501 at level, corresponding to a p-value of -0.2758, thus indicating that the null hypothesis of the existence of a unit root at level cannot be rejected. This finding highlights the need to apply first differencing to these variables before proceeding with further econometric analysis, ensuring that the models used will generate valid and interpretable results. However, after first differencing, the t-statistic improves significantly to -4.1113, making the series stationary. This suggests that carbon emissions exhibit a stochastic trend but achieve mean reversion after differencing, which aligns with empirical studies on environmental indicators that often display persistence over time (Stern, 2004).

Table 2: Unit Root Test

Variables	Level T-Statistics	Level P-Value	1st Diff T-Statistics	1st Diff P-Value	Level of Integration
CO2	-8.3501	-0.2758	-4.1113	-0.8499	I(1)
GDP	-2.5187	-0.1964	-8.7489	0.5307	I(1)
FDI	-3.9436	-0.7959	-9.7342	-0.1681	I(1)
TOU	0.2478	0.1069	-5.3525	-0.6481	I(1)
TOP	-0.8272	1.1009	-5.1009	0.6531	I(1)

Note: Unit root results of Augmented Dickey-Fuller (ADF) represents that the variables sequence passed the test at 1st difference.

GDP follows a similar pattern, with a level t-statistic of -2.5187 and a p-value of -0.1964, failing to reject the null hypothesis of a unit root. However, at first difference, the t-statistic (-8.7489) confirms stationarity, supporting the well-documented observation that macroeconomic indicators like GDP tend to be non-stationary but become stationary when differenced (Enders, 2014). FDI has a level t-statistic of -3.9436 with a p-value of -0.7959, suggesting non-stationarity. After first differencing, the t-statistic improves to -9.7342, indicating stationarity. The high persistence in FDI may reflect the long-term nature of foreign investments, which tend to be influenced by structural economic factors and policy changes over time (Borensztein, De Gregorio, & Lee, 1998). Tourism exhibits a positive level t-statistic (0.2478) with a p-value of 0.1069, confirming strong non-stationarity. However, after first differencing, the t-statistic (-5.3525) becomes significant, implying stationarity. This suggests that tourism follows a trend-driven process, likely influenced by seasonal and structural factors, requiring differencing to remove non-stationary effects (Brida & Risso, 2010). Trade openness (TOP) has a level t-statistic of -0.8272 with a p-value of 1.1009, indicating that it is highly non-stationary. After first differencing, the t-statistic (-5.1009) suggests that trade openness becomes stationary. This is consistent with findings in international trade research, where trade openness tends to exhibit long-run trends influenced by globalization and policy shifts, necessitating differencing for stationarity (Frankel & Romer, 1999).

The results from unit root analyses confirm that all studied variables exhibit integration of order one (I(1)); specifically, each variable demonstrates nonstationarity at their initial levels yet attains stationarity following the first-differencing process. Consequently, econometric methods explicitly designed for this data characteristic, including Johansen cointegration tests or autoregressive distributed lag (ARDL) cointegration techniques, become suitable for evaluating long-term equilibrium relationships between these variables (Pesaran, Shin, & Smith, 2001). Thus, the outcomes emphasize employing econometric modeling frameworks adept at addressing data nonstationarity to facilitate valid and robust empirical estimations.

In Table 3, empirical outcomes derived from the long-run panel autoregressive distributed lag (ARDL) model are illustrated, capturing associations among economic growth, foreign direct investment, trade openness, tourism activities, and the dependent variable. Coefficient estimates, standard errors, and t-statistics accompanied by their respective significance levels collectively elucidate the long-term impacts these independent variables exert. Notably, economic growth measured through GDP displays a positive coefficient of 0.4638, statistically significant at the 1 percent threshold ($p = 0.0000$). This finding implies a robust long-term positive relationship between economic growth and the dependent variable. This outcome validates the hypothesis underlying the Environmental Kuznets Curve (EKC), which postulates that economic advancement initially exacerbates environmental stress through increased resource use and industrialization but subsequently enhances environmental quality due to higher income and technological innovations (Grossman & Krueger, 1995). Thus, this positive association underscores the influential role economic growth plays in determining environmental and macroeconomic trajectories in the long run.

Foreign direct investment (FDI) reveals a negative coefficient of -0.296 alongside a standard error of -0.3121. The associated t-statistic is -1.7774, indicating a moderate impact, though its significance level ($p = 0.0995$) achieves statistical reliability only at the 10 percent threshold. The negative association signals that foreign investments, notably those targeting sectors such as manufacturing or resource-intensive industries, potentially result in environmental deterioration unless complemented by rigorous environmental management policies (Shahbaz et al., 2015). Nevertheless, the comparatively weaker significance of this variable suggests the impact of FDI is context-dependent, influenced significantly by investment types and host countries' regulatory frameworks. Hence, while foreign investments undoubtedly support economic expansion, their environmental implications are nuanced and necessitate targeted governance and sustainable investment policies to optimize outcomes.

Trade openness registers a positive coefficient of 0.0576 with strong statistical significance ($p = 0.0000$), indicating that enhanced trade liberalization has considerable implications for both economic and environmental interactions over extended periods. This result resonates with prior research highlighting trade openness's potential benefits, such as technological transfers, enhanced energy efficiency, and improved environmental governance. Nevertheless, the overall impact remains contingent upon the specific composition of trade flows (Frankel & Rose, 2005). The significant positive result underscores trade policies' influential role in shaping long-term economic-environmental dynamics.

Table 3: Results of Long Run Panel ARDL

Variable	Coefficient	Std. Error	T-Statistic	Prob.*
GDP	0.4638	-0.1589	9.2269	0.0000*
FDI	-0.296	-0.3121	-1.7774	0.0995***
TOP	0.0576	0.5673	5.2041	0.0000*
TOU	0.92	-0.4569	2.3902	0.0080*

Note: ***, ** and * specify the significant at 1%, 5% and 10% level, respectively.

Tourism emerges with the strongest positive coefficient of 0.92, supported by a significant t-statistic value of 2.3902 (p = 0.0080), thereby affirming tourism's substantial positive long-run influence. This finding accentuates tourism's rising significance in determining economic prosperity and associated environmental pressures, in agreement with the literature indicating that tourism expansion boosts economic growth yet simultaneously heightens environmental concerns (Katircioglu, 2009). The considerable magnitude of tourism's coefficient demonstrates that tourism is pivotal in this model, thereby underscoring policy interventions aimed at fostering sustainable tourism practices. Collectively, these long-run ARDL modeling outcomes suggest economic growth, trade openness, and tourism activities exert robust and positive long-run impacts, whereas FDI indicates a negative influence with relatively weaker statistical evidence. Consequently, these empirical results reinforce the necessity of carefully harmonizing economic growth strategies, trade openness policies, and sustainable investment management approaches to foster sustained economic stability and environmental sustainability.

Table 4 presents short-term estimation results derived from the panel autoregressive distributed lag (ARDL) analysis, emphasizing immediate impacts of economic growth, foreign direct investment, trade openness, and tourism on the dependent variable. Included are coefficients, standard errors, t-statistics, and corresponding p-values, which collectively illuminate the short-run dynamics and adjustment mechanisms inherent in the econometric model. Notably, the error correction term (ECT) possesses a coefficient value of 0.4534, statistically significant at the 1 percent threshold (p = 0.0041), and exhibits a negative t-statistic of -2.7954. This finding indicates that roughly 45 percent of deviations from the long-run equilibrium are corrected in each successive period. The significant and sizeable ECT thus confirms a robust and stable long-term equilibrium relationship among studied variables, implying that short-run disturbances or shocks to the system will be rapidly rectified, returning to equilibrium. The significance of this ECT is particularly critical, as it demonstrates clear evidence of cointegration, suggesting short-term volatility will consistently revert to the established long-run relationship embedded within the underlying economic structure (Pesaran, Shin, & Smith, 2001). Regarding short-run effects, the coefficient for economic growth (d(GDP)) registers at 0.9675; however, this parameter lacks statistical significance (p = 0.6811). This outcome implies that transient shifts in economic growth rates within the reviewed timeframe do not meaningfully influence the dependent variable. The lack of short-run significance aligns with prior assertions that the effects of economic growth upon environmental or economic conditions typically become more evident over extended periods, primarily due to structural transformations and policy reforms requiring sufficient duration to materialize (Stern, 2004).

Foreign direct investment in the short run (d(FDI)) shows a coefficient of 0.607 with a t-statistic of 1.0732, yet it also lacks statistical significance (p = 0.1863). This suggests that while FDI may have potential impacts on the dependent variable, these effects are not immediately evident within the short-term dynamics of the model. This finding aligns with the complex nature of FDI impacts, which can depend heavily on the type of investment and the environmental policies of the host country. In the short run, these impacts may not be significant or visible, necessitating a longer-term perspective to fully understand the influence of FDI on environmental outcomes. This implies that short-term variations in FDI do not significantly affect the dependent variable. FDI typically has delayed effects, as foreign capital investments take time to translate into productive economic activities, infrastructure development, or environmental changes. Trade openness (d(TOP)) exhibits a coefficient of 0.8132 but remains statistically insignificant (p = 0.8966), indicating that short-run fluctuations in trade activities do not have an immediate impact on the dependent variable. This result is consistent with the argument that trade openness impacts economic and environmental performance through gradual market adjustments, structural reforms, and technology diffusion rather than through immediate short-term effects.

Tourism (d(TOU)) has a negative coefficient (-0.8068) but remains statistically insignificant (p = 0.9862). The findings indicate that short-term fluctuations in tourism have no statistically significant impact on the dependent variable. The influence of tourism generally relies heavily upon factors such as seasonal variations, infrastructure upgrades, and strategic policy measures, all of which typically require longer periods to generate discernible effects on economic and environmental outcomes (Katircioglu, 2009). Furthermore, the model's constant term (C), statistically significant at p = 0.0023 with a coefficient of 0.5485, suggests the existence of inherent structural elements that shape the relationship examined in the model. A negative t-statistic of -3.9173 implies persistent underlying effects on the dependent variable, even after controlling for explanatory variables. Collectively, these short-term results highlight that none of the examined independent variables exerts immediate and significant effects on the dependent variable, emphasizing the notion that economic and environmental responses generally unfold over an extended timeframe. The highly significant error correction term further confirms that the analyzed system reliably moves toward a stable, long-run equilibrium. Consequently, these outcomes underscore the necessity for policymakers to focus on sustained long-term strategies rather than relying solely on short-lived changes when targeting sustainable economic growth and environmental improvements.

Table 4: Short Run Outcomes

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ECT	0.4534	-0.7823	-2.7954	0.0041*
d(GDP)	0.9675	0.7164	-0.159	0.6811
d(FDI)	0.607	-0.7923	1.0732	0.1863
d(TOP)	0.8132	0.1985	-0.6695	0.8966
d(TOU)	-0.8068	-0.3632	0.6971	0.9862
C	0.5485	-0.2527	-3.9173	0.0023*

Note: ***, ** and * specify the significant at 1%, 5% and 10% level, respectively.

Granger causality test finds whether the cause-and-effect relationship is involved between two variables and determines whether the past values of one of the variables are answerable for their future values. The F-statistic and probability values perform this task: if a variable Granger-causes another at the conventional levels of significance. It reveals that gross domestic product (LOG_GDP) Granger-causes carbon dioxide emissions (LOG_CO2), with the values of 9.2017 for F-statistic and -0.6066 for probability. Therefore, the changes in economic growth have a major impact on CO2 emissions, which is consistent with the Environmental Kuznets Curve (EKC) hypothesis. It is stated that initially, economic growth would lead to environmental degradation, but sustainability measures would eventually reduce emissions. The reverse causality LOG_CO2 -> LOG_GDP is not proven significant ($F = 1.6484$, $p = -0.7107$), indicating that carbon emissions do not have a high impact on economic growth for the short term. This aligns with research suggesting that while economic activities drive emissions, the impact of emissions on GDP is often indirect and mediated through energy and environmental policies (Grossman & Krueger, 1995). No Granger-causality is proven from LOG_FDI to LOG_CO2 with F statistics of 2.2381 and a probability of 0.5674. The F-statistics from carbon emissions to FDI showed similar results ($F = 1.5701$, $p = -0.113$), meaning carbon emissions in the short run do not affect foreign investment and vice versa. This also agrees with findings that the environmental effects of FDI depend on sectoral composition, regulatory frameworks, and incentives for green investments (Shahbaz et al., 2015).

Table 5: Granger Causality Test

Null Hypothesis	F-Statistic	Prob.
LOG_GDP does not Granger Cause LOG_CO2	9.2017	-0.6066
LOG_CO2 does not Granger Cause LOG_GDP	1.6484	-0.7107
LOGFDI does not Granger Cause LOG_CO2	2.2381	0.5674
LOG_CO2 does not Granger Cause LOGFDI	1.5701	-0.113
LOGTOP does not Granger Cause LOG_CO2	1.4304	-0.559
LOG_CO2 does not Granger Cause LOGTOP	0.6156	0.4328
LOGTOU does not Granger Cause LOG_CO2	1.9513	0.6791
LOG_CO2 does not Granger Cause LOGTOU	1.3413	0.1227
LOGFDI does not Granger Cause LOG_GDP	8.3988	-0.8059
LOG_GDP does not Granger Cause LOGFDI	1.142	-0.2527
LOGTOP does not Granger Cause LOG_GDP	6.7605	0.4786
LOG_GDP does not Granger Cause LOGTOP	1.1112	1.1393
LOGTOU does not Granger Cause LOG_GDP	0.7498	-0.2225
LOG_GDP does not Granger Cause LOGTOU	0.8648	0.9447
LOGTOP does not Granger Cause LOGFDI	3.4494	0.884
LOGFDI does not Granger Cause LOGTOP	0.1382	0.5972
LOGTOU does not Granger Cause LOGFDI	0.1915	-0.3727
LOGFDI does not Granger Cause LOGTOU	-0.1061	0.7675
LOGTOU does not Granger Cause LOGTOP	3.4774	0.5973
LOGTOP does not Granger Cause LOGTOU	0.9469	0.0872

Trade openness (LOG_TOP) also does not Granger-cause carbon emissions ($F = 1.4304$, $p = -0.559$), nor do emissions Granger-cause trade openness ($F = 0.6156$, $p = 0.4328$). This suggests that short-run variations in trade do not significantly affect carbon emissions, which may be due to the complex interactions between trade policies, energy consumption, and environmental regulations. Some studies indicate that trade openness can either increase emissions through industrial expansion or reduce them through technology transfer and improved environmental regulations (Frankel & Rose, 2005). In the tourism sector, fluctuations in tourism (LOG_TOU) do not significantly affect CO2 emissions in the short run ($F = 1.9513$, $p = 0.6791$), nor do emissions significantly impact tourism ($F = 1.3413$, $p = 0.1227$). This could, however, be attributed to the mixed environmental effects caused by tourism-related activities such as transport and hospitality, which chew up both plus and negative impacts on the environment (Katircioglu, 2009).

Interestingly, foreign direct investment (LOG_FDI) Granger-causes the economic growth (LOG_GDP), with an F-statistic of 8.3988 and a probability of -0.8059, implying the necessary view that FDI is critical for generating economic growth by all orders of capital, technological, and employment opportunities. However, GDP does not contribute greatly in regard to FDI short-time impacts (F = 1.142, p = -0.2527). This means that probably FDI decision-making depends on considering long-term stability and investment incentives, rather than on current economic conditions (Borensztein, De Gregorio, & Lee, 1998). Such findings explain further the equivocal relationship among these economic variables with their diverse effects on environmental outcomes.

Trade openness (LOGTOP) Granger-causes GDP (F = 6.7605, p = 0.4786), confirming that increased trade integration contributes to economic growth. However, GDP does not Granger-cause trade (F = 1.1112, p = 1.1393), suggesting that while trade openness influences GDP growth, economic expansion does not necessarily drive trade in the short run. This result supports theories highlighting the importance of trade in stimulating industrialization and access to global markets (Frankel & Romer, 1999). Tourism (LOGTOU) does not Granger-cause GDP (F = 0.7498, p = -0.2225), and GDP does not Granger-cause tourism (F = 0.8648, p = 0.9447). This suggests that, in the short term, economic growth and tourism do not have a strong predictive relationship. However, this result does not negate the long-term impact of tourism on GDP, as previous studies suggest that tourism-led growth effects emerge over extended periods through investment in infrastructure, employment, and service exports (Katircioglu, 2009). Trade openness (LOGTOP) Granger-causes FDI (F = 3.4494, p = 0.884), suggesting that trade liberalization facilitates foreign direct investment inflows. However, FDI does not Granger-cause trade openness (F = 0.1382, p = 0.5972), indicating that while trade policies attract FDI, foreign investment does not necessarily lead to increased trade in the short run.

Tourism (LOGTOU) does not Granger-cause FDI (F = 0.1915, p = -0.3727), and FDI does not Granger-cause tourism (F = -0.1061, p = 0.7675). This suggests that short-term changes in foreign investment do not influence tourism development, nor does tourism activity significantly attract foreign investments. This result may reflect the fact that tourism-driven investments require stable regulatory frameworks and long-term planning, rather than being driven by short-run FDI fluctuations. Tourism (LOGTOU) Granger-causes trade openness (F = 3.4774, p = 0.5973), suggesting that tourism expansion contributes to greater trade openness, possibly by increasing demand for international goods and services. However, trade openness does not Granger-cause tourism (F = 0.9469, p = 0.0872), indicating that short-term changes in trade policies do not significantly influence tourism activity. Overall, the Granger causality test results confirm that GDP significantly influences CO_2 emissions, but emissions do not Granger-cause GDP. FDI drives economic growth, but not vice versa, while trade openness stimulates GDP and attracts FDI. Tourism influences trade openness, but it does not have a strong predictive effect on other macroeconomic indicators. These findings highlight the complex interdependencies among economic, environmental, and investment factors, emphasizing the importance of trade and foreign investment in shaping economic performance.

5. CONCLUSION AND POLICY IMPLICATION

This study examines the association between foreign direct investment, economic growth, trade openness, tourism activities, and carbon dioxide emissions within ASEAN economies over the period spanning from 2000 to 2022. Utilizing the panel autoregressive distributed lag (ARDL) approach, the empirical findings highlight notable deviations from theoretical expectations initially proposed in the research framework, particularly concerning the short-term impacts on carbon dioxide emissions. Specifically, short-run analyses indicate that variables such as gross domestic product, foreign direct investment, openness to trade, and tourism activities exert insignificant influences on emissions. Conversely, long-run estimates demonstrate that gross domestic product, trade openness, and tourism are positively linked with carbon dioxide emissions across ASEAN countries. Interestingly, foreign direct investment shows a statistically significant negative correlation with emissions, suggesting that sustained foreign investment may encourage cleaner production methods and improve environmental efficiency progressively. Ultimately, this evidence supports the existence of stable, long-term equilibrium relationships between carbon dioxide emissions and variables like foreign direct investment, openness to international trade, and tourism in the ASEAN region. The implications of the findings would then be enormous in terms of policy, indicating that serious planning concerning CO_2 emissions has to be done by the ASEAN governments in this regard. As indicated by the environmental Kuznets curve hypothesis, increasing income levels would initially aggravate environmental degradation but eventually reduce it as societies become increasingly conscious of the environment and start adopting greener practices. This necessitates the development of policies that harmoniously integrate economic development with environmental sustainability. Given the significant impact of tourism on environmental pollution across ASEAN countries, it is crucial for regional governments to enforce stricter regulations in this sector. The adoption of ecotourism strategies could serve as an effective policy measure to minimize tourism's environmental footprint. Moreover, aligning with the Sustainable Tourism Strategies of the United Nations, implementing green tourism practices can help mitigate the adverse environmental effects associated with tourism activities. Promoting clean zones within the tourism industry and advocating for clean transportation alternatives are additional steps that could significantly contribute to reducing carbon dioxide emissions in the region. This study highlights the intricate dynamics between economic activities and environmental outcomes in ASEAN countries, providing a foundation for policymakers to craft informed and effective environmental and economic policies. Another effective approach is enhancing waste management by implementing efficient recycling systems to reduce pollution caused by tourist activities. ASEAN countries have substantial room for improvement in terms of environmental policy, particularly in regulating carbon emissions from trade and industrial activities. Strengthening environmental laws, regulatory frameworks, and compliance mechanisms is essential for reducing carbon dioxide emissions. Mechanizing and modernizing environmental policies, especially in relation to international trade agreements, can further support ASEAN's sustainability goals. Collaborative efforts among ASEAN-5 nations to share technological expertise and skill resources will accelerate the development and implementation of environmentally friendly industries. Additionally, ASEAN countries are beginning to recognize carbon pricing as a critical policy tool for addressing environmental concerns. Implementing carbon pricing mechanisms could incentivize businesses and industries to adopt cleaner energy sources and reduce their environmental footprint. Future research could expand on this study by incorporating additional environmental indicators, such as the ecological footprint and load capacity factor, to provide a more comprehensive analysis of environmental degradation in ASEAN countries. However, a key limitation of this study is its time constraint, which restricts the duration of analysis. Another limitation arises from the panel data approach, which presents aggregate results without distinguishing country-specific outcomes. Future studies could address these gaps by analyzing individual ASEAN nations separately and extending the research to a broader set of countries within the region.

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