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The Impact of Climate Change on the International Tourism Sector in Malaysia

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ABSTRACT

Global tourism has significantly contributed to the economic growth of developing nations by stimulating consumption, creating employment, and driving economic expansion. However, the sector also poses environmental challenges, particularly through increased pollution and energy consumption linked to tourism-related activities. Therefore, this study aims to examine the impact of climate change on international tourism in Malaysia from 1998 to 2019. Employing the autoregressive distributed lag (ARDL) model, this study simultaneously examines short-term and long-term effects. This research aims to elucidate the interrelationship between climate change, proxied by carbon dioxide emissions (CO_2 emissions), precipitation patterns, and temperature changes, and their impact on international tourism dynamics. The study incorporates gross domestic product per capita (GDP per capita) as a control variable to bolster the analytical rigor. The outcomes reveal that climate-related factors (CO_2 emissions, precipitation, and temperatures) have a positive and lasting impact on international tourist receipts. These results emphasize the importance of implementing more sustainable and eco-friendly tourism policies to preserve the environment and the economy for future generations in Malaysia. Through the implementation of these strategies, Malaysia can effectively attain a state of balanced symbiosis between economic advancement and the conservation of the environment. This study uncovers the significant impact of climate variables on Malaysia's tourism. It provides actionable insights for developing sustainable tourism policies crucial for the nation's long-term economic and environmental well-being.

Keywords: ARDL, climate change, CO_2 emissions, Malaysia, tourist receipts

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INTRODUCTION

Tourism plays a crucial role in fostering economic growth and development in numerous nations, making substantial contributions to foreign exchange earnings, employment generation, and the enhancement of infrastructure (Othman & Rosli, 2023). In 2019, Malaysia's inbound tourism expenditure amounted to RM86.7 billion, representing 8.8% of the total value of goods and services exports. Since 2009, the expenditure on inbound tourism has consistently constituted over 50% of service exports, as depicted in Figure 1. In terms of regional comparison, Malaysia's travel and tourism sector contributed 9.4% to the country's exports, which was slightly higher than the average of 9.1% for Southeast Asia as a whole (World Travel and Tourism Council [WTTC], 2019). Furthermore, when compared with similar GDP per capita, Malaysia ranked third at 18% in terms of travel and tourism's share in export contributions, trailing behind Croatia (39%) and Greece (30%) (WTTC, 2019).

Whilst tourism can yield positive economic impacts, it is crucial to acknowledge that it also brings forth certain negative consequences, with pollution being a prominent concern. Tourism's influence on an economy's CO_2 emissions is considerable due to escalated economic activities and heightened energy consumption (Ullah et al., 2022). Notably, CO_2 emissions, recognized as the primary driver of global warming, have witnessed a nearly quadrupled increase since the early 1960s, as evident in studies by Adebayo and Kirikkaleli (2021), Koçak et al. (2020), and Shahzad et al. (2021). The phenomenon of global warming, in turn, has been linked to detrimental effects across various societal aspects, encompassing the economy, governance, lifestyle, and social and geopolitical development (Adebayo & Rjoub, 2021; Bilgili et al., 2016). The matter of climate change, primarily attributed to human activities, has arisen as a substantial and pressing concern with far-reaching implications for various sectors of the economy, such as the tourism industry. In

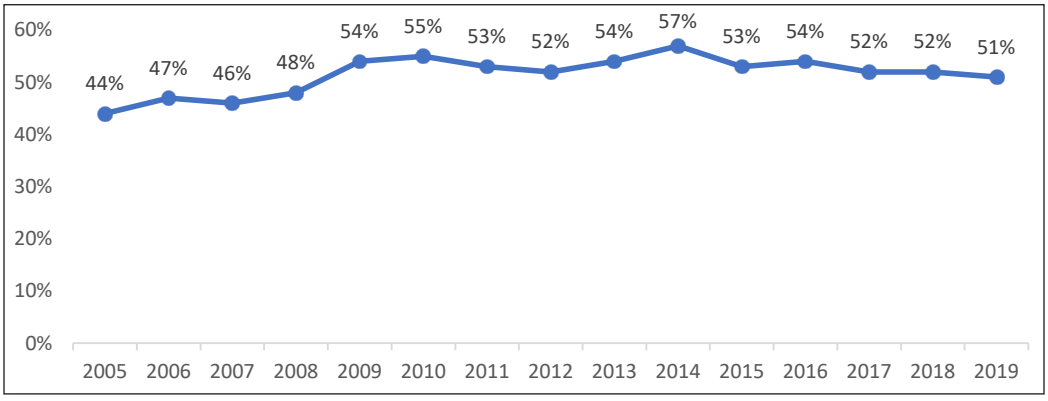

Figure 1. Inbound tourist expenditure by tourists out of total services exports, Malaysia (%)
Source: Department of Statistics Malaysia (2020)

light of the exceptional climate challenges that have emerged, it is imperative to understand the ramifications of climate change on the international tourism sector in Malaysia.

This research is presented as follows: The subsequent section provides an overview of the tourism industry and its relationship with climate change, followed by a section detailing the methodology employed in this study. The fourth section of the paper presents empirical results and is followed by a discussion. The final section provides a comprehensive conclusion.

LITERATURE REVIEW

Tourism is pivotal in global economic development, contributing significantly to GDP, employment, and cultural exchange. However, as climate change becomes an increasingly urgent global concern, its effects on tourism are becoming more pronounced. In particular, the changing climate has a direct impact on tourist destinations, influencing both tourist behavior and the overall sustainability of tourism industries. This literature review explores the multifaceted effects of climate change on tourism, focusing on Malaysia and emphasizing key climate factors such as temperature, precipitation, and extreme weather events.

Climate Change and Tourism Demand

The demand for tourism is heavily influenced by climatic factors, with temperature and precipitation being the most critical determinants of tourist preferences (Scott et al., 2012). Climate change has altered tourist behaviors and destination preferences through rising temperatures and shifting precipitation patterns. In tropical regions like Malaysia, warmer temperatures and unpredictable rainfall may decrease the attractiveness of destinations, particularly those that rely on stable, predictable weather patterns (Gössling et al., 2018). As temperatures rise, tourists may opt for cooler destinations, thus affecting both international and domestic tourism flows. Conversely, regions experiencing milder temperatures may see a rise in tourist arrivals as they become more appealing to those seeking more comfortable climates (Becken & Wilson, 2013).

In Malaysia, the tourism sector is particularly sensitive to shifts in temperature and seasonal variations. Tourists visiting beach resorts or eco-tourism destinations often seek stable, dry weather, making destinations vulnerable to changes in precipitation and temperature. A study by Mohd et al. (2021) indicated that Malaysian tourism demand is heavily influenced by seasonal rainfall patterns, with regions affected by heavy rains witnessing a drop in tourist visits during the monsoon season. Such shifts in weather patterns can disrupt peak tourist seasons, directly impacting revenue and tourism-related jobs.

Vulnerability of Coastal and Island Tourism

Coastal and island destinations, a significant component of Malaysia's tourism offerings, are particularly vulnerable to climate change. Rising sea levels caused by global

warming threaten submerged coastal areas, eroding beaches, and damaging marine ecosystems (Furqan & Winandi, 2018). This jeopardizes natural attractions and the infrastructure supporting tourism activities in these regions.

For instance, popular Malaysian destinations such as Langkawi, Penang, and the Perhentian Islands could experience coastal erosion and coral bleaching, exacerbated by rising sea levels and higher ocean temperatures (Omar et al., 2024). The degradation of marine biodiversity due to climate-induced stressors poses a significant risk to eco-tourism, which depends on coral reefs, mangroves, and marine wildlife. If left unchecked, these changes may lead to reduced tourist arrivals, particularly from international markets where eco-tourism is a significant draw.

Impacts of Extreme Weather Events on Tourism Infrastructure

Extreme weather events, such as storms, floods, and droughts, are increasing in frequency and intensity due to climate change. Malaysia, situated in the tropics, is particularly prone to such events, with the monsoon season often bringing heavy rains, floods, and typhoons. These extreme weather events can disrupt tourism activities, cause damage to infrastructure, and lead to temporary or long-term closures of key tourist destinations. For example, the 2014 floods in Malaysia significantly impacted the tourism sector, leading to the cancellation of numerous holiday bookings and a substantial reduction in tourist arrivals during peak seasons (Sungip et al., 2018).

In addition to the direct effects of these events on tourism, such disruptions may also result in longer-term economic consequences, as tourism businesses may struggle to recover from the damage to their facilities and reputation. The increased frequency of such events underlines the need for greater resilience and adaptation strategies within the tourism sector.

Climate Change and the Sustainability of Cultural and Natural Heritage

Climate change also poses a threat to the cultural and natural heritage of tourist destinations. Rising temperatures and extreme weather conditions can damage historical monuments, art, and cultural sites, significant draws for cultural tourism. Similarly, ecosystems that attract nature-based tourism are vulnerable to temperature fluctuations, droughts, and excessive rainfall, all of which can lead to the degradation of the natural attractions that tourists visit (Gössling et al., 2018).

In Malaysia, biodiversity hotspots such as national parks and nature reserves are threatened due to the changing climate. For instance, the loss of forests and wildlife habitats due to temperature shifts and erratic rainfall can reduce the appeal of eco-tourism destinations (Pimid et al., 2022). The degradation of natural habitats also affects local communities that rely on tourism for their livelihoods, creating a complex challenge that demands conservation and adaptation measures to protect these valuable resources.

The effects of climate change on tourism are becoming increasingly evident, with

rising temperatures, shifting precipitation patterns, and extreme weather events altering tourist behaviors and destination attractiveness. In Malaysia, the tourism sector is highly vulnerable to these changes, particularly in coastal areas, eco-tourism regions, and cultural heritage sites. It is essential for Malaysia to adopt adaptation strategies that incorporate climate resilience, sustainability, and infrastructure development to ensure the sustainability of the industry. By addressing the challenges posed by climate change, Malaysia can continue to thrive as a key global tourist destination while minimizing its environmental impact.

Therefore, the primary objective of this study is to examine the impact of climate change on the international tourism industry in Malaysia. In contrast to previous research that solely examined CO_2 emissions, the present study adopts a more comprehensive approach by incorporating various climate change indicators, including temperature, precipitation, and CO_2 emissions. This approach aims to provide a more holistic representation of the Malaysian context.

CO_2 Emissions, Tourism, and GDP: Insights from the Malaysian Context

Figure 2 demonstrates an interesting trend between tourism and carbon emissions in Malaysia over the years. The data shows an initial increase in CO_2 emissions from 1998 to 2007, followed by a noticeable decrease from 2007 to 2009. However, after 2007, the trend of CO_2 emissions started to rise again. Meanwhile, tourism arrivals show an ascending trend from 1998 to 2002, with a subsequent descending trend from 2002 to 2003. Following that, tourism activities in Malaysia increased

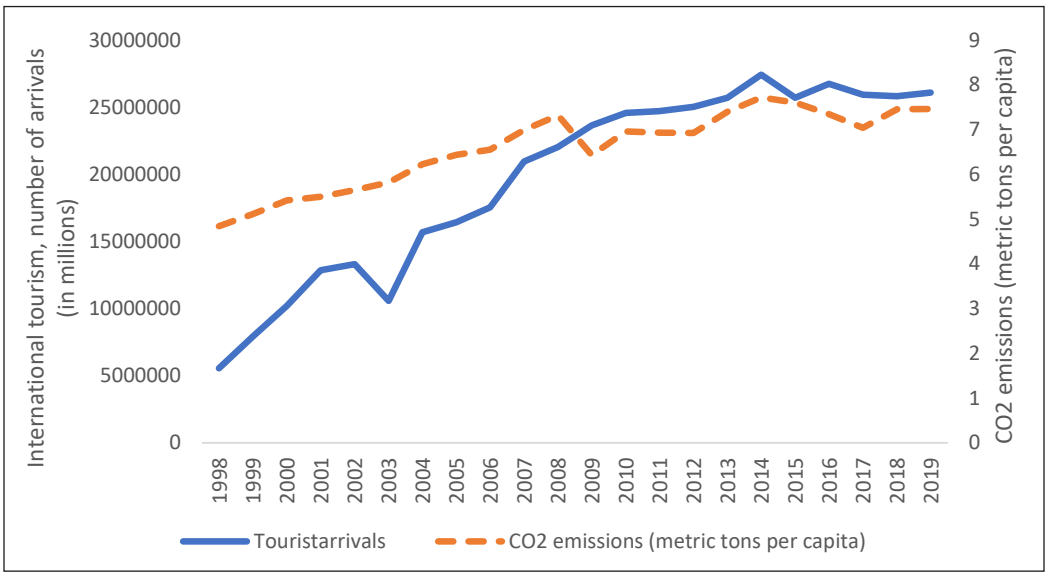

Figure 2. CO_2 emissions and tourism in Malaysia (1998–2019)
Source: World Bank (2025), Tourism Malaysia (2025)

from 2003 to 2014 before they decreased until 2015, and subsequently, there was a noticeable rise in tourism volume again. The general trend indicates a significant rise in tourism flows, which is related to a small increase in CO_2 emissions; this implies a direct connection between tourist arrivals and CO_2 emissions. The expansion of this phenomenon is accompanied by environmental considerations, specifically pertaining to the release of carbon emissions. Tourism-related activities are widely acknowledged as a significant source of carbon emissions, thereby exerting detrimental impacts on the environment, encompassing climate change, pollution, and ecological degradation.

Figure 3 illustrates the co-movement relationship between GDP and tourism in Malaysia. Both variables exhibit an upward trend over time, indicating a positive correlation. The graph demonstrates that GDP and tourism in Malaysia are positively and indirectly related. The positive co-movement between GDP and tourism suggests that the growth and expansion of the tourism sector contribute significantly to the overall economic prosperity of the country. As tourism revenues increase, they have a cascading effect on various economic aspects, including bolstering government revenues, enhancing household income, and creating additional employment opportunities. Consequently, the abovementioned cumulative effects have a favorable overall impact on the economy, fostering national prosperity and economic growth.

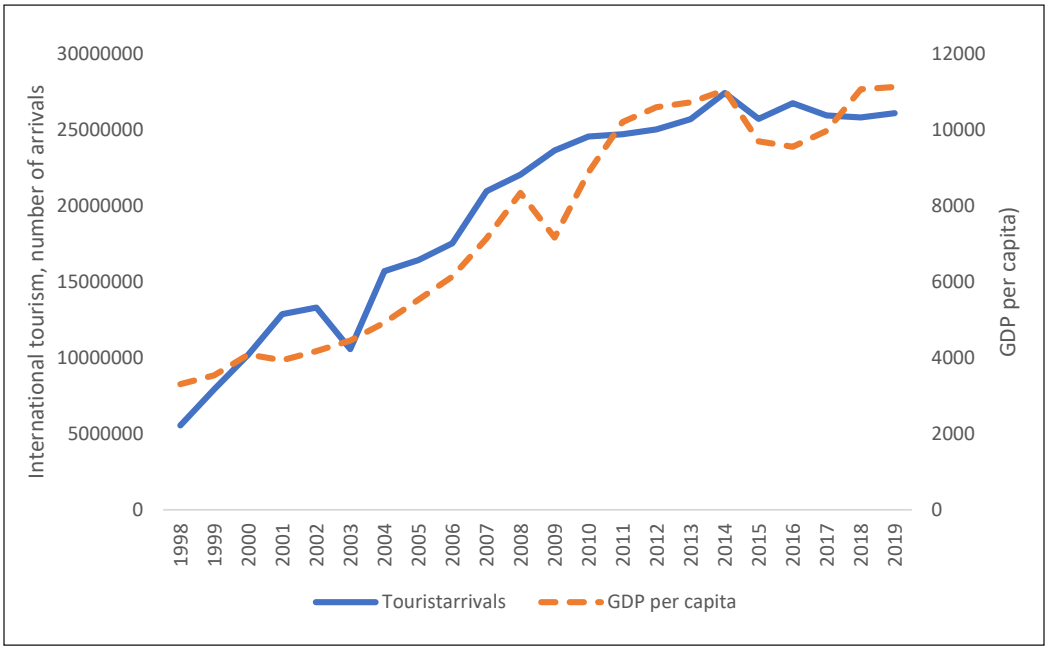

Figure 3. GDP and tourism in Malaysia (1998–2019)
Source: World Bank (2025), Tourism Malaysia (2025)

Theoretical Implications: Climate Factors and Malaysia's Tourism Sector

The relationship between climate factors—such as temperature, precipitation, and CO_2 emissions—and Malaysia's tourism sector has significant theoretical implications, particularly within the frameworks of the Global Energy Balance Theory, the Environmental Kuznets Curve (EKC) hypothesis, and the Tourism-Led Growth (TLG) hypothesis.

The Global Energy Balance Theory explains how greenhouse gases (GHGs), including CO_2, trap heat within the Earth's atmosphere, leading to climate changes that affect global weather patterns. In Malaysia's tourism sector, rising temperatures and unpredictable precipitation patterns may disrupt tourism activities, especially in eco-tourism and coastal destinations. As climate conditions shift, extreme weather events could reduce the appeal of natural attractions, potentially influencing tourist arrivals and seasonal tourism demand.

The EKC hypothesis posits that economic growth initially leads to environmental degradation, but improved policies and awareness foster a shift toward sustainability (Sharma, 2025). Malaysia's tourism-driven economic expansion has increased CO_2 emissions, particularly through air travel and transportation. However, as the country advances, investments in green infrastructure, sustainable tourism initiatives, and stricter environmental regulations could help mitigate the environmental impact of tourism. This aligns with the EKC framework, suggesting that Malaysia may eventually reach a turning point where economic growth and environmental sustainability coexist.

The TLG hypothesis asserts that tourism catalyzes economic growth by boosting employment, foreign exchange earnings, and infrastructure development (Balaguer & Cantavella-Jorda, 2002; Mester et al., 2023). While Malaysia has effectively leveraged tourism as a key driver of its economy, climate change presents a growing challenge. Rising temperatures, erratic rainfall, and worsening CO_2 emissions directly influence tourist preferences, affecting destination attractiveness and seasonal fluctuations in visitor arrivals. Additionally, climate-induced changes, such as coastal erosion and biodiversity loss, threaten Malaysia's eco-tourism and marine-based attractions.

By integrating temperature and precipitation alongside CO_2 emissions, this study extends previous research primarily focused on carbon emissions alone. This broader perspective provides a more comprehensive understanding of the long-term sustainability challenges facing Malaysia's tourism industry. The findings are expected to contribute to policy-making by emphasizing climate-responsive tourism strategies aligned with sustainable development goals (SDGs) and Malaysia's long-term economic plans.

MATERIALS AND METHODS

Theoretical Underpinnings

Several theories can be used to explain climate change, including CO_2 emissions, changes in precipitation patterns, and temperature

changes. The Global Energy Balance Theory relates how greenhouse gases (GHGs) trap heat, emit CO2, and eventually lead to an increase in global temperature in the long run. In addition, an increase in surface temperature affects atmospheric circulation, changing precipitation patterns. On the same note, the Hadley Cell Expansion Theory proposes shifting climate zones where tropical countries receive more rainfall than subtropical countries due to shifts in tropical circulation. Hence, the theoretical underpinning of this research commences by positing the notion that climate change potentially wields a substantive influence over international tourism. Existing scholarly contributions have endeavored to establish a nexus between tourism, the environment, and economic advancement (Elsayed, 2023; Eyuboglu & Uzar, 2020; Irfan et al., 2023; Khanal et al., 2022; Ullah et al., 2022). Thus, the conceptual framework underpinning the model under consideration in this study is substantiated within the scholarly discourse, guided particularly by the investigations conducted by Ullah et al. (2022) and Elsayed (2023). The comprehensive structure of the equation encapsulating the interrelationships among tourism, the environment, and economic growth takes the subsequent form:

$$Tourist\ recepits = f(CO_2, \text{Precipitation, Temperatures, GDP}) \quad [1]$$

In order to derive the direct elasticities of coefficients and enhance the smoothness of the estimation procedure, a logarithmic transformation is applied to the variables. This logarithmic transformation facilitates the identification of appropriate time series models derived from Equation 1. The representation of the equation takes the subsequent form:

$$LNTourist\ receipts_t = \beta 0 + \beta 1 LNCO2_t + \beta 2 LNPrecipitation_t + \beta 3 LNTemperatures_t + \beta 4 LNGDP_t + \varepsilon_t \quad [2]$$

The study encompasses the time frame of 1998–2019, and the data for tourism receipts were obtained from the Strategic Planning Division, Tourism Malaysia. Additionally, supplementary data were extracted from the World Bank database (World Development Indicators). The elasticities of the dependent variable, tourism receipts, are represented by the coefficients of the variables β1, β2, β3 and β4. These coefficients reflect the responsiveness of tourism receipts to variations in the independent variables, namely CO_2 emissions, precipitation (annual rainfall), average annual temperatures, and per capita GDP. The symbol β0 represents the constant term in the equation, while ε_t represent the random disturbance term. This study used the autoregressive distributed lag (ARDL) technique and time series data as analysis tools to establish the link between the short- and long-term effects of climate change and international tourism.

Pesaran and Pesaran (1997) and Pesaran and Shin (1999) created the ARDL method for cointegration. The ARDL method

offers various advantages in comparison to alternative cointegration methods, primarily due to its ability to distinguish between long-term and short-term effects within the model. By employing this methodology, it becomes feasible to ascertain the reciprocal association between the interpreted and dependent variables over extended and abbreviated time frames within a single equation, thereby facilitating the estimation and interpretation of its outcomes. According to the paper by Pesaran and Shin (1999), the ARDL technique can be adopted to evaluate the scale of impact of each explanatory factor on the dependent factors regardless of whether these factors are stationary of order zero I(0), integrated of order one I(1), or mutually co-integrated. The current study utilizes the ARDL methodology proposed by Pesaran et al. (2001) as it is known for its effectiveness in determining the stationarity of variables at different degrees, namely zero degree I(0), first degree I(1), or a combination of both.

Figure 4 depicts the trends of the five variables, which have been transformed

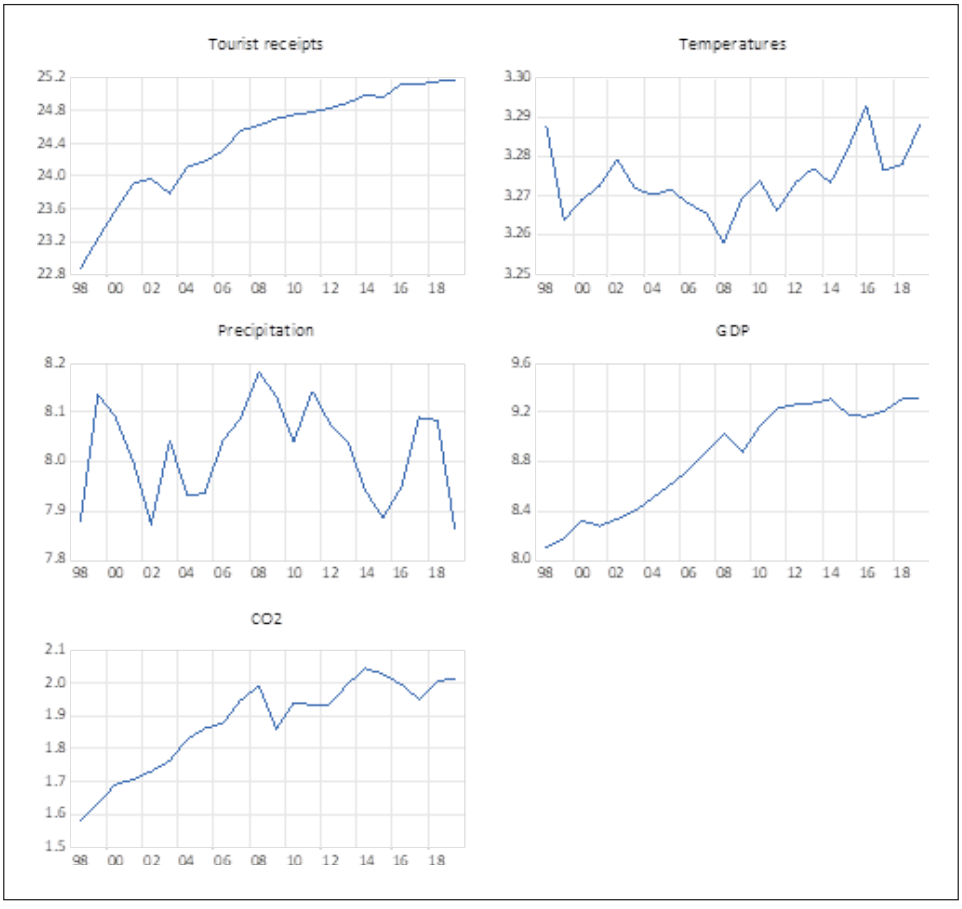

Figure 4. Trends of the natural logarithms of all variables
Source: Author's calculation

into natural logarithms, throughout the study. The figure reveals a consistent pattern among the variables being examined.

Stationarity and Unit Root Test

Before evaluating the short- and long-run coefficients of the model, it is imperative to conduct tests to ascertain the stationarity of the variables. The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are employed to analyze the time series data. The ADF model assesses the presence of a unit root using the following procedure, as shown by Equations 3–4:

$$\Delta y_t = \mu + \delta y_{t-1} + \beta_t + \sum_{i=1}^{k} d_i \Delta y_{t-i} + e_t \quad [3]$$

where k represents the number of lags, $t - I$ takes values from 1 to k, δ denotes $\alpha - 1$, and α signifies the coefficient of y_{t-i}, accompanied by Δy_t representing the first difference of y_t and e_t representing the white noise disturbance. In the context of the Augmented Dickey-Fuller (ADF) test, the null hypothesis entails δ being equal to 0, in contrast to the alternative hypothesis positing δ as less than 0. The test outcome involves non-rejection of the null hypothesis, indicating non-stationarity in the series; conversely, rejection points to the series being stationary. Moving forward, the Phillips-Perron (PP) model, employed to assess the presence of a unit root, operates as follows:

$$\Delta y_t = \mu + \delta y_{t-1} + \beta_t + e_t \quad [4]$$

Cointegration Analyses

The methodology outlined by Pesaran et al. (2001) has the ability to assess the extent to which the equilibrium relationship between the factors or variables is determined across the framework of the error correction model (ECM) of analyzing the cointegration relationship among the variables under investigation. This approach is commonly referred to as the "bounds test approach ."As a result, the ARDL bounds cointegration test can be used to establish the long-term link between the series since the variables demonstrate stationarity at the initial variation, as shown by the unit root test results. The proposed methodology involves the utilization of a model that assumes the subsequent structure as depicted by Equations 5–7:

$$\begin{aligned} &\Delta Tourist\ receipts_t \\ &= \alpha_0 + \sum \propto_1 \Delta Tourist\ receipts_{t-i} \\ &+ \sum \propto_2 \Delta CO2_{t-i} + \sum \propto_3 \Delta Precipitation_{t-i} \\ &+ \sum \propto_4 \Delta Temperatures_{t-i} \\ &+ \sum \propto_5 \Delta GDP_{t-i}\ \varphi ECT_{t-1} + \beta_1 Tourist\ receipts_{t-1} \\ &+ \beta_2 CO2_{t-1} + \beta_3 Precipitation_{t-1} \\ &+ \beta_4 Temperatures_{t-1} + \beta_5 GDP_{t-1} + \varepsilon_t \end{aligned} \quad [5]$$

where Δ' is the First Difference, α_0 is an intercept, $\propto_1 : \propto_5$ short-term parameters, $\beta_1 : \beta_5$ long-term parameters, φ Error Correction Term, ε_t residuals.

Equation 3 can be decomposed into two separate equations in the following manner:

The first equation represents the error correction model, which describes short-term data and is demonstrated as follows:

$$\Delta Tourist\ receipts_t = \alpha_0 + \sum \propto_1 \Delta Tourist\ receipts_{t-i} + \sum \propto_2 \Delta CO2_{t-i} + \sum \propto_3 \Delta Precipitation_{t-i} + \sum \propto_4 \Delta Temperatures_{t-i} + \sum \propto_5 \Delta GDP_{t-i}\ \varphi ECT_{t-1} + \varepsilon_t \quad [6]$$

Meanwhile, the second equation below refers to long-term data:

$$\Delta Tourist\ receipts_t = \beta_1 Tourist\ receipts_{t-1} + \beta_2 CO2_{t-1} + \beta_3 Precipitation_{t-1} + \beta_4 Temperatures_{t-1} + \beta_5 GDP_{t-1} + \varepsilon_t \quad [7]$$

Data and Variables

The selection of variables for this study has been guided by the theoretical framework established through prior research endeavors. The interconnections among these chosen variables have been scrutinized utilizing annual time-series data spanning 1998 to 2019. It is noteworthy that while tourist receipts data were accessible from the year 1998 onwards, precipitation and temperature data were available only until 2019. Consequently, the determination of the sampling period was contingent upon the availability of annual data predating the onset of the COVID-19 pandemic, thus enabling an examination of the enduring relationships among the variables. Table 1 shows the description of the variables and the source of data.

RESULTS

The annual records from 1998 to 2019 showed that every variable utilized in this research comprises 22 observations. Analysis of the descriptive statistics of these variables, represented in their natural logarithmic form, revealed that they exhibited a distribution that approximated a normal pattern within a reasonable range, as evidenced in Table 2. This suggests

Table 1
Data and variables

Variables	Indicators	Abbreviation	Source of data
International tourism receipts	International tourism revenue	Tourist receipts	Strategic Planning Division, Tourism Malaysia
CO_2 emissions	CO_2 emissions	CO_2	World Bank database
Precipitation	Annual rainfall	Precipitation	World Bank database
Temperatures	Average annual temperatures	Temperatures	World Bank database
GDP per capita	Malaysia's Gross domestic product per capita	GDP	World Bank database

Source: World Bank (2025), Tourism Malaysia (2025)

Table 2
The descriptive statistics of the variables

Variable	Mean	Median	Maximum	Minimum	Std. Dev	Jarque-Bera (chi^2)
Tourist receipts	24.4399	24.6635	25.1793	22.8728	0.6574	2.5684(0.2769)
CO_2	1.8781	1.9359	2.0437	1.5781	0.1381	2.3895(0.3028)
Precipitation	8.0204	8.0417	8.1832	7.8628	0.0983	1.4792(0.4773)
Temperatures	3.2740	3.2730	3.2929	3.2581	0.0084	0.9160(0.6325)
GDP	8.8454	8.9533	9.3176	8.1044	0.4287	2.3694(0.3058)

Note: The number of observations is 22
Source: Author's calculation

Table 3
Estimated results for the Unit root test at the level of the variable

	ADF		PP	
	Level	First Difference	Level	First Difference
Tourist receipts	3.4395	-3.1794***	3.2045	-3.1616***
CO_2	1.7638	-4.5235***	2.1164	-4.5235***
Precipitation	-0.0658	-5.0828***	-0.0796	-5.6725***
Temperatures	0.6675	-5.7569***	0.0125	-8.4245***
GDP	2.8027	-3.4290***	2.8833	-3.3952***

Note: The unit root test is based on ADF and PP test statistics with no intercept and no trend. ***, ** and * denote 1%, 5% and 10% significant levels

that the data's distribution is unlikely to yield misleading or spurious outcomes. Furthermore, the Jarque-Bera statistics ascertained that all series possessed a mean of zero and a finite covariance. All variables underwent a logarithmic transformation prior to the estimation process to mitigate the effects of heteroscedasticity and facilitate the computation of elasticities.

The findings of the unit root test are presented in Table 3. Based on the results of the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test, it can be concluded that the null hypothesis for all variables cannot be rejected at a significance level of 1%. However, the null hypothesis for all variables at the first difference can be rejected at a significance level of 1%. Therefore, according to the results of both the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, it can be concluded that all the variables, which are in the form of time series, exhibit first-order integration *I(1).*

The tests confirm that all variables are stationary after first-order differencing, and the sample size is relatively small at 22, so the ARDL approach is deemed the most appropriate method for conducting the cointegration test. The optimal lag length must be determined prior to evaluating the long- and short-term associations (Nkoro & Uko, 2016). The results from the Schwarz information criterion (SIC) and Akaike

Table 4
Selecting optimal lag according to VAR lag order

Lag	LogL	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	151.3785	NA	6.07e-13	-13.94081	-13.69211	-13.88683
1	220.2861	98.43954*	1.01e-14*	-18.12249*	-16.63032*	-17.79865*

Source: Author's estimation

information criterion (AIC) indicate that the most suitable lag length is 1, as presented in Table 4.

The optimal lag length of 1 was selected based on the Schwarz Information Criterion (SIC), balancing model complexity and accuracy. GDP per capita was included as a control variable to account for economic factors influencing tourist receipts, ensuring the robustness of our model's findings.

Table 5 presents a comprehensive summary of the outcomes obtained from the ARDL bounds testing. The F-statistics, calculated to be 15.553775, surpass both the lower bound tabulated value of 4.280 and the upper bound critical value of 5.840. The results of our study suggest that there exists a sustained association between international tourism and various other independent variables.

Table 5
Bound test

Test statistic	**Value**	**K**
F-statistic	15.553755	4
Critical Value Bounds		
Significance	I(0) Bound	I(1) Bound
10%	2.525	3.560
5%	3.058	4.223
1%	4.280	5.840

Source: Author's estimation

With the verification of cointegration among the variables, the coefficients of the variables must be evaluated in both the short and long term. The ARDL model has the capability to simultaneously estimate both short-run and long-run effects of the variables. The findings from the ARDL analysis (Table 6) indicate a robust and statistically significant positive association in the long term between international

Table 6
ARDL long-run coefficients

Long run coefficients				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Temperatures	29.4985***	7.2162	4.0878	0.0009
Precipitation	2.1793***	0.7089	3.0741	0.0073
CO_2	4.1801***	0.8778	4.7619	0.0002
GDP	-0.2185	0.3157	-0.6920	0.4988
C	-95.4503***	27.6668	-3.4500	0.0033

Note: ***, ** and * denote 1%, 5% and 10% significant levels

Table 7
Estimating the short-run relationship and the error correction model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D (Temperatures)	10.6023***	2.6364	4.0215	0.0010
D (Precipitation)	0.2142	0.1944	1.1022	0.2867
D (CO_2)	1.0030***	0.4156	2.4134	0.0282
D (GDP)	0.2916	0.1973	1.4780	0.1588
ect	-0.7497***	0.0643	-11.6508	0.0000
Adjusted R	0.8335			

Note: ***, ** and * denote 1%, 5% and 10% significant levels

tourism and variables such as CO_2 emissions, precipitation, and temperatures. Furthermore, a positive but insignificant correlation exists between GDP per capita and international tourism.

According to the findings presented in Table 7, the error correction coefficient exhibits a negative sign, indicating statistical significance at a level below 1%. The coefficient is reported as 0.7497, indicating that the macroeconomic system successfully resolves short-term imbalances in the independent variables from the year prior to the present one at a rate of about 75% to achieve long-run equilibrium. The obtained value of -0.7497 signifies that the economic system requires an estimated duration of approximately 1.33 years (1/0.7497=1.33) to reach a state of equilibrium. Nevertheless, the short-term coefficients of the independent variables, namely CO_2 emissions and temperatures, exhibited statistical significance, suggesting a short-term association between international tourism and these aforementioned independent variables. In the short term, a limited and statistically insignificant correlation exists between GDP, precipitation, and international tourism.

Following the research investigation of both long-term and short-term associations, diagnostic tests must be performed to verify the model's reliability and detect any potential shortcomings that could compromise the accuracy of its outcomes. Table 8 demonstrates the diagnostic tests for the ARDL model. As indicated by the adjusted R-squared in Table 7, the coefficients of determination are found to be significantly high. This suggests that a substantial proportion of the variation in international tourism can be well-explained by the explanatory variables used in the model. Furthermore, the Durbin-Watson statistic can generate a high yield, signifying an insignificant level of autocorrelation in the model's residuals. Additionally, the remaining statistics show that the model is unaffected by serial correlation, functional form, normalcy, and heteroscedasticity concerns. These diagnostic tests provide reassurance that the ARDL model used in this study is robust and reliable, thus enhancing confidence in the validity of

Table 8
Diagnostic tests for the ARDL model

Diagnostic tests	Tests	Test-statistic	Prob
Autocorrelation	Durbin-Watson stat	2.229605	
Serial correlation	Breusch-Godfrey LM Test	3.028344	0.0987
Functional form	Ramsey Reset Test	3.800908	0.0798
Normality	Jarque-Bera	0.913733	0.633265
Heteroscedasticity	ARCH LM	0.419793	0.8985

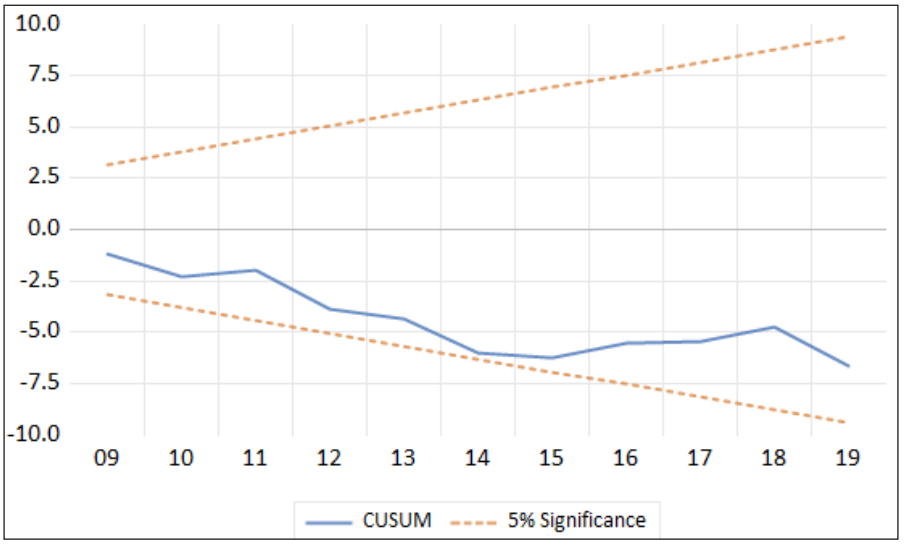

Figure 5. CUSUM plot
Note: The straight lines represent critical bounds at a 5% significance level

its findings and conclusions regarding the relationships between climate change and international tourism.

The stability of the model was examined using CUSUM and CUMSUM of Squares tests, and the results are presented in Figures 5 and 6, respectively. It is observed that the estimated parameters fall within the range between the two lines, indicating that these parameters are statistically significant at the 5% level of significance. Brown et al. (1975) reported the criticality of these tests for recognizing alterations in data structure and measuring the reliability of both long-term and short-term parameters. Apart from that, adopting Theil's Inequality Coefficients resulted in a value of approximately 0.001, which is nearly zero. This proximity to zero signifies the model's strong predictive ability, as demonstrated in Figure 7. As a result, the estimated model does not exhibit significant problems that could hinder its proper functioning. Consequently, the obtained results can be deemed reliable for estimation, forecasting, and policy-making purposes.

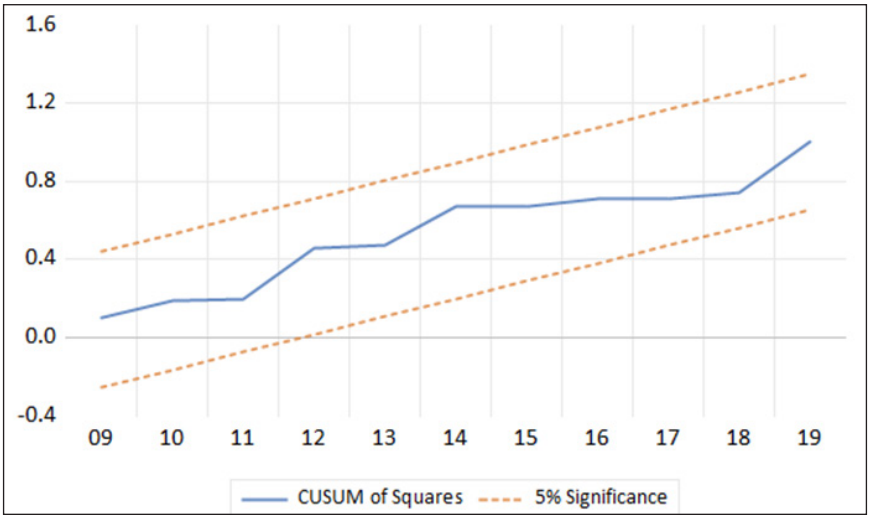

Figure 6. Plot of (CUMUS of Squares)
Note: The straight lines represent critical bounds at a 5% significance level

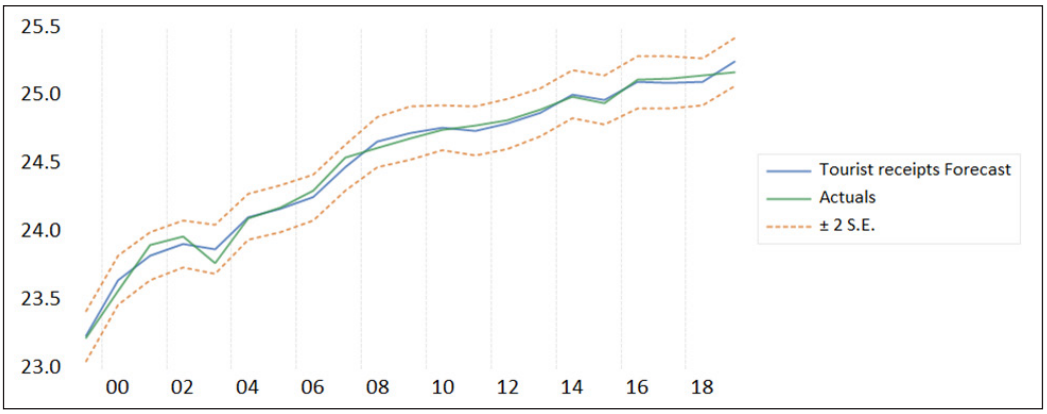

Figure 7. Predictive capability test of the unrestricted error correction model

The Fully Modified Least Squares (FMOLS) and Canonical Co-integrating Regression (CCR) methods were conducted to reinforce the reliability of the enduring outcomes derived through the ARDL framework (Table 9). Impressively, the long-term estimations from both FMOLS and CCR manifest a remarkable congruity, exhibiting identical directional trends. Evidently, the outcomes underscore that the protracted coefficient associated with CO_2 emissions adheres to the expected positive orientation, 3.0768 and 3.7402, in FMOLS and CCR analyses, maintaining a significant level of 1%. This steadfast alignment mirrors the findings procured through the ARDL estimations.

Table 9
Results of the FMOLS and CCR regressions

Fully Modified Least Squares (FMOLS)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Temperatures	15.9944**	7.5611	2.1154	0.0500
Precipitation	0.8676	0.6396	1.3564	0.1938
CO_2	3.0768***	1.0244	3.0036	0.0084
GDP	0.3345	0.3370	0.9925	0.3357
C	-43.6058	28.2766	-1.5421	0.1426
Canonical Co-integrating Regression (CCR)				
Temperatures	19.9459*	10.6218	1.8778	0.0788
Precipitation	1.3435	0.9109	1.4748	0.1597
CO_2	3.7402***	1.1017	3.3950	0.0037
GDP	0.1226	0.4055	0.3023	0.7663
C	-59.7422	40.0718	-1.4909	0.1554

Note: ***, ** and * denote 1%, 5% and 10% significant levels

DISCUSSION

Tourism assumes a crucial role at the global level, making substantial contributions to generating employment opportunities, expanding economic activities, and promoting regional integration (Othman & Rosli, 2023). Although tourism can have beneficial economic effects, it is crucial to recognize that it also carries negative consequences, particularly in terms of environmental pollution. The significance of the impacts of tourism on CO_2 emissions in a country stems from high economic activity and increased energy usage (Ullah et al., 2022). The relationship between tourism and the environment has garnered increasing attention, and this study enriches the existing body of knowledge by empirically investigating the repercussions of climate change on the international tourism sector in Malaysia.

The study employed ADF and PP unit root tests alongside long-run and short-run ARDL econometric methodologies to pursue this aim. The outcomes stemming from the ADF and PP tests revealed the stationarity of the variables under investigation—namely, tourist receipts, CO_2 emissions, precipitation, temperatures, and GDP—in their logarithmic transformations upon first differencing. Subsequently, the examination was extended to assess long-term cointegration among these variables. Employing the ARDL bounds test approach, the findings indicated the presence of at least one co-integrating relationship.

The study's findings indicate that CO_2 emissions, precipitation, and temperatures have a significant positive long-term impact on tourism receipts, highlighting the role of environmental factors in shaping tourism demand. This suggests that changes in climate variables may influence international tourist spending patterns by enhancing destination appeal or indirectly reflecting broader economic

and infrastructural developments that drive tourism revenue. This finding is in contrast to other studies, such as Atasoy & Atasoy (2020), Butler (2000), Elsayed (2023), and Durbarry and Seetanah (2015), who found that CO2 emissions have a significant negative impact on international tourism revenue. In addition, Elsayed (2023), Lise and Tol (2002), and Sookram (2009) discovered that hot or tropical climates can be detrimental to the tourism sector. On the other hand, Seetanah and Fauzel (2018) proposed that high temperatures can promote the tourism sector through an extended warm season. Additionally, CO_2 emissions and temperatures have a favorable and considerable effect on tourism receipts in Malaysia in the short run. Other factors unaccounted for in the study could be driving the positive connection between CO_2 emissions and tourist receipts. For instance, economic growth and development could simultaneously contribute to increased CO2 emissions and higher tourism revenues. Furthermore, it is crucial to consider the long-term implications of such a relationship. Although increased CO_2 emissions might be associated with higher tourist receipts in the short term, the adverse effects of climate change caused by these emissions could pose significant risks to tourism in the future. Climate change can lead to environmental degradation, extreme weather events, and ecosystem disruptions, adversely affecting tourism destinations and reducing their attractiveness to travelers.

While our findings support a positive correlation between CO_2 emissions and tourist arrivals, Elsayed (2023) and Butler (2000) suggest negative impacts of emissions on tourism, particularly in regions where environmental degradation deters travelers. This discrepancy could be attributed to Malaysia's unique positioning as a biodiversity hotspot, where higher tourism activities may coexist with increased emissions. Therefore, while the positive relationship between CO_2 emissions and tourist receipts is an interesting finding, it is important for policymakers and stakeholders to prioritize sustainable practices and mitigate climate change's adverse impacts on the tourism industry. Emphasizing eco-friendly tourism policies and reducing carbon footprints can help maintain the long-term viability of tourism destinations and protect them from the negative consequences of climate change.

CONCLUSION

Malaysia's economy confronts an enduring and formidable challenge from the ramifications of climate change, with its tourism sector particularly susceptible. Unlike previous studies that primarily focused on singular indicators such as CO_2 emissions, this paper integrates multiple climate variables—temperature, precipitation, and CO_2 emissions—to provide a holistic understanding of climate change's impact on Malaysia's tourism industry. This neoteric approach offers tailored insights specific to Malaysia's socio-economic and environmental context. Climate change, as opposed to temporary issues such as violence or health crises like COVID-19, has an extended impact on tourism, influencing the timing of tourist

seasons and the attraction of diverse tourist sites. This paper enhances the understanding of climate-tourism dynamics in developing economies, contributing to the growing discourse on sustainable tourism models in tropical regions. By examining 22 years (1998–2019), this research adds depth to understanding how climate variables shape tourism trends over time.

The results of the unit root tests show that all variables integrate at the first difference. The bounds test demonstrates a steady connection between the variables, suggesting a long-term relationship. The research results highlight the importance of the relationships between international tourism receipts and the model's independent variables. In particular, a substantial and obvious positive long-term relationship exists between international tourism and variables such as CO_2 emissions, precipitation, and temperature. Furthermore, the FMLOS and CCR findings confirm the ARDL outcomes, demonstrating that CO_2 emissions are major contributors to tourism receipts in Malaysia. The government and related stakeholders must take preemptive actions, considering the possible impacts of climate change on Malaysia's tourism business.

Implications of the Study

This study contributes significant insights to policymakers, tourism industry stakeholders, and academics. The findings highlight the importance of climate factors such as temperature, precipitation, and CO2 emissions on Malaysia's tourism sector, highlighting the need for targeted strategies to mitigate the impact of climate change on tourism arrivals. This study provides actionable insights for sustainable tourism development by demonstrating the long-term relationship between these variables. The policy implications for eco-tourism initiatives, particularly in Langkawi, offer pathways for minimizing the environmental footprint and enhancing tourism sustainability. Furthermore, integrating environmentally friendly technologies and infrastructure, such as electric buses and digital ticketing systems, aligns with global trends in sustainable tourism.

Limitations

Despite the novel contributions of this study, some limitations should be acknowledged. The research focuses on 22 years (1998–2019), and future studies may benefit from extending this time frame to account for more recent climate trends and their effects on tourism. Additionally, the study primarily relies on macro-level data, which may overlook more localized or sector-specific variations within the tourism industry. Lastly, secondary data limits the capture of real-time dynamics between climate variables and tourism arrivals, suggesting that future research could incorporate primary data from tourists and businesses to provide new insights.

Recommendations for Future Research

Future research could build upon the findings of this study by exploring the relationship between climate change and

tourism in other developing economies with similar climate vulnerabilities. Researchers may also consider employing advanced modeling techniques like machine learning to predict future tourism trends under different climate scenarios. Furthermore, studies focusing on the behavior of tourists in response to climate-induced changes, including willingness to pay for sustainable tourism options, would offer valuable insights for policymakers and businesses. Finally, exploring the integration of climate change adaptation strategies across diverse regions of Malaysia, including urban and rural areas, would provide a comprehensive framework for ensuring the tourism sector's resilience.

Policy Implications and Eco-tourism Initiatives

Policymakers in Malaysia need to prioritize the establishment of a sustainable tourism sector. This can be achieved by actively promoting the adoption of tourism-related infrastructure that relies on environmentally friendly energy sources as opposed to conventional fossil fuels. One of the most viable initiatives is promoting eco-tourism practices, particularly in Langkawi. Langkawi has the potential to be designated as a flagship destination for green tourism or as a prototype for sustainable eco-tourism practices. For example, tourists could be required to use online ticketing services for hotel reservations and entry to museums and other attractions. Expanding the use of bicycles for short-distance travel and integrating electric buses or taxis within Langkawi can enhance sustainable transportation alternatives. These measures collectively contribute to reducing emissions and preserving Langkawi's environmental beauty, thus enhancing its eco-tourism brand.

Additionally, Malaysia's eco-tourism strategy should integrate progressive, environmentally friendly technologies such as digitalization and mechanization. The widespread use of online ticketing systems and the promotion of waste reduction and recycling initiatives in tourist areas can optimize operational efficiency while minimizing the ecological footprint. Promoting responsible waste disposal among tourists and local communities through programs helps preserve the visual and environmental quality of tourist destinations.

In the foreseeable future, the government can further strengthen efforts to establish Malaysia as a distinguished international center for eco-tourism. An exemplary initiative in this regard involves the sustained implementation of the 'Malaysia Truly Asia' campaign, complemented by a focused eco-tourism strategy to attract international and domestic tourists.

Implementing these strategies will effectively attain a balanced symbiosis between economic advancement and environmental conservation. This approach will guarantee the sustained prosperity of the tourism sector while mitigating its adverse effects on climate change and the natural ecosystem. Ensuring the long-term viability and adaptability of the tourism industry

in Malaysia will also make a significant contribution to the global endeavor of addressing climate change.

While eco-friendly transportation systems, such as electric buses, are viable in urban tourist hubs like Kuala Lumpur, implementing them in remote destinations like the Cameron Highlands may face infrastructural and funding challenges. Future research could explore tourists' willingness to pay for sustainable options, bridging this gap.

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