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# Exploring the nexus: Hausman test application in tourism, globalization, and environmental sustainability- evidence of top 10 visited countries

Saba Nourin[1], Ismat Nasim[2], Hafiz Muhammad Raza ur Rehman[3]✉, Elisabeth Caro Montero[4], Mirtha Silvana Garat de Marin[4], Nagwan Abdel Samee[5] & Imran Ashraf[3]✉

Econometric analysis has long been integral to measuring sustainable environmental quality, with panel data methods, such as fixed and random effects models, becoming the focal point of modern research. Initially, such methods were used to simply investigate environmental issues, but recent years have seen a shift toward the study of random effects models, focusing on hypothesis testing and policy debates. However, several important aspects of the Hausman test have not been sufficiently investigated in the literature. This study seeks to evaluate the utility of the Hausman test using a real dataset from tourism and globalization, exploring their effects on sustainable environmental quality. Additionally, the study examines key factors contributing to environmental issues including economic growth and energy consumption, as critical explanatory variables. By investigating the relationship between tourism, globalization, economic growth, and energy use, the research focuses on the top 10 most visited economies: France, the USA, Spain, China, Turkey, Italy, Mexico, Germany, Thailand, and the UK. Using panel data and the cross-sectional random effects model for the period of 1998 to 2024, the study produces reliable estimations of these relationships. The empirical findings suggest that while the Hausman test favors the fixed effect model, the real-world characteristics of these countries point to the random effect model, highlighting the negative impact of economic growth, energy consumption, and globalization on sustainable environmental quality. It is also suggested that socio-environmental factors should be considered for each destination for sustainable environmental quality.

[1] Department of Economics, Government Sadiq College Women University, Bahawalpur, Pakistan. [2] Emerson University Multan, Multan, Pakistan. [3] Department of Information and Communication Engineering, Yeungnam University, Daegu 38541, Republic of Korea. [4] Universidad Europea del Atlántico, Santander, Spain. [5] Department of Information Technology, College of Computer and Information Sciences, Princess Nourah bint Abdulrahman University, P.O. Box 84428, Riyadh 11671, Saudi Arabia. ✉email: mrazaurrehman@ynu.ac.kr; imranashraf@ynu.ac.kr

## Introduction

Within the economic field, the betterment of econometrics has a positive impact, and understanding the modeling tools helps better data analysis and inference (Webel 2011). The Housman test, also known as the Hausman specification test, has been utilized in econometrics to test the consistency between two different estimators of a parameter (Hausman 1978). It is commonly used to choose between two different statistical models, or, to determine if certain variables should be treated as exogenous or endogenous. In the context of panel data investigation, for example, the Hausman test can help determine whether a fixed effect model or arbitrary effect model is appropriate (Hausman 1978). It evaluates whether the fixed effects assumption which assumes that distinct effects have been correlated with independent variables is violated. Researchers rely on the results of the Hausman test to decide which model to use for the analysis, as choosing the wrong model can lead to biased and inefficient parameter estimates. It is particularly important when dealing with data that could exhibit a correlation between individual effects and independent variables, such as panel data or longitudinal studies. Two of the most popular models used for this type of data are the random-effect model and the fixed-effect model, which approach panel data in different ways. Both approaches aim to correct the issue of unobserved heterogeneity, but through different assumptions and methodologies, all with their benefits and constraints (Wooldridge 2010).

The present study examines these models in detail concerning their theoretical backgrounds and empirical implementations and outlines the methodological aspects that determine the choice between these models (Baltagi 2015). Further, the Hausman test supplies a statistical procedure to choose between that benefits the true evaluation of another framework that has risen to the challenge of bridging the gap between practical and theoretical applications in the tourism field, and the relationship between tourism and globalization and environment stewardship is the Hausman test. Albeit more complex and rigid than the McIntyre Rose Test, the Hausman test is a tool that has been designed specifically for the subject through the expertise of both environmental scholars and practitioners to use in evaluating the influence of tourism and globalization on environment (Narbel & M. 2017).

The Hausman test distinguishes many aspects that enable one to consider cross-sectional relations and concerns of different types: ecological, social, and economic. The subject of the Hausman test will also be further discussed in this study as it tries to examine the relevance of the issue within the framework of sustainable environments affected by tourism and globalization. As will be explained and discussed to identify the entire applicability and validity of results obtained with the Hausman test for evaluating the principles of environmental sustainability as related to global tourism in the case studies and empirical data as well as with the help of theoretical and empirical backgrounds. This study aims to make the readers aware of these dynamics, thereby contributing to sustainable development debates and also promoting better decision-making at community, country, and global levels. Tourism, according to the UNT, is known as "the movement of individuals to countries or areas outside their regular surroundings for personal, commercial, or professional interests." Tourists/visitors are the term used to describe these individuals. A person is classed as a visitor (of the same day) if his trip does not involve a night stay, and as a tourist if his trip does include a night stay. Travel may be for business, pleasure, or personal reasons that are not shared through a resident of the country or visited location.

Tourism may be measured in terms of tourists' arrival, which might be increased not only by vacations or holidays but many other factors that influence the number of tourists. While the financial crisis strongly declined tourism as in the 2000s recession, in 2007 and 2008 global financial crisis and 2019 to 2021 Covid-19 pandemic. United Nations World Tourism Organization (UNWTO) estimated in 2020 tourism declined from 58% to 78% (United Nations Tourism 2024). Tourism may be local or international but it contributes to the national income and becomes the balance of payment (Işık et al. 2017). Tourism also impacts the local community economically and socially (Işık et al. 2024). Global tourism, green tourism, or ecotourism arose when it was reported tourism caused 8% of greenhouse gas emissions (Işık et al. 2024; M. Lenzen & Malik 2018). This emission impacts the local community and economies' environment and social structures significantly (Işık et al. 2024).

Maintainable tourism mitigates the negative effect of tourism on the environment just because of the growth of the tourism industry (Balsalobre-Lorent, 2019). After is serious issue of sustainable environment the UNWTO and many other tourist organizations focused on sustainable tourism, and UNWTO took it as a portion of maintainable development goals. Therefore, through programs such as International Year Tourism for Development 2017, eight SDGs Decent Work and Economic Growth, the twelfth SDG Responsible Consumption and Production, and the 14th SDG life below Water is implemented which is helpful to create sustainable economies (Choi & E., 2005). As this study is based on the top ten tourist countries which are mainly considered as developed economies, it does not need much focus on SDGs.

Sustainable tourism is the complete course of tourism activities which includes social, economic, and environmental interaction of tourists and finding the issues, analyzing these issues, and improving the tourists' experience along with maintaining the natural environment (Işık et al. 2018). Optimal utilization of environmental resources, which has been critical for tourist enlargement, protection of critical biological processes, and contribution to the preservation of natural heritage and diversity (Işık et al. 2020; Niedziółka & M. 2014). Respect host communities' socio-cultural authenticity, conserve their lives build cultural inheritance, and promote intercultural tolerance and acceptance. Assuring long-standing economic sustainability, offering fairly dispersed socio-economic returns to all stakeholders, containing income opportunities and steady jobs along with facilities for host communities, and thereby reducing deficiency (Işık et al. 2023, 2020).

World tourism ranking is compiled by UNTWO as part of publications of their World Tourism Barometer. Tourism ranking as per the World Population Review, 2021 for Top 10 most visited countries (Adedoyin & V. 2022; Alola & K. 2021) shows the same destinations as in the report of Wikipedia, 2023. A visual representation is given in Table 1.

France has occupied 1st position for more than 30 years due to its attractions for tourists (Alola & K. 2021). Table 2, contains the research carried out concerning specific countries.

The growing importance of tourism and sustainability, the need to respond quickly to changing consumer expectations, and the increasingly complex necessities of climate variation necessitate new studies of superlative practices to fostering economic development and lowering $CO_2$ emissions regulated globalization. Sustainability and competitiveness, among other things, are dependent on how tourism reacts to climate change (Niedziółka and M. 2014). Tourism, like transportation, agriculture, and energy, is a very vulnerable sector to climate change (Wilbanks and R.-W.-M. 2007). Even though several theoretical academic research demonstrates that tourism raises energy consumption and harms the environment (Katircioglu 2014). Rare studies only

explored the impact of tourism on the environment (Balsalobre-Lorent 2019; Grossman and Krueger 1991; Susilorini and I. 2022). The tourism industry is linked to other industries that have significant pollution potential. Transportation (Livia Bizikova and Cohen 2011), like air travel, is a big energy consumer, and as a result, they are the sectors that contribute most to the emission of carbon (Gössling 2002). Tourism business also relies on a vast number of facilities, all of which have a variety of environmental and ecological consequences (Gössling 2002). Previous research has looked into the effect of globalization on the relationship between tourism and the environment (Susilorini and I. 2022). Globalization has a technological impact as a result of advancements and new technology that make it easier to reduce $CO_2$ emissions.

**Research gaps**. The recent knowledge gap in the literature lies in the limited exploration of the Hausman test's full applicability and limitations in real-world settings, particularly in the context of tourism and globalization (Nourin et al. 2024). While much focus has been given to fixed and random effects models, a more nuanced understanding of how these models are influenced by the complex dynamics of tourism, economic growth, energy consumption, and globalization is lacking (Younus et al. 2022). Furthermore, while the Hausman test is widely used to determine the most suitable model, there is insufficient empirical work addressing its relevance in the specific context of sustainable environmental quality across diverse economies. The role of endogenous variables like economic growth and energy consumption, and their impact on environmental sustainability in highly visited countries, is under-researched (Wu et al. 2021). Additionally, the impact of globalization on sustainable development has not been thoroughly linked with tourism in a manner that fully considers the diverse socio-economic environments of the top tourist destinations (Ansari 2025). Therefore, a comprehensive analysis that combines the Hausman test with real-world data from leading tourist economies remains a crucial gap in the current literature (Roussel and Audi 2024).

**Table 1 Ten most visited countries with tourists by number visitor arrivals.**

| Rank | Destination | International tourist arrivals | | | Change in % | |
|---|---|---|---|---|---|---|
| | | 2023 | 2022 | 2021 | 2021 to 2022 | 2020 to 2021 |
| 1 | France | 100.0 | 79.4 | 48.4 | △ 64 | △ 16.1 |
| 2 | Spain | 85.1 | 71.7 | 31.2 | △ 130 | △ 64.7 |
| 3 | US | 66.5 | 50.9 | 22.1 | △ 130 | △ 15.0 |
| 4 | Italy | 57.2 | 49.8 | 26.9 | △ 85 | △ 6.7 |
| 5 | Turkey | 55.2 | 50.5 | 29.9 | △ 69 | △ 88.3 |
| 6 | Mexico | 42.2 | 38.3 | 31.9 | △ 20 | △ 31.2 |
| 7 | UK | 37.2 | 30.7 | 6.3 | △ 389 | ▽ 41.3 |
| 8 | Germany | 34.8 | 28.5 | 11.7 | △ 144 | ▽ 6.1 |
| 9 | Greece | 32.7 | 27.8 | 14.7 | △ 89 | △ 99.4 |
| 10 | Austria | 30.9 | 26.2 | 12.7 | △ 106 | ▽ 15.7 |

The information has been taken from (United Nations Tourism 2024).

**Research problem statement**. The continually increasing awareness of the environmental effects of tourism and globalization is accompanied by the absence of integrated approaches to the measures of sustainable environments. Although the Hausman test provides this avenue, its applicability and outcome in various geographical and socio-economic settings remain unknown. Thus, the research problem under consideration in this study is to critically analyze the applicability and efficiency of the Hausman test concerning the effects of tourism and globalization on sustainable environments accounting for the aspects of ecological integrity, socio-cultural factors, and economic development. Thus, resolving this research problem will help in the development of a sustainable tourism and environmental management knowledge base to support evidence-based policy-making and other practical actions towards sustainable development goals attainment.

**Contributions of study**. The study has the following measurable objectives.

- Evaluating the argumentative usefulness of the Hausman test by exploring real datasets of tourism and globalization when it is used to impact sustainable environmental quality.
- Exploring important factors and sources responsible for the degradation of a sustainable environment.
- Investigating that energy consumption and the impact of economic growth are important endogenous explanatory actors in this relationship between environmental quality, tourism, and globalization.

From the above-set objectives, the study would examine the applicability of the Hausman test in measuring the effects of tourism and globalization in various geographic locales. It assesses the strengths of the Hausman test in appreciating the multifaceted perspective of environmental stability embracing globalization, economic growth, and energy consumption. This study also explores case studies that reflect the usage of the Housman Test in various tourism destinations and determine its usefulness in steering policies and conservation initiatives. To bring forward a set of recommendations on how to improve the

**Table 2 Selected countries reference according to recent literature.**

| Country | Literature Reference |
|---|---|
| United States | (Syed Ali Raza, 2016), (Alola & K. 2021; Raza & S. 2016) |
| Spain | (Badulescu & S. 2021; Gama & M. 2023) |
| France | (Badulescu & S. 2021; Gama & M. 2023) |
| Thailand | (Wanvilai Chulaphan 2021) (Chulaphan & J. 2021), (Andrew Adewale Alola K. K. 2021) (Alola & K. 2021) |
| Germany | (Alola & K. 2021; Badulescu & S. 2021) |
| Italy | (Badulescu & S. 2021; Gama & M. 2023) |
| United Kingdom | (Alola & K. 2021) |
| China | (Xiaofang Duan 2022) (Duan & Z.-Y. 2022), (Youngjoon Choi 2021) (Choi & H. 2021), (Xia Xie 2021) (Xie & S. 2021), (Rr. M. I. Retno Susilorini 2022) (Susilorini & I. 2022) |
| Mexico | (Pedro Aguilar 2021) (Aguilar & Melgarejo 2021), (Andrew Adewale Alola K. K. 2021) (Alola & K. 2021) |
| Turkey | (Andrew Adewale Alola K. K. 2021) (Alola & K. 2021) |

usefulness and reliability of the Housman Test as a tool for evaluating and encouraging sustainable environmental development concerning tourism and globalization. For enriching the body of knowledge on sustainable environmental management and tourism through a synthesis of empirical evidence and theoretical framework elicited from an assessment of the Hausman Test.

**Organization of study**. This study has been organized into five sections. Section "Literature Review" provides a comprehensive overview of the literature and discusses the essential prior work on comparable aspects of research as well as finds out the literature gap that the study attempts to fill. Section "Methodology" is about methodology and data. Evaluation and discussion have been provided in Section "Evaluations & Discussion". Finally, the study is concluded in Section "Conclusion" which also contains policy implications and limitations also highlights some direction for future research.

## Literature Review

In the literature review, we examine recent studies that shed light on the complex interplay among tourism, globalization, and environmental sustainability, with a focus on frameworks such as the Housman Test.

Recent research by Noreen et al. (Noreen et al. 2023) highlights the significant environmental footprint of tourism activities, ranging from carbon emissions associated with transportation to land degradation and habitat loss due to infrastructure development. Similarly, (of Barcelona 2019) emphasizes the sociocultural impacts of tourism globalization, including the commodification of local cultures and the displacement of indigenous communities. These studies underscore the urgent need for comprehensive frameworks to assess and mitigate the adverse effects of tourism and globalization on sustainable environments.

The Hausman test, developed by Hausman et al. (Hossain 2018), has emerged as a promising tool for addressing this need. Drawing on principles of ecological integrity, social equity, and economic viability, the Housman Test offers a holistic approach to evaluating the sustainability of tourism and globalization. However, its application and effectiveness in diverse geographical contexts have been subject to scrutiny.

Recent empirical studies have sought to examine the applicability of the Housman Test in different tourism destinations. For example, Smith et al. (Smith et al. 2022) applied the Housman Test to assess the environmental impacts of mass tourism in coastal areas, revealing significant challenges related to waste management and ecosystem degradation. In contrast, Li and Jones (Jones et al. 2021) examined the socio-economic dimensions of tourism globalization in rural communities, highlighting the role of the Housman Test in empowering local stakeholders and promoting community-based tourism initiatives. Despite these contributions, gaps remain in our understanding of how the Housman Test can be effectively utilized to inform sustainable tourism planning and management. Recent studies by Andrew Levina (Levin et al. 2002) emphasize the need for greater integration of spatial analysis techniques and participatory approaches within the framework of the Housman Test to enhance its practical utility. Similarly, (Gama and M. 2021) advocates for the incorporation of indigenous knowledge systems and traditional ecological wisdom into the assessment process, enriching our understanding of sustainability from a holistic perspective.

Overall, the literature reviewed underscores the importance of continued research and innovation in the field of sustainable tourism and environmental management. By critically evaluating frameworks such as the Hausman Test and exploring novel approaches to address emerging challenges, scholars and practitioners can contribute to the preservation of cultural heritage, natural ecosystems, and socio-economic well-being in tourism destinations around the world. Sustainable tourism ecotourism and green tourism are new terms that enhance the importance of a sustainable environment and reveal the negative impact of tourism (Alola and K. 2020). In the twentieth century the overutilization of energy use because of increment huge monetary growth. The exchange receptiveness expanded the travel industry which prompted ecological consequences. Badulescu (Badulescu and S. 2021) made sense of do financial development and ecological quality add to the advancement of the travel industry in European nations. $CO_2$ discharge is utilized for investigation and autoregressive conveyed slack (ARDL) model for board information (EU27). Carla et al. (Gama and M. 2021) investigated the connection between the travel industry development and air contamination at a provincial level for five significant travel industry European objections. The study (Alola and K. 2020), examined whether is there a connection between the communication of development factors and worldwide natural manageability.

UNWTO has additionally entrusted (particularly objective nations) upon significance of the travel industry to accomplishing the 2030 SDGs (Sustainable Development Goals). From this aspect, (Alola and K. 2021), utilized the natural impression of the ten most visited nations (France, Italy, Spain, United States, China, Mexico, Turkey, United Kingdom, Germany, and Thailand) over time. Due to important research topical manageability in a review is necessary. Impact tourism and globalization on sustainable environment are under multidisciplinary studies but this study just takes a brief overlook of some dimensions, as depicted in Fig. 1.

Coronavirus-steered examinations, the latest pattern incorporates this boundary, and the ongoing COVID-19 pandemic has made international issues, monetary and medical care issues, and has had overflow consequences for global organizations, including the travel industry and travel, which is a vital supporter of the worldwide help economy. The study (Susilorini and I. 2022) researched the impact of COVID-19 on the travel industry. Numerous different examinations likewise researched COVID-19's progressive potential and suggestions for the movement and recreation industry's long-haul recuperation. (Alola and K. 2020) explored the presence of a connection between the communication of development factors and worldwide ecological maintainability. Some studies had analyzed whether the reliance and collaboration of unfamiliar direct speculation, energy utilization, and genuine pay was a main thrust for worldwide natural manageability in a review (Xie and S. 2021). But due to COVID-19, the research has declined on this important issue.

The Panel Cointegration for the most part utilized an econometric technique, it very well may be found most examinations assessed investigation philosophy is Cointegration and ARDL in late patterns. Which uncovered that econometrics seems to add to natural corruption in information examination. How much energy consumed came about expansion in ecological debasement. International tourism, carbon emissions, and economic growth are associated with each other. With the emergence of globalization through foreign investment directly, tourism, technological transition, international trade, and financial capital inflows, globalization has a significant impact on economic activities, which can have both positive and negative consequences for any economy (Shahbaz et al. 2018), implying an indirect causal relationship among globalization and carbon emissions, as well as the direction of causality among these macroeconomic variables, as they influence the environment. The empirical studies have formulated that in the case of tourism

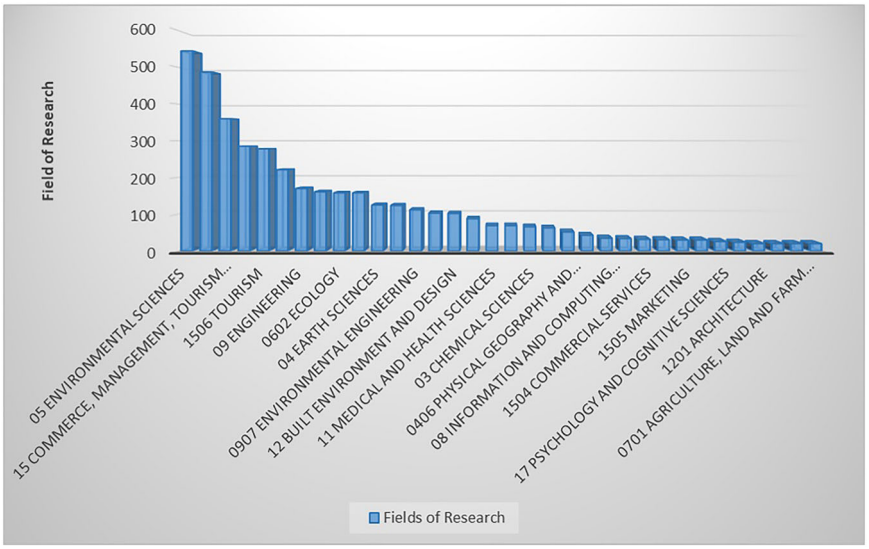


**Fig. 1** Multidisciplinary fields of research.

places, one-way causality tourism industry and carbon economic growth has primary predictive power at the level of carbon emissions (Shahbaz et al. 2018), but not the other way around. It would theoretically be correct to argue that tourism and the environment are intimately connected.

Several studies have focused on investigating the impact of tourism, political development, and financial investments on the sustainability of the environment. For example, (Özkan et al. 2024) found that increased energy usage and vulnerability can significantly increase pollution due to enhanced fuel consumption. Similarly, a negative impact of financial development and economic growth is reported in (Coban et al. 2024) on load capacity exhibiting their negative impact on environmental sustainability. In addition, while energy efficiency has a positive impact on the quality of the environment, foreign investment negatively impacts the environmental quality (Ozkan et al. 2023). These findings are further corroborated in (Özkan et al. 2024) within the context of Pakistan. On the other hand, efficient resource usage, utilizing renewable energy sources, and globalization are shown to have a positive impact on environmental sustainability (Özkan et al. 2025).

In this comprehensive literature review, one possible area of literature that is highlighted in the course of the review is the lack of sufficient material about the application and efficiency of the Housman Test in particular settings, for example, the developing world or regions with specific environmental conditions. Previous research has also considered the overall effectiveness of the framework; however, few specifically explore the framework in consideration of the application and customization of the said framework in different sociocultural and ecological environments (Balsalobre-Lorent 2019).

In addition, there is limited literature that assesses the capability of the Hausman Test in dealing with evolving issues regarding sustainability in tourism and environmental management like climate change, over tourism, or Indigenous people's rights. Although some of the reviewed studies suggested that there is a need for improvement and further advancement of the framework, there is a lack of research that would look at the possible changes for adaptation of the framework for better suitability of addressing modern sustainability issues.

Furthermore, the steps of carrying out the literature review show the lack of comparative research that evaluates the efficiency of the Hausman Test to other methods of sustainability assessment or tools. They could have been useful in generating information that would show the advantages and the disadvantages of one approach over the other in the framework of comparing methods of the assessment of the effect of tourism and globalization on the environment.

Thus, the literature review indicates a gap related to integrated investigations of the Hausman Test's specific application, its changes through time, its effectiveness contrast in various environmental and socio-economic contexts, and its potential to respond to new sustainability issues in tourism and globalization. The closeness of such a gap would further the knowledge of principles of sustainable tourism and assist in the formulation of better evaluation frameworks to inform policy and management. Is this inverse impact creating an economic paradigm in the multidisciplinary domain? How would the research give new insights to policymakers to make policies of globalization and tourism environmentally friendly?

## Methodology

The adopted methodology is discussed in this section. The proposed approach is advantageous in several aspects. Panel data analysis, particularly through the use of panel ordinary least squares (OLS) regression, offers several advantages in econometric research controlling for unobserved heterogeneity, enhanced variability and efficiency of estimation, reduced multicollinearity and panel data enables the identification and measurement of effects that are not detectable in pure cross-sectional or time-series data, such as individual behaviors or specific temporal trends.

**Theoretical framework**. The theoretical foundation of this study is based on several economic and financial theories that explain the relationship between tourism, globalization, energy consumption, and economic growth. The key theories underpinning this research are as follows.

*Tourism-led growth hypothesis*. The tourism-led growth hypothesis (TLGH) suggests that an increase in international tourist arrivals positively contributes to economic growth by boosting employment, investment, and foreign exchange earnings (Raifu and Afolabi 2024). This study incorporates tourist arrivals (TA) as a key independent variable to test its influence on economic output and growth.

*Globalization and economic development theory*. The globalization index (KOFGI) measures the extent of economic, political, and social integration with the global economy. According to globalization theories, increased international trade, foreign investments, and cross-border collaborations can stimulate economic growth (Lee 2021). However, some scholars argue that globalization may also introduce inefficiencies, market volatility, and economic inequalities, which justifies investigating its impact on this model.

*Energy-growth nexus*. The relationship between energy consumption and economic growth is well-established in economic literature. The Fossil Fuel Energy Consumption (FFEC) variable is included to analyze whether energy consumption is a driver of economic performance. The conservation hypothesis suggests that energy consumption follows economic growth, while the growth hypothesis proposes that energy consumption directly influences economic productivity.

*Endogenous growth theory*. The Endogenous Growth Theory explains how economic growth is primarily driven by internal factors such as human capital, innovation, and policy decisions. The economic output taken as GDP per capita (Y) variables aligns with this theory, emphasizing that sustained investments in economic infrastructure and technological advancements lead to long-term economic development (Leal Filho et al. 2021).

*Random vs. fixed effects in panel data*. The study employs both fixed effects (FE) and random effects (RE) models to assess variable relationships while controlling for unobserved heterogeneity. The Hausman test is applied to determine the most suitable econometric approach, ensuring the robustness of the results.

**Dataset**. To perform this study, the data is taken from different websites for 1998-2024 of the most visited nations of the world. The 'globalization' index is collected from the 'Swiss Federal Institute of Technology' while the data of other variables are taken from the 'WDI World Bank database'. The data is taken for 1998-2024 of the most visited nations of the world. Short definitions and descriptions of variables and their indicators are given in the following subsections.

**International Tourist Arrival**. The quantity of vacationers who travel to a country other than their typical residency, yet outside their standard environmental elements, is alluded to as worldwide sightseers' appearance (TA). This study intermediary global traveler appearance for the travel industry (Akadiri et al. 2019; Badulescu and S. 2021) to dispense with the possibility of experiencing multiple collinearity issues, especially when vacationer receipt has been utilized to evaluate the travel industry. World Development Indicators (WDI) insights on unfamiliar guest appearances are utilized and worlddata.info.

**Globalization Index**. We use the recently announced globalization index developed by (Dreher 2006) and modified by Gygli. This index's composition takes into account a variety of critical metrics, including economic, social, and political globalization.

**GDP per capita**. This study uses proxy GDP per capita (Y) (in current US dollars) for economic growth (Akadiri et al. 2019). GDP per capita is computed by dividing the GDP by midyear population. GDP is determined as the sum of entire resident producers' contributions to the economy as gross value, minus any subsidies not included in product value plus any product taxes. It is calculated without any assumptions, and the numbers are in current US dollars. GDP is a metric for economic growth. WDI statistics on real GDP per capita are used.

**Fossil fuel energy consumption**. A strong free factor that is intently affected by environmental quality is fuel. Non-renewable energy sources include coal, oil, and petroleum gas items. The information of this variable is taken from WDI as 'Petroleum derivative energy 'utilization (% of aggregate). The fuel 'utilization intermediary utilized in this study is petroleum product energy utilization because of the shortage of this sort of fuel.

**Model specification & functional equation**. For a selection of scenarios, four models based on carbon emissions functions would have been developed:

$$\begin{aligned}\text{Environmental Quality} = f(&\text{Tourism, Globalization,}\\ &\text{Economic Growth, Energy Consumption , … )}\end{aligned} \quad (1)$$

The CO_2 emissions function can be expressed as:

$$\mathrm{CO_2} = f(\mathrm{ta},\ y,\ \mathrm{kofgi},\ \mathrm{ffec}) \quad (2)$$

With a functional form:

$$\mathrm{CO_2} = \alpha_{it}\mathrm{ta}_{it}^{\beta_1} y_{it}^{\beta_2}\mathrm{kofgi}_{it}^{\beta_3}\mathrm{ffec}_{it}^{\beta_4} \quad (3)$$

where subscript $i$ depicts the panel cross-section ($i = 1, 2, \ldots, 10$), representing the top 10 visited economies: 10-UK, 9-Germany, 8-Thailand, 7-Mexico, 6-Turkey, 5-Italy, 4-China, 3-USA, 2-Spain, and 1-France. Tourist arrival, GDP, globalization index, and fossil fuel energy consumption are indicated by *ta*, *Y*, *kofgi*, and *ffec*, respectively.

The subscript $t$ represents the time period 1995–2021.

The log-linearized model is given by:

$$\mathrm{CO_2} = \alpha_{it} + \beta_1 \ln(\mathrm{ta}_{it}) + \beta_2 \ln(y_{it}) + \beta_3 \ln(\mathrm{kofgi}_{it}) + \beta_4 \ln(\mathrm{ffec}_{it}) \quad (4)$$

The model assumes a linear relationship between the independent variables and the dependent variable $CO_2$ The independent variables should not be perfectly correlated with each other to ensure meaningful coefficient estimates. The variance of the error term should be constant across observations. The residuals should not be correlated over time, which is particularly important in panel data analysis. The independent variables should not be correlated with the error term to avoid biased estimates. The error term should be normally distributed for valid hypothesis testing.

Concerning the panel data considerations, if a fixed effects model is used, individual-specific effects then parameters must be correlated with regressors, while in a random effects model, they must be uncorrelated.

**Descriptive statistics**. The 'Swiss Federal Institute of Technology' is used for globalization index collection while data on other variables has been taken from WDI. Eviews 9 is used to analyze panel data. Descriptive statistical analysis is represented in Table 3, the variables are available as a spread of applied statistical units. The international Tourism variable is measured in the number of arrivals, GDP per capita is measured in current international $, environmental quality is measured $CO_2$ in metric tons/capita, whereas Globalization is measured in globalization index Kofgi. The variables measure mass into composite indicators, they need to be standardized or normalized (Badulescu and S. 2021). In this study, a natural logarithm measure is used with that tourism and economic growth variables are reborn to a typical scale that assumes a "normal" distribution (i.e. a median of zero and a

**Table 3 Descriptive statistics.**

| Descriptive Statistics | $LNCO_2$ | LNTA | LNKOFGI | LN_Y | LNFFEC |
|---|---|---|---|---|---|
| **Mean** | 1.805187 | 17.74664 | 4.310381 | 9.674812 | 4.385694 |
| **Median** | 1.752943 | 17.95161 | 4.363472 | 10.12425 | 4.429248 |
| **Maximum** | 3.019055 | 19.19946 | 4.499810 | 11.69967 | 4.532865 |
| **Minimum** | 0.921819 | 12.89922 | 3.785313 | 6.412896 | 3.833541 |
| **Std. Dev.** | 0.511750 | 0.929300 | 0.153369 | 1.080705 | 0.160583 |
| **Skewness** | 0.519365 | −0.8291 | −0.92378 | −0.8920 | −2.25111 |
| **Kurtosis** | 2.798738 | 4.616195 | 3.240985 | 3.011215 | 6.96772 |
| **Jarque-Bera** | 12.59401 | 60.3195 | 39.05484 | 35.80586 | 405.1433 |
| **Probability** | 0.001842 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **Sum** | 487.4005 | 4791.593 | 1163.803 | 2612.199 | 1184.137 |
| **Sum Sq. Dev.** | 70.44783 | 232.3078 | 6.327452 | 314.1713 | 6.936667 |
| **Observations** | 270 | 270 | 270 | 270 | 270 |

**Table 4 Summary of the Panel Unit Root Test.**

| Series | Statistic | Prob- ability | Cross- sections | Obser- vations | Stationarity | Intercept/ Trend |
|---|---|---|---|---|---|---|
| **$LNCO_2$** | −3.5029 | 0.0002 | 10 | 270 | Level/I(0) | None |
| **LNTA** | −1.6696 | 0.0475 | 10 | 270 | Level/I(0) | None |
| **LNKOFGI** | −8.87399 | 0.0000 | 10 | 270 | Level/I(0) | Individual intercept |
| **LNFFEC** | −2.26877 | 0.0116 | 10 | 270 | Level/I(0) | Individual intercept |
| **LNY** | −2.05559 | 0.0199 | 10 | 270 | Level/I(0) | Individual intercept |

typical deviation of 1). Table 3 displays the basic statistics of the five variables. Specifically, it contains the standard deviation, the mean, and minimum and maximum values of the variables used in this study.

**Panel unit root test**. To start analysis on this panel data, it is necessary to find the unit root of all the series of this panel data. We direct unit pull tests for the four factors to check regardless of whether these four picked factors are fixed. As per new exploration, unit pull tests for board sets have more noteworthy strength than unit pull tests for individual time series. E-Views might figure one of the five board unit root tests (LLC) curtailed as (Breitung 2001; Im & Pesaran 2003; Levin et al. 2002), Fishers' tests in light of the ADF upgraded Dicky Fuller test, and PP (Phillips and Perron) tests. Hypothetical help for these tests is given by (Ateljevic 2001; Maddala and Wu 1999; Munday 2007).

"Panel Unit Root" is the normal name for panel information investigation. In principle, these tests are only numerous relapse conditions with unit attaches applied to the designs of board information series. At the point when individual time series are inspected utilizing increased unit root, a solitary condition with a few factors that are different slacked terms arise. At the point when a board information series is tried for stationarity or unit root, the presence of cross-sectional sources makes the test yield various series instead of a solitary condition. Table 4 depicts the test results.

Since testing methods depict, at the level, these 4 variables are stationary. Consequently, in the next analysis, this study uses the level of stationarity while conducting the process of regression. Therefore, the regression results imply that tourism and the globalization index are independent factors influencing the emission of carbon. All variables, including the dependent variable $CO_2$ emissions and independent variables **TA, GDP, FFEC**, and **KOFGI**, have been stationary at the level.

The Levin, Lin & Chu t* method assumes:

**Null Hypothesis** ($H_0$): Unit root (assumes a common unit root process).

**Table 5 Panel least squares method.**

| Variable | Coefficient | Standard deviation | t-Stat | Probability |
|---|---|---|---|---|
| LNTA | 0.054442 | 0.023674 | 2.299662 | 0.0222 |
| LNKOFGI | −0.957873 | 0.346849 | −2.761645 | 0.0062 |
| LN_Y_ | 0.494059 | 0.049343 | 10.01281 | 0.0000 |
| LNFFEC | 0.929309 | 0.130140 | 7.140861 | 0.0000 |
| $\alpha_{it}$ | −3.887761 | 1.625770 | −2.391335 | 0.0175 |

By considering the following **AR(1)** process for panel data:

$$y_{i,t} = \rho_i y_{i,t-1} + \epsilon_{i,t} + X_{i,t}\beta \quad (5)$$

The ID code for each country is represented by i = 1,2,…,N in the equation above as 10-UK, 9-Germany, 8-Thailand, 7-Mexico, 6-Turkey, 5-Italy, 4-China, 3-USA, 2-Spain, and 1-France, depicts cross-sectional series or units, and t = 1998, …, 2024 (demonstrates time period). An exogenous variable is denoted by $X_i$ in equation (5), and fixed effects and individual trends are also included in the exogenous variables. To demonstrate autoregressive coefficients, i has been added to the equation, and there is an i,t term for mistakes that are taken into consideration.

The above panel unit root results give a clear indication for the methodology, as all series are stationary at level, so panel least squares might be applicable.

## Evaluations & discussion

**Econometric test**. Table 5 represents the results of the panel least squares analysis. The analysis indicates that emissions of $CO_2$ have a +ve relationship with tourist arrivals (**TA**), economic growth (**Y**), and fossil fuel energy consumption (**FFEC**). However, $CO_2$ emissions have an inverse relationship with the globalization index (**KOFGI**).

**Table 6 Regression model summary statistics.**

| Statistic | Value | Statistic | Value |
|---|---|---|---|
| Log-likelihood | −56.52201 | F-statistic | 127.9875 |
| S.E. of regression | 0.301118 | Sum squared resid | 24.02816 |
| R-squared | 0.658923 | Adjusted R-squared | 0.653774 |
| Prob(F-statistic) | 0.000000 | Mean dependent variable | 1.805187 |
| S.D. dependent variable | 0.511750 | Akaike info criterion | 0.455719 |
| Schwarz criterion | 0.522356 | Hannan-Quinn criterion | 0.482477 |
| Durbin-Watson statistic | 0.049935 | | |

The regression equation is given as:

$$CO_2 = \alpha_{it} + \beta_1 \ln(TA_{it}) + \beta_2 \ln(Y_{it}) + \beta_3 \ln(KOFGI_{it}) + \beta_4 \ln(FFEC_{it}) \quad (6)$$

$$\ln(CO_2) = -3.89\alpha_{it} + 0.054 \ln(TA_{it}) + 0.49 \ln(Y_{it}) - 0.96 \ln(KOFGI_{it}) + 0.93 \ln(FFEC_{it}) \quad (7)$$

All variables have a significant impact on the sustainable environment in the entire countries of this panel, as shown in Table 6. The coefficients of tourism, fuel consumption, and economic growth have positive signs which prove that a sustainable environment has effected by increasing these variables or it can be narrated that a sustainable environment is depleted as these variables increase in most tourist countries.

**The Hausman test**. The Hausman test, as devised by (Hausman 1978), aids in deciding between random and fixed effects models. It is based upon the idea that in the absence of a correlation between the regressors and the individual effects, both GLS and OLS estimators have been consistent; however, OLS is inefficient. In contrast, when such a correlation exists, OLS remains consistent, but GLS becomes inconsistent.

This methodology is particularly relevant for analyzing data from the top ten visiting countries because it allows researchers to account for unobserved heterogeneity across countries. By using the Hausman test, the study can determine whether country-specific effects (e.g., cultural, economic, or regulatory differences) are correlated with the independent variables (Baltagi & Baltagi 2008). If such correlations exist, a fixed effects model is preferred to ensure unbiased and consistent estimates (Wooldridge 2010). This approach is crucial for drawing accurate conclusions about the impact of Tourism on emotions and finances across diverse populations, as it controls for country-level variations that could otherwise distort the results (Gujarati & Porter 2009).

*Key reasons for using the methodology.*

i. **Unobserved Heterogeneity**: The top ten visiting countries likely have unique cultural, economic, and regulatory characteristics that could influence tourism and its effects. The Hausman test helps determine whether these unobserved factors are correlated with the regressors (Baltagi & Baltagi 2008).
ii. **Model Selection**: It ensures the appropriate choice between fixed and random effects models, which is critical for obtaining reliable and unbiased estimates (Hausman 1978).
iii. **Cross-Country Comparisons**: By controlling for country-specific effects, the study can isolate the impact of tourism on emotions and finances, providing more generalizable findings (Gujarati & Porter 2009).

**Table 7 Results: Test (Hausman).**

| Test | Chi. Stat | Chi. d.f. | Probability |
|---|---|---|---|
| Hausman | 3.647670 | 4 | 0.4558 |

**Table 8 Results: cross-section random effects (Panel EGLS).**

| Variable | Coefficient | Standard deviation | t-Stat | Probability |
|---|---|---|---|---|
| LNTA | 0.053506 | 0.016227 | 3.297247 | 0.0011 |
| LNKOFGI | 1.518237 | 0.190902 | 7.952980 | 0.0000 |
| LN_Y_ | 0.371586 | 0.021561 | 17.234540 | 0.0000 |
| LNFFEC | 1.532262 | 0.207653 | 7.378966 | 0.0000 |
| C | −16.003600 | 0.788028 | −20.308400 | 0.0000 |

iv. **Robustness**: The Hausman test enhances the robustness of the analysis, ensuring that the results are not driven by omitted variable bias or model misspecification (Wooldridge 2010).

This methodological rigor is essential for understanding the nuanced relationship between social media usage and its consequences across diverse populations.

Hausman introduced procedures of 2 hypothesis-testing:

- Under $H_0$, consistent estimators, while $B_o$ unefficient.
- Under $H_1$, consistent and efficient $B_o$, while $B_1$ inconsistent.

The Hausman test examines that regressors have been correlated with unobservable individual effects. If the statistic's value is significant, it implies a preference for the fixed effects model. Otherwise, the random effects model is more appropriate.

The test statistic is expressed as:

$$H = \left(\left(\hat{B}^{FE} - \hat{B}^{RE}\right)\right)^T \left[\mathrm{Var}(\hat{B}^{RE}) - \mathrm{Var}(\hat{B}^{FE})\right]^{-1} \left(\left(\hat{B}^{FE} - \hat{B}^{RE}\right)\right) \sim \chi^2(k).$$

A significant value rejects the null hypothesis, favoring the fixed effects model. Table 7 illustrates the Hausman-Test summary.

**The random effect method**. The random effect model provides an alternative approach by treating the constant for every section as random variables instead of fixed parameters. Mathematically:

$$a_i = a + v_i, \quad (8)$$

where standard random variable is denoted by $v_i$ with zero mean. The random effect model is represented as:

$$Y_{it} = (a + v_i) + \beta_1 X_{1it} + \beta_2 X_{2it} + \cdots + \beta_k X_{kit} + W_{it} \quad (9)$$

$$Y_{it} = a + \beta_1 X_{1it} + \beta_2 X_{2it} + \cdots + \beta_k X_{kit} + (v_i + u_{it}) \quad (10)$$

The estimation results using the random effects model are provided in Table 8.

Concerning the values of effect specification, the following observations are made.

- **Random Cross-Section:** SD = 0.349482, Rho = 0.9553
- **Fixed Periods (Variables (Dummy)**
- **Random Idiosyncratic:** 0.075576, Rho = 0.0447

The SD for random cross-section indicates the spread of values in randomly selected cross-sections of data. It indicates how much a value is different from the mean of the sample. Since the value for the SD is not greater, it shows a smaller dispersion within the cross-section. The random idiosyncratic value indicates the random error concerning various observations.

Similar to random error in cross-section, it indicates an unobserved factor that can affect the dependent variable. The value of 0.075576 is smaller indicating a smaller random error to each observation.

**Statistics (Weighted) and (Unweighted)**. The weighted and unweighted statistics are given as follows.

- R-Sq.: 0.860682
- Adjusted R-Sq.: 0.843195
- S.D.D. Var: 0.190714
- M.D. Var: 1.805187
- S.E. of Regr.: 0.07552
- Sum Sq. Res.: 1.363081
- F-Stat.: 49.21681
- Pro(F-Stat.): 0.0000
- Durbin-Watson Stat: 0.455217

The unweighted statistics are the following.

- R-Sq.: 0.583001
- M.D. Var: 1.805187
- Sum Sq. Res.: 29.37667
- Durbin-Watson Stat: 0.021122

As the Hausman test suggested, the cross-section random effect model (REM) is significant. Here, $CO_2$ is dependent variable while TA, KOFGI, Y, & FFEC are independent variables. The equation is as follows:

$$CO_2 = -16.0036C + 0.0535\ln(\mathrm{TA}) + 1.5182\ln(\mathrm{KOFGI}) + 0.37159\mathrm{Y} + 1.5323\mathrm{FFEC} \quad (11)$$

In REM, all explanatory variables (TA, KOFGI, Y, and FFEC) has been statistically significant upon 1% level and have a +ve effect on $CO_2$. This means that $CO_2$ moves along with the movement of these variables, with $R^2 = 86\%$ (weighted statistics) and $R^2 = 58\%$ (unweighted statistics). The constant (intercept) of the equation is -16.00 and is highly significant at the 1% level.

$$\ln CO_2 = -16\alpha_{it} + 0.054(\ln ta_{it}) + 0.372(\ln_{Y_{it}}) + 1.532(\ln kof\ gi_{it}) + 0.93(\ln ffec_{it}) \quad (12)$$

## Discussion

*Fossil Fuel Energy Consumption (FFEC) and $CO_2$ emissions*. The dominant role of fossil fuel energy consumption (+153%) in driving $CO_2$ emissions corroborates well-established research. For instance, (Eltved 2020) and (Zhang et al. 2022) identified transportation and industrial energy use as primary contributors to tourism-related emissions. Similarly, (Liu et al. 2018) estimated that tourism accounts for 8% of global greenhouse gas emissions, largely due to fossil fuel dependency. However, this study extends these findings by demonstrating that even high-income tourist economies, despite investments in sustainable infrastructure, struggle to decouple energy consumption from emissions. This challenges the Tourism-Led Growth Hypothesis (TLGH), which often assumes tourism's economic benefits outweigh environmental costs (Zhang et al. 2023).

*Globalization and its paradoxical impact*. The REM revealed a positive association between globalization and $CO_2$ emissions (+151%), contrasting with earlier studies that emphasized globalization's potential to reduce emissions through green technology transfer (Razzaq et al. 2021) This discrepancy may stem from the unique dynamics of top tourist economies, where globalization amplifies carbon-intensive activities (e.g., international aviation, industrial supply chains) faster than eco-innovations can mitigate them. These results align with (Xie et al. 2024), who found globalization increased ecological footprints in Mediterranean countries due to heightened trade and transportation.

*Tourism arrivals and modest environmental costs*. Tourism's modest contribution to emissions (+5.35%) partially supports arguments that high-income countries have adopted sustainable tourism practices (Ali et al. 2021). However, this finding also underscores unresolved challenges in decarbonizing aviation and hospitality sectors, as noted by (Ghosh et al. 2022). While the results suggest progress, lower emissions are attributed to tourism's indirect supply chains. This highlights the need for stricter regulations in transportation and accommodation.

*Economic Growth (Y) and linear environmental degradation*. The linear relationship between economic growth and $CO_2$ emissions (+37%) challenges the endogenous growth theory, which posits that emissions decline after income thresholds are reached (Ludwig et al. 2014)). This aligns with recent critiques by (Molina-Collado et al. 2022), who found no endogenous growth theory evidence in top tourist economies, and (Razzaq et al. 2021), who emphasized that growth in service-oriented economies still relies on carbon-intensive energy. The absence of nonlinear terms (e.g., GDP squared) in this study limits direct endogenous growth theory testing but reinforces skepticism about automatic decoupling in affluent nations.

## Policy implications

*Tourist arrivals*. The panel analysis of most visited tourist countries shows that the more tourist arrivals a country has, the faster $CO_2$ grows.

*Economic growth*. The impact of economic growth on $CO_2$ is also positive which can be stated as economic growth increases the depletion of a sustainable environment due to an increase in $CO_2$ emission. Economic growth remains linearly tied to environmental degradation. The Hausman test highlights the significance of engaging communities, businesses, and other relevant parties in decision-making. By integrating a variety of viewpoints and expertise the approach enables participation, in governance processes ultimately fostering sustainable outcomes. To further account, for the results of a unit root in the extant literature, this study utilized the homogeneity of this penal data. Specifically, all countries are high-income and have highest tourist arrivals in the last few decades.

*Fossil fuel energy consumption*. The same impact of FFEC on a sustainable environment is observed. Because $CO_2$ is directly produced in the incineration of fossil fuel. Penal OLS is applied which produces asymptotically unbiased and efficient coefficient estimates. It is also noted that the minor impact of tourist arrival on $CO_2$ emission is approximately only 5% which indicates that these high-income countries have sustainable tourist attractions the actual sustainable environment damage is due to energy consumption i.e. 93% for different purposes like industry, agriculture, and transport which is an alarming situation for the most visited countries. Global warming and sustainable environmental damage can change the biodiversity in these regions and affect the beauty of natural tourist attractive wonders like polar mountains and beaches, etc.

*Globalization*. While globalization's impact is positive, which means that as globalization increases and improves the means of transportation, it is not enough to produce environmentally

friendly technologies that have been introduced to reduce $CO_2$ emissions but significant to reduce. In this study, a higher value of the globalization index indicates that the efforts of these 10 most visited countries to sustain the natural habitat and resources by technical advancement and revival of their traditional heritage not only attract more tourist to sustain their higher rank in most visited countries but also enhance their economic growth. So, this study concludes that these 10 most visited economies are taking benefits from globalization to boost different economic, social, and environmental sectors. Globalization in the sense of development and improving health conditions will improve the lifespan of the working population in the upcoming years.

### Limitation

*Data constraints.*

- The first is the subject matter on which the availability of data is low which necessitates the collection of more data and further analysis.
- Secondly, during COVID-19, traveling restrictions highly impacted the tourism industry and the lack of data makes the analysis difficult.
- COVID-19 is one of the biological and environmental parameters that affect significantly the tourism industry worldwide. Its impact should be further investigated in depth.

*Geographical and income bias*. The study focuses on high-income, heavily industrialized nations e.g., France, USA, etc., limiting generalizability to developing economies with different sustainability challenges.

*Methodological boundaries*. The Hausman test's assumption of exogeneity may not fully capture endogeneity between variables like globalization and energy consumption. Projected data for 2022-2024 introduces uncertainty, as actual post-pandemic recovery patterns may deviate from forecasts.

## Conclusion

This study explores the potential of the Hausman test to investigate the effect of tourism and globalization on a sustainable environment using real-world datasets. The analysis reveals that the most visited countries have the largest economies and contribute significantly to $CO_2$ emissions in their region, which has far-reaching implications on environmental and social variables. Aside from a few years of poor performance, tourist arrivals to these countries climbed steadily in the selected time frame (in this work). Being a rapidly rising economy with a large number of travelers has an important impact on the country's sustainable environment. As a result, this study looks into the relationship among $CO_2$ emissions, tourism, and the growth of the economy. For analysis, this study used panel data from 1998 to 2024 and a nonlinear model of estimation, which produces more realistic empirical results than typical linear estimating approaches such as the linear model. The insights gained from applying the Hausman test provide perspectives on the interplay between tourism, globalization, and environmental sustainability. Hausman test offers a framework for evaluating the impacts of tourism and globalization by considering ecological, social, and economic aspects concurrently. This inclusive approach allows for an understanding of the connections and tradeoffs inherent in sustainable development. Through the use of the Hausman test, it becomes clear that achieving sustainability in tourism and globalization often requires navigating tradeoffs between goals. The Hausman test emphasizes the significance of taking into account the socio-environmental context of each destination when assessing sustainability. What may work well in one location might not be suitable elsewhere. Therefore, tailoring and adjusting sustainability strategies are crucial to address challenges and opportunities. The random effect model revealed that there is heterogeneity among the top-visited countries.

## Data availability

The dataset can be requested from the authors.

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## Author contributions

Saba Nourin: conceived the idea, performed data analysis and wrote the original draft. Ismat Nasim: conceived the idea, performed data curation and wrote the original draft. Hafiz Muhammad Raza ur Rehman: performed data curation, formal analysis, and designed methodology. Elisabeth Caro Montero: did project administration, dealt with

software and performed visualization. Mirtha Silvana Garat de Marin: acquired the funding for research, and performed visualization and initial investigation. Nagwan Abdel Samee: designed methodology, did investigation and performed validation. Imran Ashraf: supervised the study, performed validation and review and edit the manuscript. All authors read and approved the final manuscript.

## Competing interests
The authors declare no competing interests.

## Ethical approval
This study does not involve human participants or their data.

## Informed consent
This study does not involve human participants or their data and an informed consent is not needed.

## Additional information
**Correspondence** and requests for materials should be addressed to Hafiz Muhammad Raza ur Rehman or Imran Ashraf.