Bridging Tourism Growth and Environmental Impact: An Empirical Analysis of CO_2 Emissions in Sri Lanka

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Abstract

Tourism significantly contributes to economic growth, job creation, and generates foreign exchange earnings. However, energy consumption from transportation is a significant factor in the adverse environmental effects of tourism. Consequently, this research seeks to examine both short-term and long-term impacts of tourism on carbon dioxide (CO_2) emissions in Sri Lanka utilizing the annual data from 1990 to 2022, by employing Autoregressive Distributed Lag (ARDL) method. In this study, CO_2 emission is employed as the dependent variable while tourism arrivals, foreign direct investment (FDI), and gross domestic product (GDP) are considered as the independent variables. The findings revealed that existence of a significant strong long-term correlation between tourism arrivals, GDP, FDI and CO_2 emissions from transport. Further, the findings confirmed that tourism has a strong and significant positive impact on CO_2 emission. Furthermore, Diagnostic assessments confirm the model's precision, and the Error Correction Model (ECM) shows that around 21.4% of the imbalance from the prior year is rectified in the current year, indicating a moderate rate of adjustment towards the long-term equilibrium. These findings emphasize the importance of sustainable tourism policies and cleaner technologies to harmonize economic advantages with environmental sustainability.

Key words: *Tourism, Economic Growth, Foreign Direct Investment, Environmental Sustainability, Transport Emissions*

JEL Codes: Q53, Z32, Q56, C32

Introduction

The tourism sector is a significant contributor to the global economy and social development, as it is a leading source of income, job creation, and infrastructure development. By attracting domestic and international tourists, this sector contributes to the local economy by facilitating small businesses and encouraging local investment. The World Travel & Tourism Council (WTTC, 2024) states that the tourism sector directly and indirectly employs millions of individuals, ranging from hospitality and transportation to tour operations and cultural preservation. The tourism industry is fueled by improved accessibility, globalization, technological advances, and rising disposable incomes. In the past, tourism was a vital source of income for developing and developed countries (Sharif *et al*., 2017; Lee & Brahmasrene, 2013; Bahar & Demir, 2023). Tourism, one of the largest global economic sectors, develops cross-cultural relations and, when well-managed, significantly aids socio-economic progress and environmental protection (Tansel, 2018). However, environmental degradation and greenhouse gas emissions are the major risks for a healthy economy (Meng *et al*., 2016: Anderson *et al*., 2016), which create an adverse impact on countries across the globe (Paramati *et al*. 2017, Mahewaranathan, 2024).

Tourism and climate change are deeply interconnected, as tourism not only contributes to climate change but also significantly affected by it. This complex relationship calls for a range of strategies focused on adaptation and mitigation (Solarin, 2014; Jamnongchob *et al.* 2017). Tourism also fosters social cohesion through creation of employment and promoting interaction within the community, particularly in underdeveloped and rural communities. Additionally, it facilitates economic growth, social and cultural landscapes, making a vital element of modern society. Sri Lanka tourism is multicultural, vibrant, and recuperating slowly from the most recent challenges. The tourist industry in Sri Lanka is driven by its culturally rich heritage, natural beauty, and wildlife. Further, international tourist arrivals and income generation show approximately 2.1 million in 2024, (38 percent increase compare with the previous year) and income generation of USD 3.0 billion respectively (Sri Lanka Tourism Development Authority, 2024).

Tourism sector significantly contributes to CO_2 emissions, especially to the transport industry, which accounts for approximately 75-80% of industrial emissions (WTTC, 2024). Among various modes of transportation, aviation is the most carbon-intensive, especially long-distance flights, followed by road transport using private cars and buses used for tours. Ferries and cruises also emit high CO_2, and cruises are particularly harmful since they burn heavy fuel. Though rail transport is comparatively more eco-friendly, especially when powered by renewable energy, it

still releases some emissions when operated with diesel fuel (Anderson *et al*., 2016). The importance of tourism for countries lies in its continuity and impact on the economy, especially in the case of developing countries (Bahar & Demir, 2023) .

Tourism relies heavily on transportation, yet transport activities are among the largest contributors to CO_2 emissions. In Sri Lanka, air travel, road transport, and intra-destination mobility form the backbone of the tourism industry, but they also generate increasing levels of carbon emissions. Rising transport-related CO_2 emissions can undermine tourism sustainability, reduce destination attractiveness, and create tensions with both national and global climate commitments.

Despite these concerns, empirical evidence remains limited regarding how transport-related CO_2 emissions have evolved over time, the extent to which these emissions influence tourism arrivals, tourism receipts, and overall tourism growth, and whether high-emissions transport systems pose risks to the long-term sustainability and competitiveness of the Sri Lanka's tourism sector (Francis & Gunathilaka, 2024). Therefore, the present study seeks to examine the impact of transport-related CO_2 emissions on tourism growth in Sri Lanka, employing the ARDL approach for the period 1990–2022.

Literature Review

The relationship between tourism growth and environmental impact, particularly carbon dioxide (CO_2) emissions, can be explained through multiple economic and environmental theories that frame the trade-off between economic development and ecological sustainability. The present study draws primarily on the Environmental Kuznets Curve (EKC) hypothesis, the Tourism-Led Growth Hypothesis, and the Sustainable Development Theory.

The Environmental Kuznets Curve, introduced by Grossman and Krueger (1991), suggests an inverted U-shaped relationship between environmental degradation and economic growth. At the early stages of economic development, pollution tends to increase due to industrialization and resource-intensive production. However, as income levels rise and economies transition towards higher-value, service-oriented activities, societies invest more in cleaner technologies, stricter environmental regulations, and renewable energy sources, leading to environmental improvement.

A substantial body of literature explores the impact of tourism on CO_2 emissions. Kocak *et al*. (2020) investigated the impact of tourism on CO_2 emissions using secondary data from 1995 to 2014 and proved a positive and significant effect on CO_2

emissions on tourism but tourism receipts have contributed to reduction of the CO_2 emissions. By employing ARDL and Granger Causality tests using data from 1975 to 2014, a study conducted on the tourist arrivals, energy consumption and pollutant emissions in a developing economy and confirmed that existing short-run and long-run relationships between tourist arrivals, per capita economic output, emissions, energy consumption and capital formation (Nepal *et al*., 2019). In their study Koçak *et al* (2019) investigated the impact of tourism development on CO_2 in top tourism countries from 1995 to 2014. Employing continuously updated fully modifies (CUP – FM) and continuously updated bias – corrected (CUP- BC) estimators, they concluded that tourist arrival positively impacts on CO_2 emission, while tourism receipts negatively impact the CO_2 emissions. Further, they confirmed a bidirectional causality between tourism indicators and CO_2 emissions. Employing panel ARDL model Can and Mert (2018) examined the effect of CO_2 emissions on tourism receipt in the top ten countries for the period from 1995 -2010.The findings demonstrated that emission from gaseous fuel have a positive impact; however, total emissions from solid fuel (only in the short run) and liquid fuel have negative impact on tourism receipt.

Lee & Brahmasrene (2013) investigated the influence of tourism on economic growth and carbon emissions, using panel cointegration techniques, fixed-effects models, cointegration tests and panel-based error correction models (ECM) from 1988 to 2009 and found tourism, CO_2 emissions and FDI have highly significant positive effects on economic growth. León *et al.* (2014) using panel data from 1998 to 2006, studied CO_2 emissions and tourism in developed and less developed countries. By applying STIRPAT model they found that the sustainable development paths with lower CO_2 emissions in tourist service consumption and production. Seyi *et al*. (2020) study the causal direction between tourism, economic growth and CO_2 emissions by incorporation newly globalization Index as additional variable. By employing new panel Granger causality testing the researchers, confirmed that tourism and output growth were major contributor to the environmental pollution this region from 1995 -2014. Further, these findings to the demand – following and supply – leading hypothesis in these regions. Adopting Johansen and Juselius, ARDL and Gregory and Hansen Structural break test, Arshian *et al*. (2027) explore the relationship between CO_2 emissions, tourist arrival and economic growth in Pakistan from 1972- 2023. Their findings revealed that one-way causality exist between CO_2 and tourism arrival.

Using panel data from 1995 to 2010, Tansel (2018) investigated the impact of carbon dioxide (CO_2) emissions on tourism in France, the USA, Spain, China, Italy, Turkey, UK, Germany, Russia, and Malaysia. Their results show that gaseous fuel emissions have a positive impact whereas total emissions, solid fuel emissions (in the short run)

and liquid fuel emissions have a negative impact on tourism receipts. Bahar and Demir (2023) applied bound testing approach, error correction model and ARDL Model to time series data for Turkey, from 1984 to 2021. They found that gaseous fuel emissions have a positive impact on tourism revenue, while total emissions, solid fuel (short term) and liquid fuel emissions, have a negative impact on tourist revenues. At the same time, Al-Mulali *et al*. (2015) analyzed the effect of tourist arrival on CO_2 from transport sector across Africa, Middle East, Americas, Asia & Pacific, Europe. Using panel data from 1995 to 2009; they employed Panel co-integration approach, Fully Modified Ordinary Least Squares and Panel Granger Causality test. They found tourism arrivals have a significant positive effect on CO_2 emissions from the transportation sector in all the selected countries except the European nations. In other words, Anderson *et al*. (2016) conducted a study on CO_2, greenhouse effect and global warming from the pioneering work of Arrhenius and Callendar to contemporary Earth System Models focusing on UK, Sweden and the USA. Their findings proved that tourist arrivals increase CO_2 emissions whereas tourism receipts contribute to reducing CO_2 emissions. Also, by applying the historical model, empirical approximation of Callendar's model and Econometric models they confirmed the bidirectional causality between CO_2 and tourism. Begum *et al.* (2025) analyzed the determinants of CO_2 emissions in Malaysia using multiple cointegration and estimation techniques, including ARDL, Johansen, Engle – Granger, DOLS, FMOLS and CR models. They concluded that GDP, energy consumption, urbanization, population growth and tourism significantly increase CO2 emissions. Further, Granger causality test confirmed that GDP energy use, and urbanization as the strongest drivers of the CO_2 emissions. Habib *et al* (2022) employed robust and advanced fixed effect panel regression approach to analyzed the impact of tourism (air transport intensity, air passenger transport and air freight transport) related carbon emissions in G20 countries from 1990- 2016. Their findings argue that mixed effects of regressors on CO_2 emissions quite varies across quantiles. In particular, the effect of tourism on CO_2 emissions is positive and increases at upper quantiles. More precisely, the effect of air transport intensity, air passenger transport, and air freight transport exert a positive and increasingly pronounced effect on carbon emissions at upper quantiles, indication substantial heterogeneity across all quantiles. Furthermore, the Dumitrescu and Hurlin causality confirmed that bidirectional relationship between tourism and CO_2 emissions. Considering the panel data of 32 tourist cities in China from 2005 to 2022, Zhao *et al*. (2024) investigated the influence of tourism on CO_2 emissions. Applying structural equation model, they found that tourism development positively impacts CO_2 emission during the study period.

Evidence suggests that the tourism CO_2 nexus varies significantly across regions. Moutinho *et al.* (2015) using panel data from 1975 – 2014, studied the impact of energy efficiency and economic productivity on CO_2 emission intensity in the Portuguese tourism industry. They applied LMDI decomposition method, panel corrected standard errors (PCSE) and panel data regression models to find that carbonization index exerts a positive influence upon CO_2 emissions in tour operators and travel agencies and statistical significance of the effects. Oh *et al*. (2010) using data from 1990 to 2005, investigated decomposition analysis and mitigation strategies of CO_2 emissions from energy consumption in South Korea and they found economic growth as the dominant driver, sectoral contribution to CO_2 emissions, fuel mix effects and decoupling trends and energy intensity reduction. Jung and Tantatape (2013) found tourism incurred a high significant negative impact on CO2 emissions during the period from 1988 to 2009 in European countries. By applying ARDL method, Yu et.al (2019) examined the relationship between tourism, environmental degradation, and logistics and transport related operations in Thailand from 2001 to 2017. Afriha & Francis (2024) the short and long-term dynamic findings revealed that fossil fuel consumption and carbon emissions have a negatively impact on tourism which stresses that policy makers should enforce green practices to mitigate the harmful environmental effects and attract foreign tourists to the country.

Yan & Phucharoen (2024) investigated tourism transport-related CO_2 emissions and economic growth in China using panel data from 2010 to 2018. They found no evidence of a cointegrated relationship between energy intensity effect and regional economic growth, although other factors demonstrated connections but there were dynamic relationships with economic growth. Employing an extended STIRPAT model integrated of EKC hypothesis, Thai and Canh (2021) investigated the relationship between tourism and CO2 emissions using a large panel of 95 countries, classified into three income-based subsamples. The findings revealed that tourism (tourism receipts and international tourism arrival) reduces total CO2 emissions. However, tourism on emissions varies significantly across the income groups. Sudharshan *et al*. (2018) and Francis and Salahudeen (2022) have argued that tourism with increase in investment the tourism income surge; in return it led to a dip in CO_2 emissions in 28 EU countries from 1990 - 2013. Considering climate change as CO_2 emission and air pollution are the dependent variables and tourism arrival is dependent variables, the results of Zikirya *et al* (2021) suggest existing of the long run relationship between the variables from 2010 to 2017 in 30 Chinese provinces. Further, the empirical findings elaborate that CO_2 emissions have a negative impact on inbound and domestic tourist arrival, while inbound and domestic tourists positively affect CO_2 emissions. Also, they proved prevalence of a bidirectional relationship between tourism and CO_2 emissions.

Focusing on 92 tourism-dependent cities in China Tong *et al*. (2022) studied the carbon emission reduction effect of tourism economy and its formation mechanism using panel data from 2005 to 2016. They found a significant positive direct impact of tourism on carbon emission intensity whereas indirect impact is significantly negative and stronger than the direct impact. Lee and Brahmasrene (2013) investigated the influence of tourism on economic growth and carbon emissions in 26 developed and 18 developing economies. They revealed that FDI and tourism have a significant positive contribution to economic growth for the EU and a very significant positive contribution to CO_2 emissions. Using panel data from developed and developing countries Paramati *et al.* (2017) investigated the effect of tourism on GDP and CO_2 emissions. By analyzing EKC hypotheses they concluded that tourism encourages economic growth but increases CO_2 emissions; however, emissions decline beyond a threshold a level particularly in developed countries. Misbah *et al* (2021); Danthanarayana *et al* (2024) and Gimhani and Francis (2016) use second-generation panel techniques to examine the long-run effects of GDP, tourism, energy use, trade openness, financial development, and urbanization on CO_2 emissions in Asian economies from 1995 to 2017. Their findings support the inverted U-shaped Environmental Kuznets Curve (EKC) hypothesis and show that all variables, including tourism, contribute positively to environmental degradation.

The literature reveals a complex and region-specific relationship between tourism and CO_2 emissions. While most of the studies confirm that tourism especially through increased arrivals lead to higher CO_2 emissions, some of the studies highlight that tourism receipts can facilitate emission reductions via investments in cleaner technologies and infrastructure.

Methodology

This study investigates the impact of tourism on carbon dioxide (CO_2) emissions in Sri Lanka using annual time series data covering the period from 1990 to 2022. The data are obtained from reliable sources such as the World Bank Development indicators and Sri Lanka Tourism Developing Authority.

In this study, the impact of tourism arrivals (TA) on transport-related CO_2 emissions in Sri Lanka is examined while accounting for other influencing factors such as Foreign Direct Investment (FDI) and Gross Domestic Product (GDP). Table 1 presents the details of the variables used in this analysis. Furthermore, all variables except FDI and GDP were transformed into their natural logarithmic form. Accordingly, CO_2 emissions and tourism arrivals were converted into log form to stabilize variance and improve model estimation.

Table 1: Explanations of Variables

Variable	Symbol	Variable definitions(measurement)	sign
Tourism Arrivals	TA	Tourism arrivals	
Foreign Direct Investment	FDI	Foreign direct investment, net inflows (% of GDP)	+
Gross Domestic Production	GDP	Gross domestic production (% of GDP)	+
CO_2 Emission from Transport	CO_2	CO_2 total mt	+

Stationarity Test (Augmented Dickey-Fuller (ADF) test)

Before estimating the ARDL model, the stationarity properties of all variables are assessed using Augmented Dickey-Fuller.

The unit root test, introduced by Dickey and Fuller in 1979, is used to determine whether the variables are stationary or non-stationary. It is shown by following equation.

$$Y_t = \beta_0 + \beta Y_{t-1} + \varepsilon_1$$

$\varepsilon \quad t \sim (0, \sigma^2)$

H_0: $\beta = 1$ (Variable Y_t has stationary)

H1: $\beta < 1$ (Variable Y_t has not stationary)

If P - value < α, H_0 will be rejected which means Y_t has no stationary.

Model Specification

The study employs the Autoregressive Distributed Lag (ARDL) approach to examine the short-run and long-run dynamics between tourism arrivals, foreign direct investment, gross domestic production and CO_2 emissions from transportation in Sri Lanka.

$$COTR_t = f(TA_t + FDI_t + GDP_t) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Equation 1 explains that CO_2 is the dependent variable and TA, FDI and GDP are the independent variables respectively. From this equation, the main hypothesis is TA will positively impact the CO_2 in Sri Lanka.

To examine the existence of a long-run relationship among the variables, the Bounds Testing Approach developed by Pesaran *et al.* (2001) is used. The null hypothesis of no cointegration is tested using F-statistics.

$$\Delta LCnOTR_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i}\, \Delta LnCOTR_{t-i} + \sum_{i=1}^{q} \alpha_{2i}\, \Delta LnTA_{t-i} + \sum_{i=1}^{r} \alpha_{3i}\, \Delta FDI_{t-i} + \sum_{i=1}^{s} \alpha_{1i}\, \Delta GDP_{t-i} + \beta_1 LnCOTR_{t-1} + \beta_2 LnTA_{t-1} + \beta_3 FDI_{t-1} + \beta_4 GDP_{t-1} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

If cointegration is confirmed, the long-run coefficients are estimated, followed by the Error Correction Model (ECM) for short-run dynamics. The significance and sign of the error correction term (ECT) indicate the stability and speed of adjustment towards long run equilibrium.

$$\Delta lnCO_{21=}\, \delta_0 + \sum_{i=0}^{q1} \delta_{1i}\, \Delta lnCO_{21} + \sum_{i=0}^{q1} \delta_{3i} \Delta lnTA_{t-i} + \sum_{i=0}^{q2} \delta_{4i} \Delta FDI_{t-i} + \sum_{t=i}^{q3} \delta_{5i}\, \Delta GDP_{t-i} + U_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$\Delta lnCO_{21=}\, \beta_0 + \sum_{i=0}^{p} \beta_1\, \Delta lnCO_{2t} + \sum_{i=0}^{q2} \beta_2 \Delta lnTA_{t-i} + \sum_{i=0}^{q3} \beta_3 \Delta FDI_{i=0} + \sum_{i=o}^{q4} 4\, \Delta GDP_{t-i} + \lambda ECT_{t-1} + V_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where: $ECT_{t-1} = \mathrm{LnCO}_{2t-1} - \theta_1\, \mathrm{LnTA}_{t-1} - \theta_2\, \mathrm{FDI}_{t-1} - \theta_3 \mathrm{GDP}_{t-1} \ldots\ldots\ldots(5)$

Δ = First difference

ECT_{t-1} = Error correction term derived from long-run equation residuals

λ = Speed of adjustment coefficient must be negative and significant, explains that how quickly deviations from long-run equilibrium are to be corrected.

Findings of the study

This study examines the relationship between tourism arrivals and CO_2 emission in Sri Lanka by using annual time series data from 1990 to 2022, extracted from World Bank development indicators and the Sri Lanka Tourism Developing Authority.

Using EViews 10 software, the present empirical study has employed the Augmented Dickey-Fuller Unit root test in examining the stationarity of variables. The exploration continues with the ARDL model, ECM model following the unit root test and individual tests, similar to the Correlation test, Ramsey RESET Test, Normality test, Heteroskedasticity test and CUSUM test to examine the stability of the variables.

Table 2. Augmented Dickey- Fuller Unit Root Test

Variables	Augmented Dickey- Fuller				
	t-Statistic	**Level**	**t-Statistic**	**1st Differences**	**Suggestion**
$LnCO_2$	-2.331575	0.1687	-5.077606	0.0003	**I (1)**
LnTA	-0.983660	0.7461	-6.624320	0.0000	**I (1)**
FDI	-6.169452	0.0000	-	-	**I (0)**
GDP	**-1.026446**	**0.7312**	**-9.188207**	**0.0000**	**I (1)**

Above Table 2 shows that ADF unit root test of the variables which are considered for the present study. Except the FDI other variables are stationary at first difference I (1) and mixed of both I(0) and I(1) variables but not in I(2). Therefore, this condition suggests the ARDL modeling.

After conducting the stationary tests, the Akaike Information Criterion (AIC) was used to determine the best ARDL model lag length. AIC indicated that among the available models, the best fit was provided by the ARDL (2, 0, 0, 1).

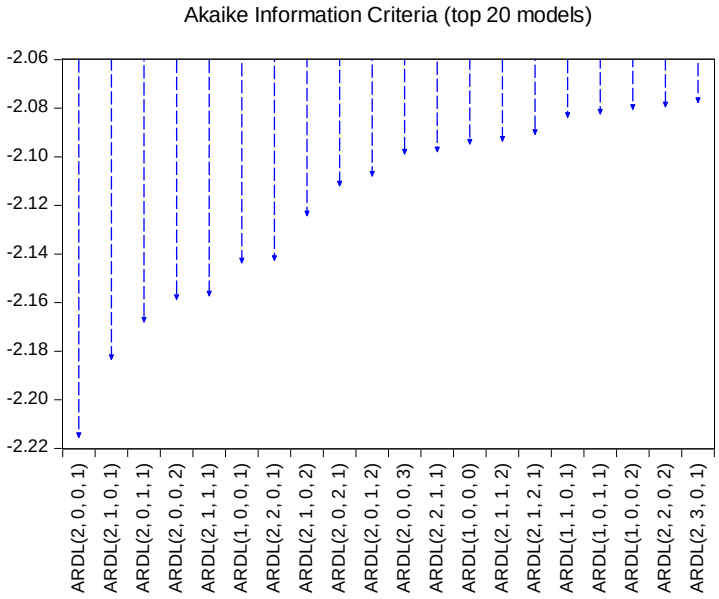

Figure 1: Akaike Information Criteria (Top 20 models)

Thus, the ARDL (2, 0, 0, 1) was selected for examining innovative impact of FDI, GDP, and Tourism Arrivals on Sri Lanka's CO_2 emissions. Figure 1, presents the Akaike Information Criteria of the best 20 models.

The estimated coefficient of ARDL model of long run and short run variables are presented in Table 3 to validate the existence of the null hypothesis employed the bound test for the existence of the long run relationship. The following Table 3 illustrates the F statistic value of 7.732047 above the upper value of I (1).

Table 3: ARDL Bound Test

Estimated equation		**$LnCO_2$ = f (LARRIVAL, GDP, FDI)**
Optimal Lag Lenth		**(2, 0, 0, 1)**
F - Statistics		**7.732047**
Significant Level	Lower bounds I (0)	**Upper bounds I (1)**
1	3.65	**4.66**
5	2.79	**3.67**
10	**2.37**	**3.2**

According the Table 4, tourism arrival has a significant positive impact on CO_2 emissions in Sri Lanka. That is one million increases in tourist arrival is associated with 0.417 mt increase in CO_2 emission. This finding supports earlier evidence Koçak et al. 2020; Al-Mulali et al. 2015; Nepal et al. 2019; Solarin, 2014; Maheswaranathan, 2024; Bahar & Demir, 2023), suggesting that expanding tourism activities, particularly transport-related energy consumption, intensifies environmental degradation. As tourism arrivals increase, demand for domestic mobility, accommodation, and supporting infrastructure also rises, leading to higher energy use and emissions.

However, this finding should be viewed through the EKC curve where early tourism expansion typically increases emissions, but further economic and technological development can promote decarbonization. Thus, Sri Lanka's challenge lies in transitioning towards low-carbon tourism through improved transport systems, renewable energy adoption, and policy incentives for sustainable operations.

Coefficient value of Gross Domestic Production (0.0562) explains that GDP has a significant positive impact on CO_2 at 5% level in the long run, means 1% increase in GDP is linked with the 0.0562mt of CO_2 emission. This positive long-run association reveals a scale effect, as economic activity expands, energy consumption and production intensify, increasing environmental pressure. This finding aligns with Sharif et al. (2017) and Oh et al. (2010), who found that GDP growth tends to raise CO_2 emissions in developing economies. For Sri Lanka, where economic

diversification remains limited, the expansion of energy-intensive industries and services (including tourism) explains this pattern.

Nevertheless, as the EKC framework implies, the transition to cleaner growth is possible as the economy matures. Government initiatives focusing on renewable energy integration, green transport infrastructure, and environmental taxation could gradually flatten the emission trajectory.

Interestingly, the negative coefficient of FDI in the long run indicates that foreign investment in Sri Lanka has contributed to reducing CO_2 emissions. This result contrasts with the "pollution haven" hypothesis and suggests that FDI inflows may facilitate technological transfer, cleaner production techniques, and environmental management systems, particularly in sectors linked to tourism and energy. This supports the argument by Lee and Brahmasrene (2013) who found that FDI could enhance environmental quality when accompanied by proper regulatory frameworks.

In the Sri Lanka's context, recent investments in renewable energy and sustainable tourism infrastructure appear to align with this trend. Thus, encouraging green FDI to serve as a policy lever for balancing tourism-led growth with environmental objectives.

In the context of this study, Sri Lanka's tourism expansion contributes positively to GDP and employment but simultaneously increases CO_2 emissions—especially from transport and energy use. However, consistent with the EKC hypothesis, sustained income growth and environmental awareness can lead to policy reforms and adoption of sustainable practices that reduce emissions in the long run. Therefore, the EKC provides an analytical lens to assess whether tourism-induced growth in Sri Lanka is reaching a stage where economic gains can support environmental mitigation.

Table 4: Long Run outputs of ARDL model

ARDL (2, 0, 0, 1) Dependent Variable = $LnCO_2$ Time Period: 1990 – 2022				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	10.70081	1.349644	7.928617	**0.0000**
LNARRIVAL	0.416198	0.099678	4.175412	**0.0003**
FDI	-0.57307	0.226061	-2.535027	**0.0182**
GDP	**0.056235**	**0.028248**	**1.990741**	**0.0580**

The ECT_{t-1} coefficient value of -0.214179 in Table 5, which can be statistically significant and consistent since it is less than 1 and negative. This indicates existence

of the long run relationship. And about 21.4% of the deviation from the long-run equilibrium is corrected each year, which means if last year's emissions were too high compared to the long-run equilibrium, 21.4% of that gap is adjusted this year. This reflects a moderate speed of adjustment and the system does not return to long-run equilibrium immediately, but it does so steadily over time. The Durbin–Watson statistic of 2.326589 indicates that the model does not suffer from serious serial correlation. Since the value is close to the benchmark value of 2, the residuals are approximately uncorrelated. Although the statistic is slightly above 2, suggesting mild negative autocorrelation, it is not statistically significant and therefore does not affect model reliability.

Table 5: Short Run outputs of ARDL model

Variable	Coefficient	Std. Error	t- Statistic	Prob.
D(LnCO_2 (-1))	-0.218646	0.147143	-1.485948	**0.1503**
D(FDI)	-0.070229	0.023917	-2.936382	**0.0072**
ECT_{t-1}	-0.214179	0.031891	-6.715922	**0.0000**
R-squared	0.592920			
Akaike info criterion	-2.362796			
Durbin-Watson stat	**2.326589**			

To attain the study objectives and confirm that the estimated ARDL (2, 0, 0, 1) model best suits the purpose, a diagnostic test is carried out. The results of diagnostic tests as presented in Table 6.

Table 6: Diagnostic Test

Type of Test	F-statistic	Prob.
Breusch-Godfrey Serial Correlation LM Test	1.816716	**0.1861**
Heteroskedasticity Test: Breusch – Pagan-Godfrey	1.144360	**0.3677**
Ramset RESET Test	0.815856	**0.3758**
Normality Test	**2.317382**	**0.3138**

Godfrey Serial Correlation LM Test (p = 0.1861) used for the identification of autocorrelation are illustrated in Table 05. The values are too large for a level of 5%. Therefore, the model determines that estimated ARDL (2, 0, 0,1) model normally distributed residuals, strongly supports the lack of autocorrelation and verifies homoscedasticity.

Figure 2 below shows the CUSUM experiment results of the model tested ARDL (2, 0, 0,1). To ensure the robustness of the estimated ARDL model, study conducted stability diagnostics using the CUSUM and CUSUMSQ tests. Both test statistics remained within the 5% significance boundaries throughout the sample period, indicating that the model is structurally stable and does not suffer from parameter instability. Thus, the estimated coefficients can be considered reliable for inference.

Stability Test

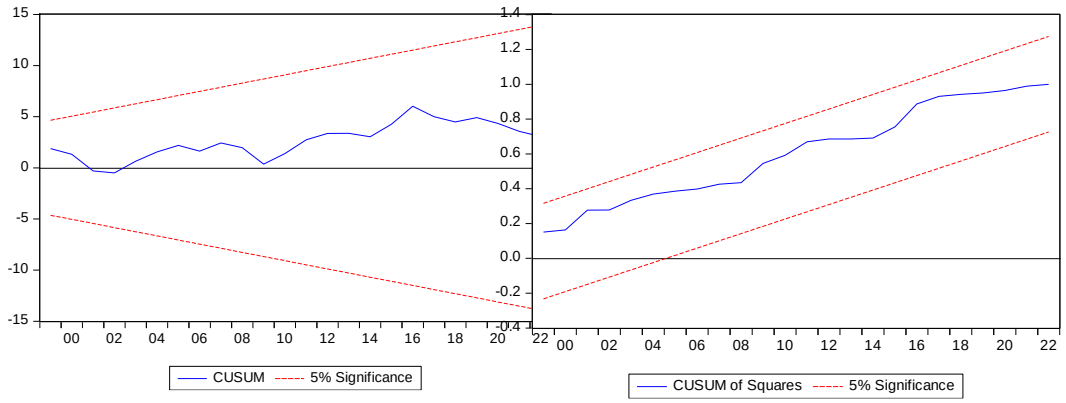

Figure 02: CUSUM Test

Here, the trend line is represented by the blue line while the red lines represent the 95% confidence interval. A good model should possess a regression line between the upper and lower limits of the 95% confidence interval. From the results of the CUSUM plot, this places the significant borders at around the 5% significance level.

Conclusion

By applying ARDL bound test and ECM, this research analyzed the impact of tourism on CO_2 emissions in Sri Lanka for the period from 1990-2022. The findings revealed a significant long-run cointegrating relationship between CO_2 emissions and tourism arrivals, foreign direct investment, and gross domestic production.

Both in the short and long term, Gross Domestic Product (GDP) and tourism arrivals demonstrated a significant positive impact on CO_2 emissions. Specifically, a 1% increase in tourism arrivals is associated with a 0.41% rise in CO_2 emissions in the long run, while a 1% increase in GDP leads to a 0.05% increase in CO_2 emissions. Conversely, foreign direct investment was found to have a mitigating effect, with a 1% increase leading to a 0.57% decrease in CO_2 emissions. The diagnostic test results revealed that increased confidence in the validity and reliability of the coefficient estimates obtained from the ARDL model. Further the error correction term indicates that 21.4% of the short-term disequilibrium in CO_2 emissions adjusts

back to the long-run equilibrium. The findings suggest that Promoting Low-Carbon Tourism, Encouraging Green FDI, Strengthen Environmental Regulation, Promoting Eco Tourism and Awareness and Technological Innovations are the implications for the sustainable development of the nation.

Limitations and Future Research

While the present study provides robust empirical evidence, it has several limitations. First, it focuses primarily on aggregate CO_2 emissions from transport, excluding emissions from accommodation and other tourism services. Second, it does not capture the seasonal or regional variation in tourist activities across Sri Lanka. Future research should employ spatial econometric models or sectoral decomposition to assess the differential impact of tourism sub-sectors on emissions. Moreover, integrating renewable energy consumption and environmental policy indices could further enrich the understanding of the tourism–environment nexus.

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