

Article

The Nexus Between Tourism and Environmental Quality in Countries Most Dependent on Tourism: A RALS Approach to the Cointegration Test

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Abstract: Sustainable tourism encompasses the evaluation of its present and prospective economic, social, and ecological consequences by prioritizing the demands of its natural environment and the local populations. This study examined how tourism affects critical socio-economic variables, such as life expectancy, energy intensity (EI), economic growth (EG), and population, on the environmental quality (EQ) of tourism-dependent countries. The authors employed the newly developed “residual augmented least squares (RALS) cointegration econometric method” to estimate the long-term associations between the study factors. On the other hand, the “autoregressive distributed lag (ARDL) model” was used to estimate long- and short-run estimates. The consequences revealed that, in the long run, the population, the EI, and tourism exert positive pressure on carbon emissions. However, in the short run, the EI, EG, life expectancy (LE), and population exert positive pressure to boost emissions, resulting in environmental degradation. Based on these findings, sustainable tourism management and green EG should be given priority to preserve environmental quality.

Keywords: sustainable tourism; economic growth; RALS cointegration; ARDL model; tourism-dependent countries



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1. Introduction

As a global force, tourism can improve the ecological, social, and economic well-being of people and places if it is managed responsibly [1]. However, the unfavorable effects of this industry’s rapid growth have elevated sustainability to the top of the global political agenda. The promotion of tourism has been recognized as a significant means of attaining the United Nations’ Sustainable Development Goals, which aim to bring prosperity to tourist destinations [2]. According to the report of the “World Tourism and Travel Council” [3], the tourism industry contributes 7.6% to the global EG (GDP), which increased by 22% over 2021 and created 22 million new job opportunities in 2022. Nevertheless, if tourism is not developed sustainably, it has the potential to undermine the ongoing economic progress [4]. Conversely, it is imperative to investigate how tourism affects the ecological quality in its host communities in light of global issues such as social alienation, climate change, and overconsumption.

The prevailing argument suggests that the emissions of carbon dioxide (CO₂) resulting from international travel contribute significantly to climate change [4–6]. The surge in international tourism is expected to amplify energy consumption, thereby establishing a credible link between the expansion of international tourism and CO₂ emissions [7–10].

Furthermore, data from the “International Transport Forum and World Tourism Organization [2]” indicate that transportation-related CO₂ emissions constitute approximately three-quarters of all global tourism-related emissions [11]. This scenario has emerged as a significant concern for the global economy and poses a threat to the environment [12]. Figure 1 illustrates the correlation between tourism and CO₂ emissions.

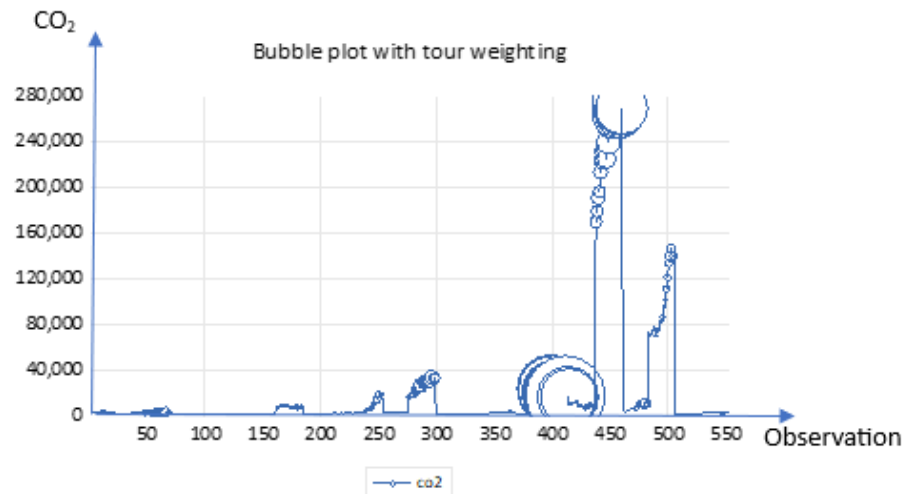


Figure 1. Bubble plot of the CO₂ emissions in the most tourism-dependent countries.

The effective accessibility and affordability of electricity play pivotal roles in facilitating tourist activities and fostering infrastructural development [13]. Conversely, the substantial energy consumption associated with tourism raises concerns regarding carbon emissions and its environmental impact. Previous studies have indicated that there is a constructive connection between ecological degradation and energy usage in tourism [14] since the tourism industry increases energy consumption and creates considerable long-term effects [15]. Consequently, it is necessary to restructure the sector of international tourism to ensure ecological sustainability and the sustainable development of nations [5]. However, following a comprehensive approach to sustainability not only involves evaluating how tourism impacts the environment, but also accounting for population well-being and demographics. While the careful management of population growth can foster sustainable development in tourist destinations, research on the relationship between population growth, density, and CO₂ emissions remains limited [16]. Furthermore, there exists a causal relationship between EG, carbon emissions, and life expectancy, as these factors contribute to environmental degradation, which in turn affects health outcomes and sustainable development [17].

According to this background, the goal of this study was to characterize the impacts of global tourism on the EI, EG, life expectancy, population, and EQ in the most tourism-dependent countries from 2000 to 2022. The nations included were Malta, the Maldives, the Bahamas, the Seychelles, Vanuatu, Cabo Verde, St. Lucia, Cyprus, Belize, Fiji, Cambodia, Barbados, Bahrain, Antigua, Barbuda, Dominica, Montenegro, Croatia, Jamaica, Thailand, Georgia, the Philippines, Kiribati, and Iceland. This research has significance due to the substantial impact of international tourism on the economic viability of these countries. The results of this research are anticipated to aid these countries in developing green and clean energy initiatives and formulating ecologically sustainable tourism strategies to concurrently achieve economic prosperity and environmental well-being.

This study provides a substantial addition to the current body of literature (see Appendix A). Although the influence of foreign tourism on CO₂ emissions has been broadly investigated, none of the studies have included the EI as a controlled variable

in their analyses, to the best of our knowledge. However, it is crucial to account for this energy factor throughout the analysis since it is considered essential in the present time to make the international tourism business more environmentally friendly and mitigate the negative environmental effects linked to the rise in international tourism [18]. The purpose of this study was to fill the existing research gap by looking into the impact of international tourism development on CO₂ emissions while considering the level of EI in countries that heavily rely on tourism. In terms of methodological contribution, the authors used the recently developed “RALS unit root test and RALS cointegration” to examine the stationarity of the data and the long-term relationship between the factors of concern. Furthermore, this research contributes to the existing body of literature by using the “Autoregressive Distributive Lag (ARDL) Model” [19] as an econometric method to examine the relationship between variables in both the short and long-term, resulting in more accurate and dependable results [20,21]. This study connected tourism and the EI to the Sustainable Development Goals (SDGs) and can thus help policymakers make appropriate policies. This research paper has the following segments: an overview of related literature works, the presentation of the data and the methodology used, an explanation of the findings, and a summary with recommendations for future actions or interventions from a policy perspective regarding each section covered in this document.

The Conceptual Framework

Tourism-Sustainable Development Nexus and Prerequisites

The urge for tourism practitioners to quickly address the globalizing effects of tourism on destinations is increasing [1]. Tourism, being one of the greatest global sectors, significantly contributes to community development while also exerting substantial cultural, social, and ecological effects. The sector’s dependence on nature is intensifying the need for the sustainable use of natural resources to address the global challenges of climate change and biodiversity loss [22,23].

Tourism both influences changes in the environment and is impacted by the environment. A significant issue is tourism’s influence on land use transformations, and such modifications, coupled with global warming, result in rising surface temperatures and a decline in ecological integrity and human well-being [24]. The incorporation of sustainable development concepts in tourism is essential since this sector is one of the largest globally. The tourism sector needs to take part in the adoption of environmental and socio-cultural sustainability practices to enhance the welfare of both people and the planet [25]. Despite this recognition, detrimental environmental repercussions continue to manifest as a result of tourism operations [26]. For these reasons, scholars warn that the effects of climate change, propelled by greenhouse gas emissions, transportation, and land use alterations resulting from population growth, need immediate and urgent action, especially in prominent tourist regions where the impact on quality of life is significant [27].

Sustainable development encompasses economic, environmental, and social components, referring to growth that meets the present demands without compromising the ability of future generations to meet their own needs [28,29]. The primary focus of the ecological dimension of sustainability is to restrict human activities within the ecosystem’s carrying capacity, which includes the materials, energy, land, and water in a specific area while prioritizing the quality of human existence, which is critically linked to air quality and health. Conversely, economic sustainability emphasizes the effective use of resources to improve the operational profit and increase the market value. It also addresses the substitution of natural resources with synthetic ones, as well as reuse and recycling. Moreover, social sustainability emphasizes the social welfare of the population [30].

The attainment of sustainability relies on the crucial collaboration between the economy, the environment, and society. In the case of tourism-dependent countries, employing the industry as a source of economic growth could be linked to increased energy consumption to meet the demands of the industry and tourists, a rise in the population, and changes in environmental conditions and the life expectancy of people. For instance, scholars have reported that densely residential areas have less greenery while prioritizing efficient land use, which means elevated levels of heat stress that are associated with increased mortality and an amplified chance of acquiring numerous illnesses [31]. Moreover, it is argued that a country's social, economic, and environmental characteristics are indicative of its citizens' life expectancy [32]. Therefore, gauging the interactions among variables such as economic development, renewable energy resources, CO₂ emissions, and life expectancy aligns with the sustainable development paradigm [33].

2. Literature Review

2.1. *Tourism vs. Carbon Emissions*

The impact of tourism on CO₂ emissions in Brazil was studied recently by Ref. [4], the author of which found similar results. Other studies, such as Ref. [34] in China, Ref. [10] in Thailand, Ref. [9] in Kuwait, and Ref. [8] in the most visited countries, have declared that tourism imposes a positive impact on carbon emissions. Furthermore, the authors of Ref. [35] stated that the tourism development coefficient is positively associated with carbon emissions in the case of 70 nations. Additionally, research findings have indicated that the tourism industry negatively affects the EQ [36–41].

However, many other studies, such as Refs. [42–44], have used threshold OLS estimation, bootstrapping ARDL, the panel-corrected standard errors (PCSE) model, and the quantile autoregressive distributed lag (QARDL) model to estimate the tourism–carbon emissions link. All of these studies have reported that, in the studied destinations, tourism has a positive impact on environmental quality. Furthermore, the authors of Refs. [45,46] applied the QARDL econometric model to Malaysia and China, and they demonstrated that tourism development had a positive influence on the environment. In light of the aforementioned literature, which is inconsistent, further research is necessary to advance the literature.

2.2. *EI and Carbon Emissions*

Despite its importance, the EI is rarely discussed in the context of CO₂ emissions, and the few available studies show a lack of agreement on the nature of the interaction. For instance, Ref. [47] demonstrated that energy efficiency has consistently led to a drop in CO₂ emissions at all levels, with the greatest reduction seen at the 90th percentile in developing nations. The authors of Ref. [48] used the statistical techniques of the panel-generalized method of moments (GMM) and two-stage least squares (2SLS) to measure the impact of the EI on the mitigation of CO₂ impacts via a reduction in its intensity. In a similar vein, the authors of Ref. [49] used spatial econometric regression techniques within the framework of China's environment and observed a negative association between two variables. According to their findings, increasing the EI may help reduce carbon emissions in a local area.

On the contrary, Ref. [50] revealed that the EI enhanced the carbon emission intensity in the surrounding areas. Multiple studies, including Ref. [49] in 25 large emerging economies; Ref. [51] in 50 African countries; Ref. [52] in developing and transition economies; Ref. [53] in Morocco; Ref. [54] in China; and Ref. [55] “in higher-, upper-middle-, lower-middle-, and low-income groups” have shown that increased energy intensities lead to elevated quantities of carbon dioxide emissions. The contradictory character of the findings described in

the literature necessitates further investigation into the correlation between EI and CO₂ in our study.

2.3. EG and Carbon Emissions

The empirical findings have substantiated the presence of the EKC phenomenon with CO₂ emissions inside China. The authors of Refs. [56–60] have confirmed the existence of the EKC, which posits that, in the first stages of economic development, there is a direct relationship between environmental deterioration and EG. However, once EG and the per capita income surpass a specific threshold, there is an observable trend of environmental pollution mitigation. Nevertheless, several academics have expressed skepticism over the EKC's legitimacy. Typical cases are provided in Ref. [61] in Turkey and Ref. [62] in China. However, the authors of Refs. [12,63–65] stated that EG decreases the EQ, whereas EG squared increases the environmental quality. The authors of Refs. [63,66] discovered that EG decreases CO₂, which boosts the ecological environment. Given the importance of EG and CO₂ emissions in the sustainable tourism discourse, we included EG as an explanatory facet in our study.

2.4. Population, Life Expectancy, and Carbon Emissions

The examination of the impact of demographic variables on carbon dioxide emissions has emerged as a hot topic recently. In terms of the study scope, the primary focus of the investigation has been mostly within a single nation [17,67–69] or a group of countries, such as 154 countries [70]; BRICS [71]; the next 11 economies [72]; Portugal, Italy, Ireland, Greece, and Spain (PIIGS) [73]; or 46 Sub-Saharan African countries [74]. Simultaneously, the majority of research inquiries have centered on the following three themes: LE [17,67,69,71,75], population [68,72,74], and urbanization [70,73,76]. The theoretical frameworks used to analyze these three parameters provided varying results. Therefore, we used two factors, LE and population, to estimate the link with carbon emissions in the case of the most tourism-dependent countries. A summary of the aforementioned literature is presented in Appendix A.

3. Methodology

3.1. Data

The methodology employed in our study consisted of multiple steps, as illustrated in the flow chart in Figure 2. Our research investigated the association between carbon emissions, energy, tourism, EG, LE, and population in the case of 24 of the most tourism-dependent economies in the world. A basic econometric framework was developed, as shown below:

$$CO_2 = a_0 + a_1 TOUR_{it} + a_2 ENERGY_{it} + a_3 GDP_{it} + a_4 LIFE_{it} + a_5 POP_{it} + \alpha_{it} \quad (1)$$

In Equation (1), the addition of a logarithm was used as a means of facilitating computations pertaining to sizable numerical values, hence aiding in the comparison of the magnitudes of distinct quantities.

$$\ln CO_2 = a_0 + a_1 \ln TOUR_{it} + a_2 \ln ENERGY_{it} + a_3 \ln GDP_{it} + a_4 \ln LIFE_{it} + a_5 \ln POP_{it} + \alpha_{it} \quad (2)$$

In Equation (2), CO₂ depicts the carbon emissions, measured as “CO₂ emissions (kt)”. Carbon emissions are seen as an indicator of the EQ among the 24 economies that heavily rely on tourism. Emissions arise because of the combustion and use of fossil fuels, including solid, liquid, and gaseous fuels, as well as gas flaring activities. The TOUR symbolizes the tourism as “international tourism, number of arrivals”. International inbound tourists

refer to individuals who travel to a foreign country that is distinct from their habitual place of residence, but not inside their customary surroundings, for less than one year and with a purpose that does not include remunerated endeavors. The ENERGY reflects the symbol of the EI, as follows: “EI is the ratio between energy supply and gross domestic product measured at purchasing power parity”. The EI refers to “the measure of energy consumption required to generate a single unit of economic output”. A lower ratio signifies a reduced use of “energy in the production of a single unit of output”. The GDP is used as a symbol of the EG of the tourism economies. It is calculated as “the aggregate of the gross value contributed by all domestic producers within the economy, accounting for any applicable product taxes and deducting any subsidies that are not accounted for in the product valuation”. The LIFE refers to the LE of the residents of the tourism economies. It indicates the following: “LE indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life”. The POP is representative of the total population of the tourism economies.

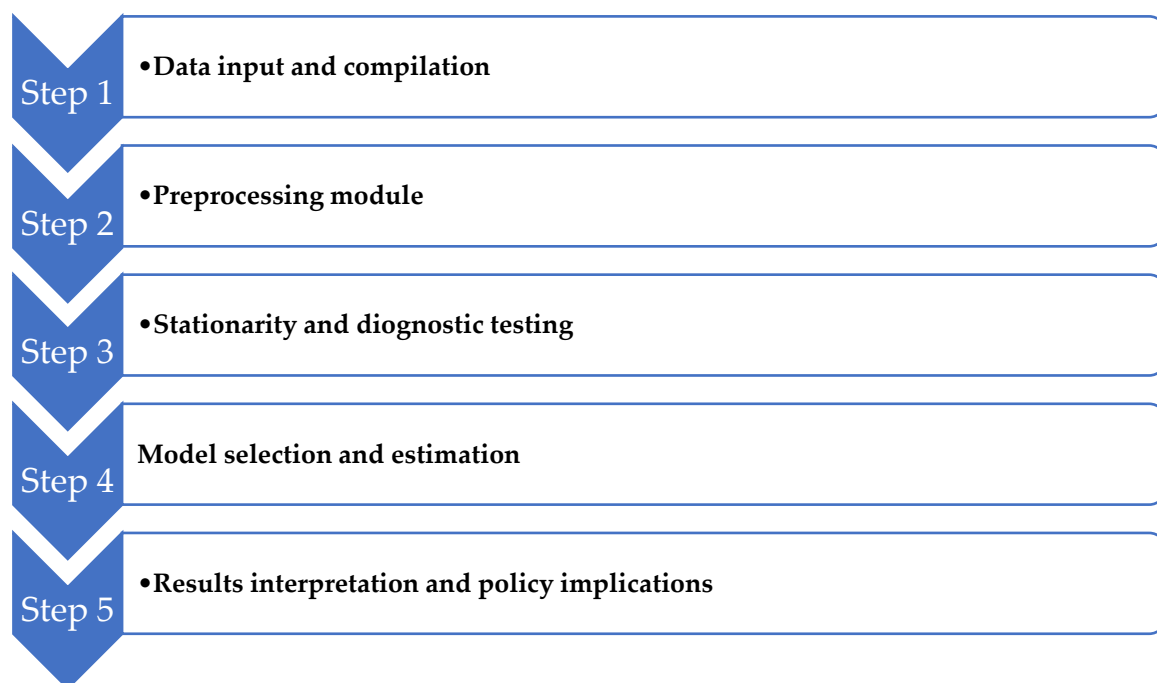


Figure 2. Flow chart depicting the stages used to obtain the study outcomes.

Although model specifications in Equations (1) and (2) are linear for the sake of simplicity and tractability, we do appreciate that some variables—such as tourism arrivals and energy intensity—can have an influence on economic growth (GDP), thereby potentially introducing endogeneity in the model. For instance, tourism-led growth and energy-led growth hypotheses consider tourism development and energy consumption as factors capable of influencing GDP growth importantly. This interconnectedness implies that GDP may be a mediating rather than a strictly exogenous predictor. To address this concern, we embarked on the ARDL modeling strategy, which is widely recognized as being robust to small samples and for accommodating potentially dynamically interrelated variables. Additionally, because ARDL does not impose strict exogeneity, it can accommodate both short- and long-run variable interactions, mitigating simultaneity to a certain extent.

The population is determined by the de facto definition, including all the individuals residing within a certain area, irrespective of their legal status or citizenship. The a_0 , a_1 to a_5 , i , t , and α refer to the intercept, coefficients of independent facets, countries of the

study (in our case, the following 24 tourism economies: “Malta, the Maldives, the Bahamas, Seychelles, Vanuatu, Cabo Verde, St. Lucia, Cyprus, Belize, Fiji, Cambodia, Barbados, Bahrain, Antigua, Barbuda, Dominica, Montenegro, Croatia, Jamaica, Thailand, Georgia, the Philippines, Kiribati, and Iceland”), time period (2000–2022 (23 years)), and white noise, respectively. The information was retrieved from the “World Bank database”. All of these countries were selected based on the share of tourism in their GDP, using World Bank data as the main data source. Specifically, we considered those countries where tourism has been responsible for more than 25% of the GDP over the past decade as “most dependent on tourism”. All of these countries have small populations (in most instances, less than one million), but their economies rely heavily on tourism, and they are the most suitable for investigating the environmental impact of tourism activity. This selection, based on thresholds, ensured that the sample was suitable for achieving the research aim of investigating the tourism–environmental nexus in tourism-dependent economies. Table 1 shows the data’s synopsis.

Table 1. Data synopsis.

Symbol	Variable Name	Unit of Calculation (Measurement)	Source
CO ₂	Carbon emissions	“CO ₂ emissions (kt)”.	WB
TOUR	Tourism	“International tourism, number of arrivals”.	WB
ENERGY	Energy intensity	“Ratio between energy supply and gross domestic product measured at purchasing power parity”.	WB
GDP	Economic growth	“GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products”.	WB
LIFE	Life expectancy	“Life expectancy indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life”.	WB
POP	Population	“Total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship”.	WB

Source: authors compilation, note: WB = World Bank, <https://databank.worldbank.org/source/world-development-indicators>. accessed on 2 October 2023.

3.2. Econometric Structure

The current study employed a robust econometric model in examining the dynamic relationships between energy consumption, tourism, economic growth, population, life expectancy, and carbon emissions. To assist in establishing the stationarity and validity of the series data, we began by applying the augmented Dickey–Fuller (ADF) test and the residual augmented least squares ADF (RALS-ADF) test, recommended in Ref. [77]. RALS-ADF offers superior performance, particularly when the error terms do not follow a normal distribution.

To test whether there were long-run relationships among the variables, we used the Engle–Granger (EG) cointegration test [78] and the RALS-EG cointegration test [79], which is more efficient. The EG test is a two-stage test that starts with an estimation of the long-run relationship using ordinary least squares (OLS) followed by a stationarity test of the residuals. If the residuals are stationary, then the variables are cointegrated. However, since conventional cointegration tests may lose power if the errors are non-normal, we also ran the RALS-EG test for additional robustness and accuracy.

In addition, during non-normal errors, nonlinear cointegration tests have less power than their linear counterparts [80]. If non-normal errors exist, then the RALS estimator can still be used to ensure no loss in statistical strength by implementing standard least squares forecast under linearity assumptions. The Engle–Granger (EG) test was developed

in Ref. [78] as a “two-step cointegration test that relies on the residual framework and conventional t-statistics”. The key advantage of the RALS method is that it can capture the higher-order moments (e.g., skewness and kurtosis) of the error distribution. The test modifies the standard cointegration equation by adding an additional term, $\hat{\phi}_t$, to account for non-normality. This term includes squared and cubed residuals and enhances the precision of the test statistics. Adjusted t-statistics with modified asymptotic distributions are employed to test the null hypothesis of “no cointegration”.

Residual augmented least squares (RALS) cointegration was employed for its robustness under non-normal error distributions, which are typical in macro-panel datasets of many countries over various periods of time. In contrast to the earlier cointegration methods (e.g., Engle–Granger or Johansen tests), the RALS method allows for higher-order moments such as skewness and kurtosis and therefore yields more statistically robust results where normality assumptions are violated. This property is even more important in tourism-based research, wherein heterogeneity of data and structural shocks dominate across countries.

The autoregressive distributed lag (ARDL) model was chosen due to its capacity to handle small sample sizes and composite orders of integration (i.e., $I(0)$ and $I(1)$). As compared to other models such as the vector error correction model (VECM), where all series are required to be $I(1)$, the ARDL model allows for greater flexibility regarding model specification. It is also very effective in describing both short- and long-run dynamics in a unified framework, which is something that aligns with the objective of the study of assessing the differential temporal effects of tourism and energy consumption on the quality of the environment.

To begin the study, we first determined the order of integration of all the variables to make them compatible with the ARDL method. This was achieved by specifying a static integrating threshold whereby we utilized the employment of both the augmented Dickey–Fuller (ADF) and the residual augmented least squares ADF (RALS-ADF) unit root test. We used these tests in an effort to ascertain whether each variable was integrated of order zero [$I(0)$] or order one [$I(1)$]. Identification of this threshold was important because the ARDL model only supports variables as a mixture of $I(0)$ and $I(1)$ but not of $I(2)$ or above. Hence, the term “static integrating threshold” summarizes the requirement that no variable in the model should be integrated higher than the first order—a prerequisite to the subsequent application of the cointegration and ARDL frameworks.

$$y_t = \epsilon Z_t + \xi_t \quad (3)$$

The “augmented Dickey–Fuller (ADF) unit root test” was performed on the acquired residuals ($\hat{\xi}_t$) in order to determine the level of integration in the system.

$$\Delta \hat{\xi}_t = \epsilon_0 + \epsilon_1 \hat{\xi}_{t-1} + \sum_{i=1}^p \epsilon_{i+1} \Delta \hat{\xi}_{t-1} + \lambda_t \quad (4)$$

The RALS approach demonstrates promise in ensuring more dependable, exact, and enduring results, mainly when the error term is not normally distributed. In their study, the authors of Ref. [79] employed the method as a supporting method to enhance the “EG cointegration test”. The approach to this research was new and involved two and three integration moments for residuals from ordinary cointegration tests. To enhance the execution of the RALS technique, Equation (4) was supplemented with the following term.

$$\hat{\phi}_t = \omega(\hat{\xi}_t) - \hat{\eta} - \hat{\xi}_t \hat{\psi}_t, t = 1, 2, 3, 4, 5 \dots, T$$

where $\hat{\xi}_t$ represents the residuals derived from Equation (4) previously provided.

$$\omega(\hat{\xi}_t) = [\hat{\xi}_t^2, \hat{\xi}_t^3], \hat{\eta} = \frac{1}{T} \sum_{i=1}^T \omega(\hat{\xi}_t), \hat{\psi}_t = \frac{1}{T} \sum_{i=1}^T \omega'(\hat{\xi}_t)$$

Moreover, as proposed by Ref. [81], the equation shown above corresponds to the RALS term.

$$\hat{\phi}_t = [\hat{\xi}_t^2 - m_2, \hat{\xi}_t^3 - m_3 - 3m_2\hat{\xi}_t] \quad (5)$$

where $m = T^{-1} \sum_{i=1}^T \hat{\xi}_t^j$. In addition, RALS cointegration regression is shown in Equation (6) below by including $\hat{\phi}_t$ in Equation (4).

$$\Delta \hat{\xi}_t = \omega_1 \hat{\xi}_{t-1} + \sum_{i=1}^p \omega_{i+1} \Delta \hat{\xi}_{t-1} + \hat{\phi}_t \Psi + \Omega_t \quad (6)$$

The null hypothesis was analyzed using a traditional t-test, which states that there is “no cointegration among the examined variables” if $\omega_1 = 0$. In addition, in order to construct the “three different asymptotic distributions of t-statistics”, Equation (7) was applied.

$$t^* \rightarrow \rho \cdot t + \sqrt{1 - \rho^2} \cdot Z \quad (7)$$

To examine the interrelationships between tourism, the EI, EG, life expectancy, the population, and carbon emissions, we proceeded to estimate the short-run and long-run dynamics using the autoregressive distributed lag (ARDL) model. This model is suitable for dealing with small sample sizes and has the ability to integrate variables to different orders (I(0) or I(1)). The general specification of the ARDL model used in this study is given in Equation (8), where the dependent variable is the log of CO₂ emissions and the independent variables are tourism, energy consumption, GDP, life expectancy, and population. To achieve this, we modified Equation (2) into Equation (8), as shown below:

$$\begin{aligned} \Delta \ln \text{CO}_{2,i,t} = & a_0 + a_1 \ln \text{TOUR}_{i,t-1} + a_2 \ln \text{ENERGY}_{i,t-1} + a_3 \ln \text{GDP}_{i,t-1} + \\ & a_4 \ln \text{LIFE}_{i,t-1} + a_5 \ln \text{POP}_{i,t-1} + \sum_{t=1}^p a_1 \Delta \ln \text{TOUR}_{t-i} + \sum_{t=1}^q a_2 \Delta \ln \text{ENERGY}_{t-i} + \\ & \sum_{t=1}^q a_3 \Delta \ln \text{GDP}_{t-i} + \sum_{t=1}^q a_4 \Delta \ln \text{LIFE}_{t-i} + \sum_{t=1}^q a_5 \Delta \ln \text{POP}_{t-i} + \alpha_{it} \end{aligned} \quad (8)$$

The error correction model (ECM), using the ARDL model, is presented in Equation (9). This model includes the error correction term (ECT), which indicates the speed with which the system returns to long-run equilibrium after a short-run shock. A statistically significant and negative coefficient of the ECT indicates the presence of a stable long-run relationship.

$$\begin{aligned} \Delta \ln \text{CO}_{2,i,t} = & a_0 + \sum_{t=1}^p a_1 \Delta \ln \text{CO}_{2,t-i} + \sum_{t=1}^q a_2 \Delta \ln \text{TOUR}_{t-i} + \\ & \sum_{t=1}^q a_3 \Delta \ln \text{ENERGY}_{t-i} + \sum_{t=1}^q a_4 \Delta \ln \text{GDP}_{t-i} + \sum_{t=1}^q a_5 \Delta \ln \text{LIFE}_{t-i} + \\ & \sum_{t=1}^q a_6 \Delta \ln \text{POP}_{t-i} + \lambda \text{ECM}_{t-1} + \alpha_t \end{aligned} \quad (9)$$

The term marked as λECM_{t-1} represents the “rate of adjustment towards long-run equilibrium after a sudden shock within a brief timeframe”.

4. Results and Discussion

4.1. Unit Root and Cointegration Estimations

The stationarity of facets was assessed through the implementation of the RALS-ADF and ADF unit root tests. In Table 2, the ADF test’s stationarity outcome is shown. The findings indicated that all the variables except CO₂ and ENERGY exhibited stationarity at this level. However, CO₂ and ENERGY were found to be non-stationary when they were different at the first order. Moreover, this study used the RALS-ADF method, revealing that all the variables except the GDP demonstrated non-stationarity at the first difference

and exhibited stationarity at this level. Hence, the obtained findings allowed us to perform an estimated cointegration analysis on the dataset.

Table 2. Unit root test results.

Variables	ADF	RALS-ADF	ρ^2
CO ₂	−2.49	−1.87	0.51
TOUR	−4.12 ***	−2.99	0.74
ENERGY	−2.33	−2.15	0.63
GDP	−3.85 ***	−7.39 ***	0.91
LIFE	−3.98 ***	−2.83	0.63
POP	−3.63 ***	−1.19	0.55
ΔCO ₂	−23.04 ***	−54.99 **	0.81
ΔTOUR	−12.14 ***	−26.87 ***	0.91
ΔENERGY	−24.21 ***	−38.55 ***	0.84
ΔLIFE	−26.62 **	−42.55 ***	0.90
ΔPOP	−23.39 ***	−63.85 ***	0.86

Note: *** and ** indicate significance at 1%, 5%, and 10%, respectively. The 1%, 5%, and 10% critical values for the ADF were −3.58, −2.93, and −2.60, respectively. The 1%, 5%, and 10% critical values for the RALS-ADF were −3.75, −3.30, and −3.05, respectively.

Furthermore, the estimated outcome of the cointegration test is shown in Table 3. The EG estimations reflect that the critical value (−5.02) was higher than the t-statistic (−5.33) at the 1% significance level, suggesting the existence of cointegration among the facets of the study. Moreover, the outcomes of RALS-EG presented in Table 3 show that the t-statistic (−4.73) was less than the cut-off number (−4.19). Hence, the outcomes of EG were confirmed by the RALS-EG. Therefore, we declined the null hypothesis of the nonexistence of cointegration of CO₂, tourism, the EI, EG, life expectancy, and the population.

Table 3. RALS cointegration test results.

Methods	K	Test Statistics	ρ^2
EG	0	−5.33 ***	—
RALS-EG	0	−4.73 **	0.81

Note: *** and ** indicate significance at 1%, 5%, and 10%, respectively; K shows the optimal lag length found using recursive statistics; the 1%, 5%, and 10% critical values for the EG test were −5.02, −4.32, and −3.98, respectively; and the 1%, 5%, and 10% critical values for the RALS-EG test were −4.80, −4.19, and −3.88, respectively.

4.2. ARDL Short- and Long-Term Estimations

The short- and long-term estimations of the ARDL estimators are depicted in Table 4. The coefficient associated with the “error correction term” was established to be negative and exhibited statistical significance, as shown by a *p*-value of 0.000. The error correction term is a measure of the rate at which the output adjusts to its long-term equilibrium after experiencing a shock in the short term.

Furthermore, the ARDL analysis indicated that the coefficient (0.019) linked to the variable TOUR had a positive and statistically significant correlation at a significance level of 1%, although this association was only seen in the long term. In light of these outcomes, a 1% increase in tourist activity in countries that strongly rely on tourism is only connected to a 0.019% decrease in the overall quality of the environment. The findings of our research are corroborated by Ref. [5] in 10 GDP countries, Ref. [4] in Brazil, Ref. [34] in China, Refs. [10,44] in Thailand, Ref. [9] in Kuwait, Ref. [8] in the case of most visited economies, Ref. [43] in 15 Mediterranean countries, Ref. [41] in the USA, and Ref. [37] in South Asia. Consequently, while tourism has positively impacted the economies of the nations under examination, it is evident that a rise in the influx of foreign tourists, particularly in nations

heavily reliant on tourism, has a harmful effect on the natural environment and results in an escalation in energy consumption.

Table 4. ARDL results (dependent variable: LOG (CO₂)).

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Long-Run Coefficients				
LOG(TOUR)	0.019	0.006	3.028	0.002 ***
LOG(ENERGY)	0.004	0.002	2.01	0.041 **
LOG(GDP)	0.007	0.015	0.465	0.642
LOG(LIFE)	0.070	0.158	0.441	0.659
LOG(POP)	0.023	0.010	2.247	0.025 **
Short-Run Coefficients				
ECM (−1)	−0.043	0.010	−4.262	0.000 ***
DLOG(ENERGY)	0.568	0.041	13.570	0.000 ***
DLOG(GDP)	0.853	0.024	34.305	0.000 ***
DLOG(LIFE)	0.670	0.315	2.12	0.033 **
DLOG(POP)	0.216	0.025	8.570	0.000 ***

Note: *** and ** indicate significance at 1%, 5%, and 10%, respectively.

The ARDL estimation demonstrated that the coefficients (0.002 and 0.568) pertaining to the ENERGY variable exhibited a positive and statistically significant correlation at the 5% and 1% degrees of importance in the long and short run. These results suggest that a minimal increase of 1% in the EI in countries that largely depend on tourism is linked to a decrease in the EQ of around 0.002% and 0.568% in the long and short term, respectively. It is intriguing to observe that the extent of the EI's impact on the environment is greater in the short term compared to the long term. These estimations were confirmed by Refs. [49,51,52,54,55,82] in the case of 25 large emerging economies, 50 African countries, the USA, developing and transition economies, Morocco, China, and the high-income group. Energy is an important element in fulfilling fundamental needs and attaining EG objectives. However, in cases where energy generation relies heavily on carbon-based fuels, the escalation of the EI may result in adverse environmental consequences. Hence, our findings demonstrate that, despite the focus on reducing the EI in nations heavily reliant on tourism, the advancements in energy efficiency remain inconsistent. Thus, the achievement of energy transition may be facilitated by the incorporation of key factors such as affordability, energy efficiency, energy independence, and dependability. The use of this measure is expected to mitigate the adverse environmental impacts resulting from a high EI in the most tourism-dependent countries.

Furthermore, the ARDL estimate demonstrated that the coefficient (0.568) associated with the GDP variable showed a positive and statistically remarkable relationship in the short run at an important degree of 1%. However, these coefficients were found to be negligible in the long term. The outcomes indicate that 1% growth in economic development among nations heavily reliant on tourism is associated with a short-term decline in the EQ of around 0.853. These estimations are verified by Refs. [56–58,60,83–89] in the context of India, China, the African economies, the OECD nations, France, South Asian developing economies, South European countries, middle- and low-income economies, BRICS, Vietnam, the Middle East nations, and West Asian and South American countries, respectively. The results of our study suggest that countries largely dependent on tourism experience economic development, but this prosperity comes at the cost of environmental damage. Furthermore, this finding suggests that the environmental performance of countries heavily reliant on tourism is influenced by EG.

Likewise, the ARDL estimate shows that the coefficients (0.023 and 0.216) related to the variable POP have a positive association that is statistically significant at the 5% and 1% levels of significance, both in the long run and the short run. Accordingly, an increase of one percent in the population in nations whose economies are heavily dependent on tourism may be connected to a reduction in the quality of the environment of around 0.023% and 0.216% over the short and long term. It is fascinating to note that the magnitude of the influence that the population has on the ecosystem is the greatest in the short term as opposed to the long term. The results of these estimates are consistent with Refs. [68,72,74,76] in the case of the USA, the next 11 economies, 46 Sub-Saharan African countries, the PIIGS countries, and China. Moreover, the ARDL estimate showed that, at the 5% level of significance in the short run, the coefficients (0.670) related to the variable LIFE indicate a statistically significant and favorable connection. According to the findings, a short-term decline in EQ of around 0.670% is associated with a 1% increase in LE in nations that heavily rely on tourism. Our estimations are verified by Ref. [71] in BRICS and Refs. [17,69] in the case of Turkey. The findings of this research diverge from those of Ref. [70], the authors of which examined 154 countries and argued that the rise in LE had an important effect on the reduction in carbon dioxide emissions.

5. Conclusions

In this study, we investigated the nexus of tourism, the EI, EG, population, and LE on carbon emissions in the case of most tourism-dependent countries. We employed RALS cointegration and the augmented distributed lag model (ARDL) on data spanning from 2000 to 2022 in order to estimate the cointegration link among the facets of the study and the long- and short-run coefficients.

The outcomes of the RALS estimator demonstrated the long-run association amidst the relevant factors. Moreover, the ARDL estimator showed that the ECT-1 term has a negative coefficient, affirming the existence of a long-term association between the independent variables and the dependent variable. Likewise, the ARDL econometric estimator revealed that, in the long run, the EI, tourism, and the population have substantial positive effects on carbon emissions, whereas LE and EG have insignificant coefficients with carbon emissions. Furthermore, in the short run, the ARDL estimator predicted that the EI, EG, life expectancy, and population growth have positive and substantial coefficients with carbon emissions, whereas tourism has insignificant coefficients with carbon emissions. These outcomes suggest that the boost in the EI, EG, life expectancy, and population hampers the EQ in the case of tourism-dependent countries.

5.1. Policy Recommendations

Nowadays, as destinations face a variety of social, economic, and environmental challenges, sustainable development is not only an option but a necessary strategy that governments should implement. This is critical for tourism-dependent destinations, given that tourism is recognized as one of the largest industries with inevitable environmental and societal impacts [1,23,26]. Accordingly, the first policy recommendation for such nations is to adjust their current tourism-planning processes with the goals of sustainable tourism development.

Using the findings of our study, it is essential for destination policymakers to increase the variation in the forms of incentives allocated to tourism business owners, such as hoteliers, restaurateurs, and other hospitality and tourism organizations, to reduce their reliance on polluting energy sources. The strategy of long-term loans to change power sources from fossil fuel to green energy plans and deducting the taxes from business owners

who follow sustainable energy production and consumption strategies can also help these destinations reduce their energy intensity and carbon dioxide emissions.

Moreover, it is necessary for policymakers to control the migration of residents from rural places to cities. This can happen by providing adequate facilities and supporting eco-tourism and sustainable tourism development in the less-urbanized parts of the nations. Such strategies can not only create jobs but also motivate people not to move to larger and more populated cities.

The governments of the most tourism-dependent countries can implement well-defined regulations about environmental quality. For example, tourist places that have a significant adverse influence on the environment should allocate sufficient financial resources towards ecological restoration to preserve their ecological assets.

These nations need to demonstrate a rigid commitment to mitigating carbon intensity by actively pursuing enhanced energy efficiency measures. Moreover, they need to prioritize the attainment of energy efficiency strategies. The use of enhanced methods of production, together with the utilization of renewable energy sources, may be regarded as a viable solution to address the escalating energy requirements.

Additionally, the acceptance and growth of renewable energy are heavily influenced by green technological innovation, which necessitates a substantial investment. It is essential to allocate resources towards renewable technology via both governmental and non-governmental programs to augment the proportion of green energy within the overall energy consumption. Thus, the investigation of renewable energy sources must be given top priority, including wind, solar, and geothermal sources, as well as bio-diesel fuel.

Furthermore, it is simultaneously essential to implement measures aimed at progressively diminishing the use of fossil energy in the pursuit of economic objectives.

Finally, for EG, the industrialization strategies of these nations must prioritize energy conservation, as well as emission implementation reduction measures and environmentally friendly methods of manufacturing.

5.2. Limitations

This study was subject to various limitations since it was only carried out in nations reliant on tourism. Moreover, its scope was constrained since it only covered the time period from 2000 to 2022 due to the unavailability of data for the preceding years.

5.3. Future Studies

The present study exhibits the possibility of further expansion across several dimensions. The examination of the impact of CO₂ emissions on the well-being of the local populations living in major tourist destinations is an intriguing subject of study. However, it is of interest to use techniques that can make predictions, such as the neural system, to assess the long-term impact that the tourism business may have on the ecological aspects of a country.

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Data Availability Statement: This research investigated the association between tourism, energy, economic growth, life expectancy, population, and carbon emissions in the case of 24 of the most tourism-dependent economies in the world. When seeking numerical data for a wide range of components and variables, it is essential to consider the World Bank Data collection. A total of 23 years were studied between 2000 and 2022, with data being collected on an annual basis throughout the period.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Sr. No.	Authors	Time Period	Country	Method	Results Remarks
1	[5]	1995–2018	10 GDPC	MMQR	TOUR (+), sig → CO ₂ EG (+), sig → CO ₂
2	[4]	1990–2019	Brazil	ARDL	TOUR (+), sig → CO ₂ EG (+), sig → CO ₂
3	[34]	1997–2012	China	EEBT and SDA	TOUR (+), sig → CO ₂
4	[10]	1990–2020	Thailand	ARDL	TOUR (+), sig → CO ₂ EG (+), sig → CO ₂
5	[9]	1995–2020	Kuwait	VEC	TOUR (+), sig → CO ₂ EG (+), sig → CO ₂
6	[8]	1995–2018	MVC	FEPQR	TOUR (+), sig → CO ₂
7	[43]	2001–2017	15 MC	Threshold OLS	TOUR (−), sig → CO ₂
8	[44]	1994–2014	Thailand	Bootstrapping ARDL	TOUR (−), sig → CO ₂
9	[35]	2000–2017	70 countries	GNS	TOURDEV (+), sig → CO ₂ (DE) TOURDEV (−), sig → CO ₂ (IE)
10	[6]	1995–2014	TIT	BPGC	TOUR (+), sig → CO ₂ EG (+), sig → CO ₂
11	[42]	1998–2014	95 countries	PCSE	TOUR (−), sig → CO ₂ EG (−), sig → CO ₂ EG ² (+), sig → CO ₂
12	[41]	2001–2017	USA	PMWC	TOUR (+), sig → CO ₂
13	[46]	1970–2019	Malaysia	QARDL	TOURDEV (−), sig → CO ₂
14	[37]	1980–2018	South Asia	NARDL	TOUR (+), sig → CO ₂
15	[39]	2005–2016	China	SEM	TOUR (+, −), sig → CO ₂ (IUSC UDTA) TOUR (−, +), sig → CO ₂ (USC-DTA)
16	[36]	2000–2020	DDC	GMM, FMOLS, and DOLS	TOUR (+), sig → CO ₂
17	[40]	1995–2014	12 PCC	GNC	TOUR (+), sig → CO ₂
18	[38]	1990–2020	Turkey	DOLS	TOUR (+), sig → CO ₂ EG (+), sig → CO ₂

Sr. No.	Authors	Time Period	Country	Method	Results Remarks
19	[45]	1995Q1–2017Q4	China	QARDL	TOURDEV (−), sig → CO ₂ (LT) EG (+), sig → CO ₂ (LT)
20	[47]	1990–2014	DC	FE-PQR	EI (−), sig → CO ₂ EG(Y) (+), sig → CO ₂ EG ² (Y2) (−), sig → CO ₂
21	[49]	1990–2018	25 LEE	ARDL	EI (+), sig → CI
22	[48]	2005–2018	BRICS and OECD	2SLS and GMM	EI (−), sig → CI
23	[51]	1980–2018	50 African countries	PCS-DL	EI (+), sig → CI EG (+), sig → CO ₂
24	[52]	1995–2017	DTE	MG and AMG	EI (+), sig → CO ₂ EG (+), sig → CO ₂ EG ² (−), sig → CO ₂ POP (+), sig → CO ₂
25	[53]	1990–2020	Morocco	ARDL	EI (+), sig → CO ₂
26	[54]	1980–2019	China	ARDL	GDP (+), sig → CO ₂ GDP ² (−), sig → CO ₂ EN (+), sig → CO ₂
27	[50]	2006–2019	China	SER	EI (−), sig → CO ₂
28	[55]	1990–2017	HULG	GMM	EI (+), sig → CO ₂ (HIG)
29	[83]	1990–2018	India	VECM	EG (+), sig → CO ₂
30	[84]	2001–2016	China	Spatial econometric model	EI (+), sig → CO ₂ EG (+), sig → CO ₂
31	[85]	1980–2019	African economies	PLS	EG (+), sig → CO ₂
32	[86]	2000–2014	35 OECD	GMM and PVAR	EI (+), sig → EP EG (+), sig → EP
33	[88]	1987–2019	France	ARDL	EG (+), sig → CO ₂
34	[57]	1990–2014	SADE	FMOLS and DOLS	EG (+), sig → CO ₂ EG ² (−), sig → CO ₂
35	[90]	1990–2018	SEC	CCEMG	EG (+), sig → CO ₂ EP (−), sig → CO ₂
36	[60]	1990–2018	LMHIAC	MG	EG (+), sig → CO ₂ EG (−), sig → CO ₂
37	[89]	1990–2019	BRICS	FE	EG (+), sig → CO ₂ URB (+), sig → CO ₂
38	[87]	2007–2015	OECD	Regression	EG (+), sig → CO ₂
39	[56]	1986–2018	Vietnam	Threshold regression	EG (+), sig → CO ₂ EG ² (−), sig → CO ₂ FE (+), sig → CO ₂

Sr. No.	Authors	Time Period	Country	Method	Results Remarks
40	[58]	1990–2017	WAME	CUP-FM and CUP-BC	EG (+), sig → EF EG ² (−), sig → EF POP (+), sig → EF
41	[12]	1971–2016	USMCA	AMG	EG (−), sig → CO ₂ Canada and USA EG (+), sig → CO ₂ Mexico EG ² (+), sig → CO ₂ Canada and USA EG ² (−), sig → CO ₂ Mexico
42	[80]	1995–2020	SAC	PMG, MG, and DFE	EG (+), sig → CO ₂
43	[69]	1971–2019	Turkey	AARDL and DARDL	LE (+), sig → EF EG (+), sig → EF EG ² (−), sig → EF
44	[70]	1992–2016	154 countries	Threshold regression	URB (+), sig → CO ₂ LE (−), sig → CO ₂ POP (+), sig → CO ₂ EG (+), sig → CO ₂ EG ² (−), sig → CO ₂
45	[67]	1975–2020	Pakistan	ARDL	CO ₂ (−), sig → LE
46	[71]	1999–2016	BRICS	PARDL, PCSE, FGLS, and PMG	LE (+), sig → EQ (LT) EG (+), sig → EQ (LT) LE (−), sig → EQ (ST) EG (−), sig → EQ (ST)
47	[17]	1960–2018	Turkey	WC, FTY, and BCFDSC	LE (+), sig → CO ₂
48	[68]	1971–2016	USA	GMM and GLM	PG (+), sig → CO ₂ and EF
49	[72]	1990–2017	Next 11	BQR	POP (+), sig → AP
50	[74]	2000–2015	46 SSA	GMM	POP (+), sig → CO ₂
51	[73]	1990–2019	PIIGS	DOLS	URBPOP (+), sig → CO ₂
52	[76]	2000–2015	BTHUA	Entropy method	URBPOP (+), sig → EQ URBPOP (−), sig → EQ

Note: MMQR = method of moment quantile regression; ARDL = autoregressive distributed lag model; EEBT = emissions embodied in the bilateral trade; SDA = structure decomposition analysis; TOUR = tourism; EG = economic growth; CO₂ = carbon emissions; VEC = vector error correction model; FMOLS = fully modified ordinary least squares; FEPQR = fixed-effect panel quantile regression; OLS = ordinary least squares; GNS = generalized nested spatial model; BPGC = bootstrap panel Granger causality; PCSE = panel-corrected standard error model; PMWC = partial and multiple wavelet coherence; USA = United States of America; SBM-DEA = super-efficiency slacks-based measure and data envelope analyses; QARDL = quantile autoregressive distributed lag model; PARDL = panel autoregressive distributed lag model; SEM = spatial error model; GMM = generalized moment method; DOLS = dynamic ordinary least squares; GNC = Granger non-causality test; FE-PQR = fixed-effect panel quantile regression; 2SLS = two-stage least squares; PCS-DL = panel cross-sectional augmented distributed lags; MG = mean group; AMG = augmented mean group; SER = spatial econometric regression; VECM = vector error correction model; PLS = panel least squares; FE-2SLS = fixed-effect two-stage least squares; PVAR = panel vector autoregressive regression; CCEMG = common correlated effects mean group; FE = fixed-effect estimation model; CUP-FM = continuously updated fully modified; CUP-BC = continuously updated bias-corrected; DFE = dynamic fixed effect; AARDL = augmented autoregressive distributed lag model; DARDL = dynamic augmented autoregressive distributed method; PCSE = panel-correlated standard error; FGLS = feasible generalized least squares; WC = wavelet coherence; FTY = Fourier Toda–Yamamoto; BCFDSC = Breitung–Candelon frequency-domain spectral causality; GLM = generalized linear model;

BQR = bootstrap quantile regression; BTHUA = Beijing–Tianjin–Hebei urban agglomeration; PIIGS = Portugal, Ireland, Italy, Greece, and Spain; SSA = Sub-Saharan African countries; BRICS = Brazil, Russia, India, China, and South Africa; SAC = South American countries; USMCA = USA–Mexico–Canada Agreement; WAME = West Asian and Middle East nations; OECD = Organization of Economic Coordination and Development; LMHIAC = low-income, middle-income, and high-income Asian countries; SEC = South European countries; SADE = South Asian developing economies; HULG = higher-, upper-middle-, lower-middle-, and low-income groups; DTE = developing and transition economies; LEE = large emerging economies; DC = developing countries; PCC = post-communist countries; DDC = developing and developed countries; TIT = tourism island territories; MC = Mediterranean countries; MVC = most visited countries; GDPC = gross domestic product countries; DE = direct effect; IE = indirect effect; ST = short term; LT-IUSC = long-term inverted U-shaped curve; LQ = lower quantile; UQ-IUSC = upper quantile inverted U-shaped curve; IUSC UDTA = inverted U-shaped in underdeveloped tourism areas; USC-DTA = U-shaped in developed tourism areas; CI = carbon intensity; HIG = high-income group; EP = environmental performance; AP = air pollution; TOURDEV = tourism development; EG^2 = economic growth squared; EI = energy intensity; GDP = gross domestic product; GDP^2 = gross domestic product squared; POP = population; EN = energy; EP = energy productivity; URB = urbanization; FE = fossil energy; LE = life expectancy; PG = population growth; URBPOP = urban population.

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