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How Does Tourism, Trade Openness and Green Energy Influence CO2 emissions? Evidence from ASEAN Countries

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Abstract
This study explores the effects of Tourism (TOU), Gross Domestic Product (GDP), Foreign Direct Investment (FDI) and Trade Openness (TOP) upon carbon di oxide emissions (CO_2). The article has taken top seven tourist destinations in ASEAN (Association of Southeast Asian Nations) through 2000-2020. The approaches used to analyze results are autoregressive distributed lag (ARDL) and secondly the Granger causality technique. The data is panel data; hence we can also say it is panel ARDL. The outcomes exhibited an interesting relationship between the variables under study. Where, GDP, TOP and TOU were significantly and positively correlated with CO_2. Whereas FDI showed huge and negative correlation with CO_2. The results of the study showed that in the long run there is a significant association between FDI, TOP and TOU and carbon emissions. The study findings are thoroughly examined, accompanied by analysis of policy implications and recommendations for future research.
Keywords: ARDL estimation, Granger Causality, Carbon emissions, tourism, FDI, GDP and trade-openness

1. Introduction

Today Global Warming is not the primary concern as it was considered in previous century, regardless of the fact of continental drift. The drift happened about 4.5 billion years ago and moved the tectonic plates which brought many geographical changes on the face of globe. Koeberl (2006); (Pata et al., 2023); (Huang et al., 2024). The present-day challenges the world is facing are rising inequality, uncontrolled resource consumption, and environmental degradation. Altogether the above mentioned factors can lead to rampant situations. Such as the average global temperature could rise by 3°C. In such situation a strong integrated global systematic plan of action is need of the hour. Otherwise it would have an impact on all the ecosystems, leading to an increase in collapses such as drought, food shortages, Decreased agricultural output and the Quick dissolution of glaciers and ice caps. This would have an beyond repair (Mongo et al., 2021; Wei & Lihua, 2023). Masses think that human activities aggregate emissions of hazardous gases, such as CO_2. Also, CO_2 is mostly blamed for the rise in global temperatures that is harming both natural and human ecosystems (Wei & Lihua, 2023; Song et al., 2024).

Tourism has become one of the most fundamental component of the global economy. Also this sector i.e. tourism is burgeoning at fast pace. It has close ties with climate and environment Ben Jebli and Hadhri (2018). In order to cater the needs of these tourist electricity is required for transport and recreational activities. Most part of the provided electricity is produced by nonrenewable (fossil fuels). Such production of electricity not only degrade the natural fossils which takes millions of years by decomposition of plants and animals but are also high in CO_2. Coal, oil and/or natural gas is used As tourism sector itself is developing, hence most of the times lack of infrastructure inadequate logistics become a necessity to burn fossil fuels. Which in return causes high threats to environment. Each of these things increases emissions of CO2 Huang et al. (2020); (Huang et al., 2021; Wang & Wu, 2022). Tourism adds a significant amount in economic growth. Thus making it possible for countries to bring more advancement(s) through urban development and industrial expansion. The correlation between tourism, global warming, and environmental pollution is significant Akadiri et al. (2020); (Pata et al., 2023; Awan et al., 2023). Most of the activities related to tourism have negative impact on environment; which includes accommodation and transportation. Ehsanullah et al. (2021); (Li et al., 2022; Wang & Wu, 2022). Hence, tourism must be managed, if not it can be baneful. As, it has the potential to severely harm the environment and have catastrophic long-term economic impact Wang and Wang (2018); (Wei & Lihua, 2023; Shahzadi et al., 2023).

Domestic savings levels can lead to investments, if the savings are insufficient to cater the required investment Foreign Direct Investment (FDI) becomes an indicator of economy's ability to grow and develop (Abdul-Mumuni et al. 2023; Ullah et al., 2023). When foreign direct investment FDI creeps into an economy the results are manifold. As long as it is economically beneficial for the host country it may have negative impacts on the environment as well. Zhu et al. (2016). In an economy which has taken boom due to Foreign Direct Investment (FDI), environmental concerns might have been compromised. In such scenario the cost of economic boom might have been really high; i.e. high carbon emissions causing environmental degradation through depletion of natural and human resources.

Hence, it can be assumed that in long run, Foreign Direct Investment (FDI) led economies are not just a cause of environmental conservation, in fact practical decisions and actions must be taken. As the high Carbon emissions have the potential to offset any economic benefits that would have resulted from Foreign Direct Investment (FDI) inflows Zahra et al. (2023). Therefore, when thinking about the environmental impacts of a Foreign Direct Investment led economic boom, it can be reason of concern Shahbaz et al. (2018). The connection between carbon emissions and Foreign Direct Investment has been the subject of numerous real facts and figures (Chang, 2015; Gao et al., 2022); Koçak and Şarkgüneşi (2018); (Minh, 2020; Ochoa-Moreno et al., 2021; Ren et al., 2021; Tabassum et al., 2023). Theoretically, this could be because of circumstances, comprising of two key components i.e. polluting industries and stringent environmental regulations. The Pollution Heaven Hypothesis (PHH) claims that lenient environmental regulations in a host nation may draw multinational corporations to invest more and more FDI, to increase output resulting in release carbon dioxide emissions and other externalities (Abdul-Mumuni et al., 2023); Huang et al. (2022).

The bifold challenges of responsible environment conservation and fostering economic growth are becoming more difficult to cope for nations. In our study of ASEAN countries this is unquestionably the exact case. Ninty percent (90%) of regional energy needs for commercial use are met by Fossil fuel combustion, as Lean and Smyth (2010), and Munir et al. (2020), discuss. The vertical growth in these economies is mostly led by fossil high energy consumption. It might be an important factor in greenhouse gas emissions leading to a threatening.

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Concern has been expressed that these nations' explosive growth, which has been fueled by high energy consumption rates, could contribute to greenhouse gas emissions and the consequent effects of climate change (ASEAN Centre for Energy, 2015). As per The World Bank predication made in 2016: by the year 2060 there would be further 6-9 million additional deaths. The financial cost of these deaths shall be equal to 1% of world's total GDP Javaid et al. (2023). The matter of concern is that 92% of these deaths would be in emerging and poor nations. The countries with poor planning can pollution related develop illnesses. As a result the productivity of workforce is affected in both production and services sector. This can cause a reduction of 2% of county's annual GDP Landrigan et al. (2018). The effects of rising environmental pollution and co2 emissions can worsen the situation Beck and Mahony (2018); (Liu et al., 2023). A casual attitude towards the environmental checks can up bring serious problems. If such situations sustain for Long-term, development is vulnerable by unchecked environmental contamination, this is why the studies examining the relationship between ecological degradation and GDP per capita have gained fame and attention Bakhsh et al. (2017). In addition, the GDP per capita of each nation is the main objective. The environmental effects of advanced economies are a constant source of concern (Awan & Azam, 2022); Raworth (2017).

According to a research by Oktavilia and Firmansyah (2016), Indonesia's trade openness increased the nations CO2 emissions between 1976 and 2014. As a result of which foreign demand and international trade got boost. It can be well explained by the two hypothesis: The race-to-the-bottom hypothesis: this one says that the country compromise on environmental factors over economic gains from trade openness Zhao et al. (2023). On the other hand gain from trade hypothesis emphasizes the benefits of trade for environmental quality (Ibrahim & Rizvi, 2015). Furthermore, international commercial openness will have both beneficial and bad effects on the environment, according to Managi (2004). The three aspects of an impact that can be broken down are composition, technique, and scale effects. An increase in income is seen when trade led development occurs. The reason for this is that trade entails import and export which necessitates the computation of exchange rates for costs and other factors Rahman et al. (2022). The United Nations Framework Convention to Climate Change and 26th Conference of the Parties (COP26) adopted the Glass-Grow climate convention on November 13, 2021, requiring nations to uphold the Paris Agreement and keep that when global temperatures increase to 1.5°C, three main factors—scale, technique, and composition contribute to the impacts observed. With trade-led development, there is a noticeable rise in income due to the nature of trade, which necessitates calculations involving exchange rates and pricing. As a result, nations all around the world have established targets for being carbon neutral. Hence researchers are now concentrating on the connection between trade and the decrease of carbon emissions (Wang et al., 2023; Wiedmann & Lenzen, 2018; Yang et al., 2020).

First, utilizing the most recent econometric techniques, the current study investigates the effect of GDP, TOU, TOP and FDI on CO2 emissions. Second, this research uses the most recent econometric methodology, namely panel ARDL methods, in contrast to earlier studies that used antiquated techniques. Considering both symmetry and asymmetry, the panel ARDL approaches appear appropriate for researching the effect of GDP, FDI, TOU and TOP on CO2 emissions in ASEAN Countries. Thirdly, using the most recent data, this study investigates how these variables affect CO2 emissions. Finally, the findings have significant policy ramifications for ASEAN nations dealing with severe pollution and environmental difficulties. This paper is further broken into four section: the "Literature Review" section summarizes earlier studies on the subject and assesses the literature review that is relevant to this study. The "Data and Methodology" section contains an introduction to the data and methodology. The results are shown in the "Results" section, while the discussion and "Policy Implications" part. This paper's "Conclusion" section offers a summary of the findings and information for the research.

2. Literature Review

2.1. Nexus Between Tourism and CO_2

The relationship between tourism and environment has become a vital area of study. According to Bekun et al. (2022), the demand for tourism raises CO2 emissions in developing industrialized nations. Applying the DOLS, FMOLS and CCR method to Brazilian data collected between 1990 to 2019 Khoula et al. (2022). A contentious topic is how tourism effect pollution. While some academics stress that tourism worsens pollution and the state of the environment Selvanathan et al. (2021), Wei and Lihua (2023) . According to Tiwari et al. (2013), OECD countries environmental benefit from tourism. In the panel 34 countries, the results of (Abbasi et al., 2021; Ozturk, 2016) confirmed long-term association between the environment and tourist factors. The study examines the connections between Turkey's tourism, economic growth and CO2 emissions between 1960 to 2014 Dawood et al. (2023). The findings demonstrate that energy use, growth and tourism all have a positive effect on CO2 emissions. They also support long-term travel, which demonstrates the environmental consciousness of travelers by Eyuboglu and Uzar (2020). According to Katircioglu et al. (2014), in Cyprus, a small island that welcomes more than 2 million visitors a year, the study investigates that long-term equilibrium link among the consumption of energy, international tourism and CO2 emissions. The findings indicate that tourism and CO2 emissions are positively impacted in a statistically significant, inelastic way, which has an adverse effect on climate change. According to the error correction models, CO2 emissions via tourism channels, carbon dioxide emissions increase, gradually converging to their long-term equilibrium route at a rate of 95.4% annually.

2.2. Nexus Between FDI and CO_2

The literature presents conflicting empirical findings about connection among foreign direct investment and environmental damage. The link among foreign direct investment and CO2 emissions is U-shaped (Chenran et al., 2019); Christoforidis and Katrakilidis (2021); (Shahbaz et al., 2019). According to U-shaped relationship between FDI and CO2, first CO2 rises the expected inflow of FDI, and then it starts to decline after FDI reaches a particular threshold. There has been evidence of FDI detrimental impact on CO2 emissions in Vietnam (Chenran et al., 2019). According to (Shahbaz et al., 2019), FDI raises CO2 emissions both initially and beyond a specific threshold. There are two ways that foreign direct investment might fuel the growth pollution nexus. First, FDI may results in higher national output, which rises pollution levels and suggests the PHH validity. Second, FDI makes it possible to employ more efficient production technology, which reduces pollution (Lau et al., 2014). Different studies on the connection between FDI and the environment are not entirely in agreement. While some studies, like Rahaman et al. (2022), contend that foreign direct investment exacerbates environmental deterioration and supports the PHH hypothesis, Zhang et al. (2022), make the opposite claim. This study by Haug and Ucal (2019), using the NARDL approach, investigates the effect of FDI, foreign trade on CO2 emissions per person. FDI, however, has no appreciable long-term effects. Over time, export declines lower emissions, but export increases have no appreciable impact. This research Zhang and Zhou (2016), looks at geographical variations in the association among China's emissions of CO2 and FDI. The findings demonstrate

that FDI helps reduce emissions, with a decline from western to eastern and central location. This corroborated by the pollution halo theory Shahid et al. (2024).

2.3. Nexus Between GDP and CO_2

The average global annual rate of reduction in CO2 emissions intensity of GDP must higher than 3% in order to maintain global warming at 2°C. As a result, global CO2 emissions should peak as soon as feasible and then start to fall while the world GDP grows at a rate of about 3% annually. By about 2030, the global CO2 emissions intensity of GDP must fall by more than 4% on average year in order to allow overall CO2 emissions to continue to decline. The global GDP CO2 intensity should continue to decline after 2030 at a quicker pace, reaching 6%-7% or more, in order to ensure global economic growth while maintaining temperature below 2°C He et al. (2018). Alper and Onur (2016), investigated the connection between China's GDP growth and emissions from 1977 to 2013. The discovered The Environmental Kuznets Curve (EKC) failed to adequately explain China's total CO2 emissions by using the FMOLS approach. Barış-Tüzemen et al. (2020), examined Researchers examined the correlation between GDP growth and pollution to ascertain Turkey's N-shaped Kuznets curve from 1980 to 2017. They confirmed the absence of evidence supporting an N-shaped Environmental Kuznets Curve (EKC) in Turkey through quantile regression and ARDL techniques. Magazzino (2016), operating annual data ranging from 1960-2013, the study investigates the association among CO2 emissions, real GDP and energy use in six Gulf Cooperation Council nations. The findings indicate unit roots and a distinct long-run association that is unique to Oman. Granger causality research demonstrates that in Kuwait, Oman and Qatar, real GDP is driven by energy use Zulfiqar et al. (2022). The objective of this study by Marjanović et al. (2016), is to create and implement an Extreme Learning Machine (ELM) that forecasts GDP by utilizing CO2 emissions. Artificial neural networks and genetic programming are used to compare the outcomes. The computational models are shown to be reliable, the coefficients of determination for the ANN, GP and ELM techniques are 0.4475, 0.8756, and 0.9271, respectively.

2.4. Nexus Between Top and CO_2

A substantial and expanding body of research has examined the relationship among CO2 emissions and trade openness since the early 1990s, when trade openness began to rapidly develop and environmental problems began to deteriorate. First off, a number of research show that trade openness and CO2 emissions have a favorable connection. Empirically, Shahzad et al. (2017), proposed that the elasticity is 0.247% in the long-run and 0.122% in the short-run, using Pakistan as an example. Nevertheless, It has been found that over the long term, this positive relationship becomes linear when incorporating square and cubic terms of trade openness, but in the short-run it seems to have a non-linear cubic form Oktavilia and Firmansyah (2016). Moreover, trade openness and CO2 emissions have long-term positive feedback relationship as well as a one way causal link, in other words, they are each other's Granger causes Al-Mulali and Sheau-Ting (2014). Furthermore, other variables like wealth and economic growth also have an impact on the relationship among CO2 emissions and trade openness (Chen et al., 2021). This research by Zhang et al. (2017), investigates the potential influence of the environmental Kuznets curve (EKC) on emissions of carbon dioxide in ten recently developed nations between 1971 and 2013 Rahman et al. (2019). The results showed that real GDP and energy have a beneficial effect on emissions of carbon, whereas trade openness has a negative impact. The study suggests that in order to lower CO2 emissions and promote growth, policymakers should support trade openness. Mutascu (2018), using wavelet methods, the research investigates the association among the emission of carbon dioxide and trade openness in France from 1960 to 2013. The neutral hypothesis is confirmed by the results, which indicate no discernible movement between trade openness and gas emissions. In contrast, CO2 emissions have a medium-frequency positive impact on trade openness, indicating that robust environmental regulations promote global trade.

3. Methodology

This research study analyzes the effect of Tourism, FDI, Gross domestic product, trade openness and on carbon emissions in the case of ASEAN region (Brunei Darussalam, Thailand, Vietnam, Singapore, Philippines, Malaysia, and Indonesia) for 2000-2022. The data from these nations has been gathered from the database of IMF and World Development Indicators managed by the World Bank 2020. The Co_2 Emission is measured in (Kt), FDI, net inflows (% of GDP), Tourism in (number of arrivals), GDP per capita (constant 2015 US$) and Trade-openness in (the imports of services and goods (% of GDP), and the exports of services and goods (as % of GDP), moreover all variables are descripted in logarithm form. The study presents the descriptions, measurements, and data sources of the variables utilized in Table 1.

Table 1: Description of Variables and Data Sources

Variables	Description	Measurement Unit	Data Sources
CO_2	Carbon Dioxide Emissions	Kilotons (kt)	WDI
FDI	Foreign Direct Investment	Per Worker in Constant 2015 US$	IMF
GDP	Gross Domestic Products	GDP Per Capita (Constant 2015 US$)	WDI
TOU	International Tourism	Number of Arrivals	WDI
TOP	Trade-Openness	Imports and Exports of Goods & Services (% of GDP)	WDI

3.1. Econometric Model

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

Table 2: Descriptive Statistics

	CO2	GDP	FDI	TOP	TOU
Mean	4.9851	3.8583	0.8734	2.0792	6.8221
Median	5.1433	3.7068	0.8323	2.0822	6.8792
Maximum	5.7819	4.8284	1.5616	2.6408	7.6816
Minimum	3.6646	3.07332	3.8611	1.5181	5.8857
Std. Dev.	0.5700	0.5180	0.2498	0.2649	0.4563
Skewness	-0.9092	0.5060	0.7359	0.2604	-0.4111
kurtosis	2.8775	1.8226	4.7079	2.6331	2.4799
Jarque-Bera	22.283	16.169	34.1031	2.7233	6.3508
probability	0.0000	0.0003	0.0000	0.2562	0.0417

Table 2 denoted the variables descriptive statistics. The mean value of emission of CO2 is 4.9851, with 5.7819 and 3.6646 being the minimum and maximum values along with standard deviation of CO2 emissions is 0.5700 and the average value of GDP, FDI, TOP and TOU is 3.8583, 0.8734, 2.079287 and 6.8221.

The outcome of the unit root test is labeled in Table 3, which revealed a mixture of I (0) And I (1) results, while maximum series become stationary after taking first difference.

Table 3: Unit Root Test

Variables	Level		1st Difference		Level of Integration
	T-Statistics	P-Value	T-Statistics	P-Value	
CO2	-8.5608	0.6144	-4.6382	0.0000*	I(1)
GDP	-2.1500	0.0158	-7.9626	0.0000*	I(1)
FDI	-4.6542	0.0000	-8.8368	0.0000*	I(1)
TOU	0.7451	0.7719	-5.0906	0.0000*	I(1)
TOP	-0.6972	0.2428	-4.9511	0.0000*	I(1)

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

Initially, standard tests are conducted to assess data stationarity both at level and first difference using the augmented Dickey-Fuller (ADF) test (Dickey & Fuller, 1979). For the application of the ARDL bounds test, all variables must exhibit stationarity at either level I (0) or first difference I (1). Hence, the ARDL technique is selected as the most suitable model due to its unbiased nature and superiority over other models for small sample sizes. The null hypothesis of the ADF unit root tests (Dickey & Fuller, 1979) posits the presence of a unit root, while the alternative hypothesis suggests its absence, indicating stationarity in the time series. From the results presented in Table 3, it is observed that FDI is stationary at level I (0), whereas CO2, GDP, TOU, and TOP are stationary at first difference I (1) The equation of an ARDL formula as the model with intercept can be written as:

$$\Delta CO_{2_{it}} = \alpha_0 + \sum_{i=1}^{m} \beta_{ik}\, \Delta CO_{2_{j,t-i}} + \sum_{i=1}^{m} \beta_{ik} \Delta FDI_{j,t-i} + \sum_{i=1}^{m} \beta_{ik} \Delta TOU_{j,t-i} + \sum_{i=1}^{m} \beta_{ik} \Delta GDP_{j,t-i} + \sum_{i=1}^{m} \beta_{ik}\, \Delta TOP_{j,t-i} + \varphi_1 CO_{2_{t-1}} + \varphi_2 FDI_{t-1} + \varphi_3 TOU_{t-1} + \varphi_4 GDP_{t-1} + \varphi_5 TOP_{t-1} + e_{it}$$

I=1… N for each country and t=1… T for each period, βik and it are country and time fixed effects respectively. e_{it} represent the estimated residuals.

However, ARDL (Pesaran & Shin, 1995) has gained prominence in recent usage owing to its inherent advantages. One of its key benefits is its applicability regardless of whether series are I(0), I(1), or fractionally co-integrated. (Adom et al., 2012; Wolde-Rufael, 2010). Another benefit is the ability to simultaneously generate estimates for both short-term and long-term scenarios.

Table 4: Results of Long – Run Panel ARDL

Variable	Coefficient	Std. Error	T-Statistic	Prob.*
GDP	1.217272	0.124015	9.815551	0.0000*
FDI	-0.176531	0.106298	-1.660720	0.0995***
TOP	0.525794	0.090044	5.839329	0.0000*
TOU	0.184088	0.068198	2.699312	0.0080*
Mean dependent var	0.014738	S.D. dependent var		0.030013
S.E. of regression	0.026407	Akaike info criterion		-4.468268
Sum squared resid	0.080190	Schwarz criterion		-3.587867
Log likelihood	405.6956	Hannan-Quinn criter.		-4.110790

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

According to (Pesaran & Shin, 1995), Since the ARDL model lacks residual correlation, concerns regarding endogeneity are mitigated. By appropriately incorporating lags, serial correlation and endogeneity issues are addressed. The long-run coefficients of the ARDL method demonstrate the positive influence of GDP, TOU, and TOP on environmental improvement within ASEAN countries. Both short-term and long-term estimates indicate statistically significant impacts of economic liberalization on environmental enhancement, with significance levels of 5% and 10% respectively. Holding other variables constant, a 1%

increase in GDP leads to a 1.217% rise in carbon emissions in these nations, highlighting a positive and significant relationship between them Liu et al. (2023) Conversely, TOP and TOU exhibit a positive and significant influence on CO2 emissions, while FDI demonstrates a negative and significant relationship with CO2 emissions (Chen & Raza, 2023; Pata et al., 2023). The findings regarding TOU indicate that, both in the long and short term, TOU positively impact environmental improvement. Holding other factors constant, a 1% increase in TOU leads to a 0.18% and 0.9% rise in CO2 emissions in the long and short run, respectively (Raihan, 2023; Wei & Lihua, 2023). These results are statistically significant at the 10% level of significance. They suggest that TOP also positively affect environmental improvement in both the short and long run. Holding other variables constant, a 1% increase in TOP corresponds to a 0.184% and 0.0080% increase in CO2 emissions in the long run, and a 0.89% increase in the short run, respectively (Wang et al., 2023). The long-term findings are statistically significant at a 1% level of significance, while the short-term results do not demonstrate significance. In the long run, FDI has a negative and significant impact on environmental improvement (Pata et al., 2023). According to (Shahid et al., 2021) and (Sunde, 2017) the value of ECT (-) This is a noteworthy result of short-term dynamics, indicating the speed of adjustment from the short to the long run.
Furthermore, Table 5 presents the short-term ARDL estimates. FDI, GDP, TOP, and TOU exhibit significant positive and negative associations with CO2 emissions, but all coefficients are significant.

Table: 5

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ECT	-0.195576	0.066813	-2.927198	0.0041*
d(GDP)	0.091236	0.221429	0.412032	0.6811
d(FDI)	0.017720	0.013329	1.329424	0.1863
d(TOP)	-0.011489	0.088218	-0.130238	0.8966
d(TOU)	0.000452	0.026019	0.017379	0.9862
C	-0.296342	0.094903	-3.122575	0.0023*

A Positive TOU coefficient (0.000456) indicates that, at a 5% significance level, a 1% rise (fall) in education will result in a 0.98% reduction (rise) in CO2 emissions. On the other hand, FDI, GDP and TOP have positive coefficients (0.09, 0.091 and -0.011) and an insignificant relation toward CO2 emissions.
In this study, error correction representations with the following specifications are employed to analyze both long- and short-run dynamics.

$$\Delta \mathrm{CO}_{2_{\mathrm{it}}} = \alpha_0 + \alpha_1 t + \sum_{i=1}^{m} \beta_{ik}\, \Delta CO_{2_{j,t-i}} + \sum_{i=0}^{m} \beta_{ik} \Delta\, FDI_{j,t-i} + \sum_{i=0}^{m} \beta_{ik} \Delta\, TOU_{j,t-i} + \sum_{i=0}^{m} \beta_{ik}\, \Delta GDP_{j,t-i} + \sum_{i=0}^{m} \beta_{ik}\, \Delta TOP_{j,t-i} + e_{it}$$

If cointegration is detected, the subsequent step in the ARDL process involves establishing the long-run ARDL equation as follows.

$$\Delta CO_{2_{it}} = \beta_0 + \sum_{i=0}^{p} \beta_{ik}\, CO_{2t-i} + \sum_{i=1}^{q} \beta_{ik}\, FDI_{t-i} + \sum_{i=1}^{r} \beta_{ik}\, TOU_{t-i} + \sum_{i=0}^{s} \beta_{ik}\, GDP_{t-i} + \sum_{i=0}^{t} \beta_{ik}\, TOP_{t-i} + e_t$$

To determine the lag values p, q, r and s in Eq. (4), the criteria of selection of model which includes AIC, SIC, Adjusted R-squared, Hannan–Quinn information criteria are used. The most suitable classical is the model that has the lowest evidence criteria or the highest value of R-squared. Ultimately, the ARDL short-run estimation model also told as error-correction model which investigated through the following equation.

$$CO_{it} = \delta_0 + \sum_{i=0}^{p} \delta_{ik} \Delta\, CO_{2t-i} + \sum_{i=1}^{q} \delta_{ik} \Delta\, FDI_{t-i} + \sum_{i=0}^{r} \delta_{ik}\, \Delta TOU_{t-i} + \sum_{i=0}^{s} \delta_{ik}\, \Delta GDP_{t-i} + \sum_{i=0}^{t} \delta_{ik}\, \Delta TOP_{t-i} + e_{it}$$

In the event of a short-term shock, the calculation of ECM (α) assists in gauging the pace of adjustment towards equilibrium over the long term. To ascertain the directional relationship between two variables necessary for the ARDL method, we delved deeper into Granger causality (Freeman, 1983) In investigating environmental upgrading and its determinants, namely FDI, GDP, TOU, and TOP, we evaluated Granger causality employing the Granger method (1969) Freeman (1983) to explore the causal direction.
In table 4 results shows that CO2 and GDP have unidirectional causality, while FDI and CO2 have no causality among them.

5. Conclusion and Policy Implication

The main focus of this study is on the connection between ASEAN countries FDI, economic growth, trade openness, tourism and emission of carbon dioxide on ASEAN countries for the period of 2000-2022 applying Panel ARDL method. In the short-term, there is a disagreement between the study framework and the ARDL findings about the variable of CO2 emissions. The short-rum impact of GDP, FDI, TOP and TOU on CO2 emissions is zero. Among ASEAN nations, GDP, TOP and TOU all significantly and positively correlated with CO2 emissions. However, FDI has a negative and large impact on CO2 emissions. A long-term association between ASEAN countries and carbon dioxide emissions, foreign direct investment, TOP, and TOU is also demonstrated by the results. The study has significant policy implications for ASEAN countries to minimize the increase in CO2 emissions based on the findings. As a result, ASEAN societies could call for environmental improvements to improve air quality and reduce the danger of climate change. The rise in income will turn into an environmentally beneficial factor since the EKC hypothesis is correct. As a result, the governments of ASEAN need to concentrate on developing policies that carry out environmental and economic development concurrently.
Regarding the sustainability of the economic, social, and environmental spheres, a number of new topics of discussion have emerged as a result of the swift development of economic integration between nations. The government now considers environmental factors before making decisions that affect commerce or business within the nation. Economic activities that have the least negative effects on the environment while also producing the greatest economic and social benefits are prioritized. For the emerging ASEAN countries, striking a balance between environmental sustainability and economic profit is not an easy

issue. Economic growth in these countries is probable to possess a negative impact on the environment up until a tipping point is achieved. This finding implies that actions intended to lessen the effect of economic development on environmental quality are necessary in these nations. The ASEAN-5 are already taking significant steps in this area under the aegis of APAEC (ASEAN Centre for Energy) and, more generally, the APEC EGEE&C. This includes the region's commitments to pertinent multilateral environmental agreements being strengthened and enhanced, transboundary pollution being managed and prevented, environmentally sound technology being promoted, sustainable use and management of freshwater and marine environments being managed, and sustainable forest management Chandra and Astriana (2015).

Governments in ASEAN should also impose regulations on the travel industry. In ASEAN nations, tourism contributes to increased environmental pollution in its current form. The ecotourism approach might be a possible policy choice to lessen it. In order to mitigate the environmental harm that the tourism industry does, ASEAN governments should also implement green tourism practices by adhering to the Sustainable Tourism Strategies of the United Nations. Additionally, clean zones for the tourism industry and clean transportation can help lower CO emissions. A further tactic is to minimize pollution by efficiently recycling the trash that visitors produce. Developing ASEAN nations undoubtedly have a lot of space for improvement, particularly when it comes to their environmental policy. To reduce carbon dioxide emissions, it is necessary to improve and mechanize environmental laws, rules, and regulations, particularly when it comes to international trade. The development and implementation of environmentally friendly industry will be accelerated if the ASEAN-5 countries pool their technological and skill resources. Furthermore, the ASEAN countries are beginning to see the carbon pricing as one of the policies that needs to be taken seriously.

The ecological footprint and load capacity factor in ASEAN countries, among other variables and environmental indicators, could be used in future research, according to this study. As a result, several conclusions regarding environmental degradation will be reached. However, there is another restriction on how long this study can be carried out. A further drawback stems from the approach employed, which solely presents panel data without considering outcomes from particular countries. More ASEAN nations may be the subject of future studies.

Table 6

Null Hypothesis:	Observation	F-Statistic	Prob.
LOG_GDP does not Granger Cause LOG_CO2	147	9.01445	0.0002
LOG_CO2 does not Granger Cause LOG_GDP		2.37292	0.0969
LOGFDI does not Granger Cause LOG_CO2	147	1.64606	0.1965
LOG_CO2 does not Granger Cause LOGFDI		0.80701	0.4482
LOGTOP does not Granger Cause LOG_CO2	147	1.21150	0.3008
LOG_CO2 does not Granger Cause LOGTOP		0.27251	0.7619
LOGTOU does not Granger Cause LOG_CO2	147	1.15961	0.3166
LOG_CO2 does not Granger Cause LOGTOU		1.06632	0.3470
LOGFDI does not Granger Cause LOG_GDP	147	9.07489	0.0002
LOG_GDP does not Granger Cause LOGFDI		0.58045	0.5610
LOGTOP does not Granger Cause LOG_GDP	147	7.04724	0.0012
LOG_GDP does not Granger Cause LOGTOP		0.51605	0.5980
LOGTOU does not Granger Cause LOG_GDP	147	1.64600	0.1965
LOG_GDP does not Granger Cause LOGTOU		1.04204	0.3554
LOGTOP does not Granger Cause LOGFDI	147	4.05339	0.0194
LOGFDI does not Granger Cause LOGTOP		0.89483	0.4110
LOGTOU does not Granger Cause LOGFDI	147	0.70043	0.4981
LOGFDI does not Granger Cause LOGTOU		0.60582	0.5470
LOGTOU does not Granger Cause LOGTOP	147	3.74002	0.0261
LOGTOP does not Granger Cause LOGTOU		0.21803	0.8044

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