Human Nature Journal of Social Sciences
Vol.7, No.2 (June, 2026), Pp.1-23
ISSN(online): 2788-5240, ISSN(print): 2788-5232
DOI: https://doi.org/10.71016/hnjss/dhr32876

Original Article https://hnpublisher.com

Does Climate Change Moderate the Tourism–Growth Nexus? Panel Evidence from Pakistan's Provinces

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ABSTRACT

Aim of the Study: This study investigates how climate change influences provincial economic growth in Pakistan via international tourism, using annual data for 2009–2021 across Punjab, Sindh, Khyber Pakhtunkhwa and Balochistan. It examines the direct effect of climate change on growth, the positive contribution of international tourist arrivals to economic output, and whether climate stress weakens tourism's growth dividend through a climate–tourism interaction term.

Methodology: Climate change is proxied by mean annual temperature and precipitation; international tourist arrivals measure tourism activity. The analysis applies a sequential second-generation panel approach: Pesaran (2004) cross-sectional dependence test, Pesaran–Yamagata (2008) slope homogeneity test, CIPS and CADF panel unit-root tests, Westerlund, Pedroni and Kao cointegration tests, FMOLS and DOLS long-run estimators, and the Dumitrescu–Hurlin (2012) heterogeneous panel causality test. A conditional effect is tested via an interaction term (lnIT × CC).

Findings: All variables are I(1) and exhibit a stable long-run cointegrating relationship. FMOLS and DOLS estimates consistently show a significant negative direct effect of climate change on provincial GDP and a significant positive impact from international tourist arrivals. The interaction term is negative and statistically significant (FMOLS: −0.015, $p < 0.01$; DOLS: −0.020, $p < 0.05$), indicating that climatic stress attenuates tourism's positive contribution to growth. Dumitrescu–Hurlin tests indicate bidirectional causality between tourism and economic growth.

Conclusion: Tourism-led growth in Pakistan is vulnerable to climatic deterioration; sustaining tourism's macroeconomic benefits requires integrating climate adaptation into tourism policy, investing in resilient infrastructure, and coordinating provincial climate–tourism governance to protect long-run economic prospects.

Keywords: Climate Change; Tourism-led Growth; Economic Growth; Panel Cointegration; FMOLS; Sustainable Tourism.

Article History

Received:
February 13, 2026

Revised:
May 17, 2026

Accepted:
June 16, 2026

Online:
June 30, 2026

1. INTRODUCTION

1.1 Global Context: Climate Change as a Macroeconomic Constraint

Climate change is a structural issue that poses a major threat to macroeconomic stability in the 21st century. It now has a wide range of implications that go beyond the environmental arena and are discussed in development economics, fiscal sustainability, and long-run growth policy. Increased temperatures altered precipitation and more extreme weather events impact economies in various ways, such as reduced agricultural productivity, infrastructure damage, reduced labour efficiency and increased health spending. Together, these pressures result in significant welfare and output losses in both advanced and developing countries (Rasooli & Yawar, 2025; Kashif et al., 2025; Baber et al., 2025). The burden is high in countries where economic activity remains dominated by climate-sensitive activities and where adaptive institutional and fiscal capacities are comparatively low.

Climate variability impacts macroeconomics in several ways, both through supply-side and demand-side pathways. Loss of crops, water shortages, disruptions to energy supplies, and climate-related damage to infrastructure raise production costs and reduce total factor productivity. At the same time, climatic uncertainty is affecting consumption habits, investment decisions, and the functioning of service-based sectors such as tourism. The indirect impacts are no less important. Human capital costs of heat-related illness, reduced labour productivity, and increased incidence of vector-borne diseases are significant and extend beyond lost production (IPCC, 2022). These shocks can alter development paths when they occur more frequently than before, heighten structural vulnerabilities, and exacerbate structural inequalities, especially in low- and middle-income economies.

There has been an increasing formalisation of the climate–growth nexus through empirical research within macroeconomic modelling frameworks. Findings from computable general equilibrium models, structural climate-economy approaches, and panel estimations all confirm that economic growth is reduced by temperature anomalies and precipitation instability. The impacts are especially severe in economies that are already at their ecological and physiological limits in tropical and subtropical regions (Chang et al., 2023; Kamolthip, 2025; Karydas & Xepapadeas, 2021; Kompas et al., 2024; Kahn et al., 2021; Zhao & Liu, 2023). The new consensus calls for the use of climate risk in designing macroeconomic policies and supports a deeper exploration of the climate risks affecting sectors, such as the tourism sector, which is a significant source of growth and foreign exchange in many developing countries.

1.2 Tourism as a Climate-Sensitive Growth Driver

Tourism plays an important role in developed and developing economies due to the many backward and forward linkages. Tourism creates jobs in both the formal and informal sectors, contributes to foreign exchange earnings, drives infrastructure development, and has multiplier effects across the transport, retail, agriculture, and handicrafts sectors, among others (Brida et al., 2016; Khan et al., 2020; UNWTO, 2023). In many low- and middle-income countries, tourism is considered a key policy tool for export diversification and structural transformation, especially when industrial growth is constrained by limited technological and financial capacity.

Tourism is highly vulnerable to climate change but has development potential. Weather stability, ecosystem quality and environmental reliability are tightly correlated with destination attractiveness, visitor mobility, and tourism seasonality (Scott et al., 2016). Climate change thus presents different threats to different parts of the tourism sector. Sea level rise, storm surge, and thermal discomfort are increasing threats to coastal tourism. Snowfall uncertainties, glacial retreat, and the loss of snow reliability pose threats to mountain and winter tourism, and ecosystem degradation and biodiversity loss threaten ecotourism (Demiroglu et al., 2018; Seetanah & Fauzel, 2019). There is also evidence that climate change could affect the geographic distribution of tourism demand by reducing demand in heatstressed coastal and lowland areas and increasing demand in higher-elevation and/or higher-latitude areas, potentially leading to shortened and unstable existing tourism seasons (Scott et al., 2016).

The tourism-climate change connection is not one-way. Tourism is associated with high levels of greenhouse gas emissions, including those from aviation, accommodation, food systems, and surface transport. Measured over a full life cycle, the sector is expected to contribute around 8-11 percent of the global emissions (Lenzen et al., 2018). This forms a feedback loop in which tourism growth compounds the environmental pressures that jeopardise its sustainability. Consequently, there is an increased need to recognise the importance of frameworks that account for environmental externalities, carbon accountability, and destination resilience in sustainable tourism analysis, alongside more traditional growth-based indicators.

1.3 Pakistan: Climate Vulnerability and Tourism Potential

The Pakistan case is unique in providing a compelling context for analysing the climate–tourism–growth relationship. It is one of the most climate vulnerable countries in the world as it is exposed to frequent floods, extended drought cycles, glacier lake outburst floods (GLOFs) in the Karakoram and Hindu Kush Mountains, increasing heat stress, and significant rainfall variation (Eckstein et al., 2021; Salik et al., 2015). Pakistan was among the worst-hit countries by extreme weather events, and the recent 2022 floods have caused damage of more than USD 30 billion, highlighting the macroeconomic impact of climate shocks (Eckstein et al., 2021; Government of Pakistan, 2022).

Meanwhile, the country has an impressive tourism potential, thanks to its geographical and ecological diversity. Some of the world's highest mountain ranges, glaciated valleys, and protected trekking corridors are in Pakistan's northern region, which has been steadily gaining attention for adventure and nature-based tourism. The UNESCO-recognised archaeological and cultural heritage sites of Punjab and Sindh, and marine ecosystems and beach tourism opportunities of the coastal areas of Sindh and Balochistan. This variety also increases the exposure to climate change. Northern areas are at risk of landslides, GLOFs, and transport disruption, as coastal areas are susceptible to erosion, saline intrusion, and marine ecosystem degradation (Shahzad et al., 2021).

While the tourism sector was on the ascent for a long time before the pandemic and has been recognised as a strategic growth sector in Pakistan's Vision 2025 and subsequent development plans, empirical evidence of the tourism sector's performance across provinces, conditioned by climate, remains limited. Most existing research either evaluates climate vulnerability qualitatively or analyses tourism–growth relationships in general, without specifically addressing the impact of climate change. Meeting this need is the prime motivation of the present study.

1.4 Research Problem and Motivation

The central issue addressed in this study is not merely whether tourism contributes to economic growth, since this relationship is already well established within the international literature. The more important one is whether climate change systematically reduces tourism's contribution to growth. The issue is of special policy relevance in Pakistan, where tourism is being encouraged as a regional development and foreign exchange-earning sector, even though important tourism resources in the country are located in environmentally worrisome and hazard-prone areas. Climate related shocks can impact tourism in a variety of interconnected ways.

Environmental degradation and floods, landslides, and extreme weather events can affect the attractiveness of destinations, damaging roads, bridges, and tourism infrastructure, thereby affecting accessibility to tourism sites. The actual and perceived risks to safety can also increase with climatic instability, as well as with changing seasonal patterns in tourism and tourism-related enterprise operating costs. If these impacts remain, there could be a climate threshold between tourism and economic growth. Tourism is likely to contribute to growth in relatively stable environments but yield modest or negative results in the face of protracted climate stress. To examine this conditional relationship, the empirical framework must enable simultaneous estimation of the direct effects of climate change on growth, the autonomous effect of tourism, and the interaction effect that accounts for the moderation of tourism-driven growth by climate conditions.

1.5 Research Questions and Objectives

This study addresses the following research questions:

1. Does climate change exert a significant negative effect on economic growth across the provinces of Pakistan?
2. Does climate change moderate the relationship between international tourist arrivals and economic growth?
3. Does climate change reduce international tourist arrivals?
4. Do international tourist arrivals contribute positively to provincial economic growth?

The corresponding objectives are:

i. To examine the direct effect of climate change on provincial economic growth.

ii. To test whether climate change moderates the tourism–growth relationship;

iii. To evaluate the effect of climate change on international tourist arrivals, and

iv. To determine whether tourist arrivals contribute positively to economic growth in Pakistan.

1.6 Contribution of the Study

The study is significant in three ways to the body of literature related to environmental economics, tourism economics, and development policy. First, it builds an integrated empirical framework between climate change, tourism and economic growth across the provinces of Pakistan. The provincial-level focus is especially crucial in a nation with considerable variability in climate exposure, tourism intensity, infrastructure availability, and adaptation capacity, which is difficult to capture in national-level analyses.

Second, the study takes advantage of second generation panel estimation techniques that can account for cross-sectional dependence and slope heterogeneity. In provincial datasets, where climatic shocks, national policy changes, and interdependencies in economic activities lead to correlated shocks across provinces, these characteristics are particularly relevant. Thirdly, the analysis explicitly examines the mechanism by which climate change could reduce the tourism sector's growth-enhancing impact. The study goes beyond the additive modelling frameworks used in previous research, providing a more theoretically informed understanding of how climate stress limits tourism's capacity to drive development pathways and how it affects the sustainability of regional development.

2. LITERATURE REVIEW

2.1 Macroeconomic Consequences of Climate Change

In the macroeconomic literature on climate change, the focus has shifted from hypothetical simulations to empirical analysis of observed and near-term economic consequences. An important step in this transition was taken by Burke et al. (2015), who found a strong non-linear relationship between per-capita income and temperature. They conclude that the most efficient economic production is achieved at a temperature around 13°C, and that rising temperatures lead to progressively smaller production losses beyond this point. The impacts are highly skewed to the tropics and subtropics of the developing world, where climatic conditions are already at or near the physiological and agricultural limits. Mitra et al. (2025) build on this literature and find that the impacts of persistent climatic change and short-term weather variability are non-transitory, in line with long-run panel data for 174 countries, and especially in countries with high agricultural dependency. Macroeconomic pathways to climate change constraints are well understood. In Agriculture, the sector contributes over 19 per cent of Pakistan's GDP and employs a significant portion of the population. In this sector, rising temperatures, changes in rainfall patterns, and the increasing frequency of droughts affect crop productivity, heighten food price volatility, and heighten food security risks (Fahad et al., 2024).

Climate related disruptions also put huge stress on infrastructure systems. The rising frequency of extreme weather events threatens roads, irrigation networks, and energy infrastructure, causing them to degrade more quickly, operate less efficiently, and cost the public significant sums for repairs and reconstruction (Martino, 2023). Energy systems are subjected to twin pressures: warmer temperatures drive up electricity demand for cooling, and reduced river flows limit hydropower generation capacity, both increasing industrial energy costs and decreasing productive efficiency (IEA, 2021).

Another indirect impact of climate change on macroeconomic outcomes is through its effects on human health and labour productivity. As temperatures rise, heat stress, dehydration, and cardiovascular strain will increase, resulting in reduced labour supply due to diminished physical capacity and increased interruptions to working hours (De Sario et al., 2023; Gibb et al., 2024). These effects are especially harsh for outdoor and agricultural workers who are exposed to prolonged extreme heat. Chronic kidney disease has also been correlated with prolonged heat exposure and significant productivity losses in labour-intensive industries (Gibb et al., 2024). Meanwhile, the rising prevalence of climate-sensitive diseases drives up health care costs and puts financial strain on low- and middle-income economies.

Taken together, these interrelated mechanisms position climate change not as a peripheral environmental concern, but as a systemic constraint on macroeconomic stability, productive capacity, and long-term development.

2.2 Tourism, Economic Growth, and the Tourism-Led Growth Hypothesis

The tourism-led growth hypothesis is related to the theory that tourism can drive economic growth. The theoretical underpinning of the Tourism-led Growth Hypothesis (TLGH) as a model of economic growth is that tourism growth has positive direct, indirect, and induced multiplier effects that stimulate overall economic activity in a nation. In addition to spending on accommodation, transportation, food services, and recreation, tourism creates demand in the agriculture, manufacturing, construction, and local service sectors, which are interconnected (Alcalá-Ordóñez et al., 2024). The sector has several macroeconomic impacts; it generates foreign exchange earnings to ease balance of payments pressures, jobs across a variety of skill levels, tax and service fee revenue, and infrastructure that improves overall productive capacity. There is substantial empirical evidence for the TLGH, albeit with varying levels of size and consistency in different economic settings. Meta-analytical and systematic review studies usually conclude that there is a positive relationship between tourism development and economic growth, but the magnitude and direction of this relationship depend on structural and institutional conditions in the host countries (Ahmad et al., 2020).

The impact of income levels, institutional quality, tourism intensity, and economic diversification on translating tourism activity into sustainable growth is significant. The multiplier effects are generally smaller in developed economies where tourism has weak linkages in the domestic production system, but larger in developing economies. In economies with import-dependent supply chains in the tourism industry, or high foreign ownership in the sector (revenue leakage), growth benefits are likely to be lower, by contrast. The Tourism-Led Growth Hypothesis has been the subject of much empirical work in South and Southeast Asian countries. Using panel data for developing countries, Khan et al. (2020) found a positive relationship between tourism and economic growth, but this relationship was moderated by institutional quality and domestic investment capacity. This is also reflected in the existing literature on the subject, which shows a positive, albeit comparatively weak, link between tourism receipts and GDP growth in Pakistan (Shahzad et al., 2021). Still, one can only find a few studies that address two key issues. Most analyses are at the national level, which masks provincial-level differentiation, and only a few studies explicitly examine the effect of climate-related stressors on the tourism–growth nexus. The question of tourism's sustainability amid growing climatic instability remains unanswered and is a key focus of the current study.

2.3 Climate Change and the Tourism Sector

Climate change and tourism have been examined from various angles on both the demand and supply sides of the tourism sector, given the sector's reliance on environmental stability and climatic suitability. Climatic factors such as temperature, precipitation, duration of sunshine, and exposure to extreme weather events have a major influence on tourists' destination choice, travel time, and length of stay from a demand-side perspective (Scott et al., 2016). Climate analogue modelling and tourism demand elasticities are both empirical models that consistently project increases in temperature, causing changes in the spatial and seasonal distribution of global tourism demand. Regions in tropical and subtropical areas will likely become less competitive in the future due to rising thermal discomfort and environmental instability, whereas regions in cooler and high-latitude areas will likely experience relative increases in tourism demand (Gössling & Hall, 2023). These dynamics have significant implications for coastal and beach tourism, particularly in the southern parts of Pakistan, where rising temperatures make outdoor activities less appealing, and sea-level rise and storm surges pose risks to coastal infrastructure and tourism assets.

The supply-side view is the climate change impact on the environmental infrastructure that tourism activity relies on. Glacier retreat and changing snowpack trends are altering hydrological systems and water availability and are introducing a greater risk of glacier lake outburst floods (GLOFs) and landslides, which periodically impact transport and access to tourism in high-altitude areas like northern Pakistan (Shahzad et al., 2021). Climatic stress also contributes to biodiversity loss and ecosystem degradation, with declines in the ecological value of wildlife and ecotourism sites, as well as in their long-term competitiveness. In a study of alpine ski tourism, Demiroglu et al. (2018) report dramatic changes in visitor behaviour driven by glacier retreat and declining snow reliability. The analysis focuses on winter tourism, but the results are also applicable to Pakistan's trekking and mountain tourism industry, where environmental degradation is posing a threat to its sustainability.

Cross-country evidence further reinforces the vulnerability of tourism to climatic stress. Seetanah and Fauzel (2019), using panel data on world island economies, report that temperature and precipitation anomalies have statistically significant negative impacts on tourist numbers and tourism revenue, but with varying degrees due to some institutional capacity and the level of destination diversification. The two pillars of sustainable tourism governance identified by Scott et al. (2016) in the assessment of the tourism implications of the IPCC Fifth Assessment Report are climate resilience and sectoral decarbonisation. They highlight the need for tourism's resilience to climate risks and for its own contribution to the climate challenge. Collectively, the literature suggests that climate change is no longer a peripheral environmental issue for tourism policy; rather, it has become a structural determinant of destination competitiveness, tourism sustainability, and long-run sectoral performance.

2.4 Sustainability, Energy, and Adaptation Frameworks

The UNWTO Global Tourism Dashboard and the 2030 Agenda for Sustainable Development call for a sustainable tourism development framework that highlights that there must be a decoupling between the development of tourism and environmental degradation, and that this development must be managed in a way that ensures the quality of tourism destinations for generations to come (UNWTO, 2023). In this context, sustainability calls for simultaneous efforts at mitigation and adaptation. Mitigation is about making the sector less carbon-intensive by using low-emission transportation, more energy efficient accommodation and more sustainable patterns of production and consumption. Adaptation, on the other hand, focuses on enhancing the climate resilience of tourism destinations through climate-resilient infrastructure, disaster risk management, and ecosystem protection.

Energy efficiency plays a central role in this transition. Tourism-related activities, such as accommodation and tourism transport, are also energy-intensive and major contributors to GHG emissions and operating costs. Buildings, including hotels and other resort properties, account for a significant share of global energy use and offer substantial emission-reduction potential at relatively low cost through energy-efficiency measures (IEA, 2021). Energy efficiency in tourist-related operations has several economic and environmental benefits, especially in developing countries like Pakistan, where energy insecurity and reliance on fossil fuels are enduring structural problems. The decrease in energy use also yields cost reductions, a drop in carbon emissions, and greater resilience of tourism businesses to energy price fluctuations and supply disruptions.

Adaptation measures are also crucial at the destination level in ensuring the sustainability of tourism competitiveness in the face of climate change. These measures involve climate-risk mapping for planning tourism infrastructure, investment in flood protection and soil stabilisation systems within tourism corridors at risk, the development of early-warning systems for extreme weather events, and the diversification of tourism products, thus minimising reliance on environmentally vulnerable products. These actions are not just environmental protection and have definite economic value. Proactively building climate resilience usually results in reduced post-disaster recovery costs and greater competitiveness in a tourism sector dominated by travellers' perceptions of environmental safeguards and reliability.

2.5 Empirical Gaps and the Provincial Pakistan Context

Although the number of studies on the interlinkage of climate change and tourism has increased significantly in recent years, there are still some important empirical gaps that need to be addressed. First, much of the existing literature relies on national-level analysis, which obscures substantial within-country variation in climate exposure, tourism resources, institutional capacity, and adaptive resilience. This limitation is particularly problematic in geographically diverse countries such as Pakistan, where provincial disparities are substantial. Second, most tourism-growth studies treat climate conditions as a contextual backdrop rather than modelling climate change as an explicit moderating variable. As a result, the literature provides limited insight into whether tourism's growth effects vary systematically across different climatic conditions. Third, empirical evidence on the climate–tourism–growth nexus within South Asian continental economies remains comparatively limited, particularly in contrast to the extensive focus on small island developing states in the broader tourism-climate literature.

There are significant climatic variations, topographical differences, variations in tourism potential, infrastructure, demographic concentration, and economic composition among the four provinces of Punjab, Sindh, Khyber Pakhtunkhwa (KPK), and Balochistan. Such variations result in meaningful differences in climate exposure and tourism intensity which provide an analytically useful context to outline the effect of climate change on tourism performance and the impact on economic growth. Therefore, panel estimation methods which incorporate unit-specific heterogeneity and adjust for the cross-sectional dependence from the common climatic and macroeconomic shocks provide a more robust and policy-relevant estimation scheme than standard aggregate level estimation methods in this context.

2.6 Hypotheses

Drawing on the theoretical frameworks and empirical evidence reviewed above, the following hypotheses are advanced:

- H1: Climate change exerts a significant negative effect on provincial economic growth in Pakistan.
- H2: Climate change significantly moderates, specifically attenuates, the positive relationship between international tourist arrivals and economic growth.
- H3: Climate change significantly reduces international tourist arrivals.

- H4: International tourist arrivals exert a significant positive effect on provincial economic growth.

3. DATA AND METHODOLOGY

3.1 Research Design

The study is descriptive-explanatory research with panel data analysis, corresponding to the nature of the research questions and the hypotheses. The analytical level goes beyond recognising simple associations and considers directionality in causal relationships, interactions, and long-term dynamics among climate change, tourism, and economic growth. To achieve these goals, a panel-data approach is especially suitable, as it accounts for variability in the data over time and across provinces. The study creates a balanced panel of four provinces in Pakistan (N = 4) over 13 years (T = 2009-2021), yielding 52 province-year observations. The use of provincial instead of national level analysis is theoretically and empirically justified. The climate, tourism resources, population density, infrastructure development and economic composition of the provinces of Pakistan vary significantly. These structural differences have direct implications for the understanding of the impact of climate change on the relationship between tourism activity and economic growth. Such a summary could mask this variation and may mask important regional variation that is key to the theory in this paper.

3.2 Data Sources and Sample

Data are taken from different national data sources and internationally recognised databases and analysed at the provincial level. The provincial expenditure aggregates from the State Bank of Pakistan (SBP) are used as a proxy for provincial economic growth because no consistent provincial GDP series is available in Pakistan's national statistical system. Expenditure aggregates are less than ideal measures because of their measurement limitations, but this proxy is probably the most practical and broadly applicable measure of provincial economic activity in situations where data are limited and is consistent with other empirical studies for analysis. Data on climate related variables (Annual Average Temperature and Annual Total Precipitation) have been retrieved from the World Bank Climate Change Knowledge Portal (World Bank 2022) for harmonised and station-interpolated gridded climate data for the provinces of Pakistan. Information on International Tourist Arrivals (ITA) by province is obtained from the Pakistan Bureau of Statistics (PBS). Population density (persons per sq. km.) data are used from PBS publications, and petroleum energy product consumption (metric tons) are sourced from the State Bank of Pakistan. To ensure the sample period is as consistent as possible (2009-2021), the data for each variable included in the analysis must cover the same period.

3.3 Variable Description and Operationalisation

The dependent variable is Economic Growth (EG), which is proxied by the provincial expenditure in billions of Pakistani Rupees. Climate Change (CC) is the main explanatory construct, and is operationalised by two indicators: annual average temperature (°C) and annual total precipitation (mm). The following variables represent the prominent dimensions of climatic variability that are significant to Pakistan's economic infrastructure, especially tourism activity and agricultural productivity. International Tourist Arrivals (IT) is a tourism channel that can be used to predict the impact of climate change on the economy and is tracked using provincial figures of tourist arrivals reported by the Pakistan Bureau of Statistics (PBS). The model also includes two control variables. Population Density (PD) is the number of people per square kilometre and reflects demographic concentration, urbanisation pressures, labour availability, and environmental stress at the provincial level. A proxy for energy intensity and industrial activity is Petroleum Energy Products Consumption (PEC), in metric tons. Since IT, PD, and PEC are skewed, they are natural-log transformed to make the distribution less skewed, more stable in variance, and to enable estimated coefficients to be interpreted as elasticities. Hypothesis 2 is tested by adding an interaction term (IT×CC) between logged tourist arrivals and the climate change index to the model. This interaction term is the main component for testing the interaction between climate and tourism contribution to economic growth.

Table 1 presents the variables incorporated into the empirical specification

Table 1. *Variable Description, Measurement, and Data Sources*

Variable	Symbol	Measurement	Source	Expected Sign
Economic Growth	EG	Provincial expenditure (PKR billions)	State Bank of Pakistan	— (Dependent)
Climate Change	CC	Annual avg. temperature (°C); Annual total precipitation (mm)	World Bank Climate Change Knowledge Portal	Negative (H1)
Tourist Arrivals	lnIT	International tourist arrivals (log)	Pakistan Bureau of Statistics	Positive (H4)
Tourism × Climate	lnIT×CC	Interaction of lnIT and CC	Computed	Negative (H2)
Population Density	lnPD	Persons per sq. km (log)	Pakistan Bureau of Statistics	Control
Energy Consumption	lnPEC	Petroleum products consumption, metric tons (log)	State Bank of Pakistan	Control

3.4 Model Specification

The baseline empirical specification that captures the long-run relationship between economic growth, climate change, international tourist numbers and control variables is summarized as following:

$$EG_{it} = \beta_0 + \beta_1\, lnIT_{it} + \beta_2\, CC_{it} + \beta_3\, (lnIT_{it} \times CC_{it}) + \beta_4\, lnPEC_{it} + \beta_5\, lnPD_{it} + \varepsilon_{it} \quad (1)$$

where i indexes provinces (i = 1, 2, 3, 4) and t denotes time (t = 2009,…,2021). EG_{it} is a proxy for provincial economic growth (expenditure aggregates). $lnIT_{it}$ is the natural log of the number of international tourists, and CC_{it} represents the climate change index. The interaction term ($lnIT_{it} \times CC_{it}$) accounts for the moderating effect of climate conditions on the tourism–growth relationship. The consumption of petroleum energy products and population density are both expressed in log form, denoted as $lnPEC_{it}$ and $lnPD_{it}$, respectively, and ε_{it} is the stochastic disturbance term. The coefficient of primary theoretical importance is β_3, which quantifies the relationship between tourism and the climatic condition variable. An empirical rejection of Hypothesis 2 would be indicated by a negative, statistically significant value of β_3, indicating that climate stress reduces the positive impact of tourism on economic development. The direct effects of tourism and climate change on economic growth are evaluated using the coefficients β_1 and β_2, respectively, corresponding to Hypotheses 4 and 1.

3.5 Econometric Strategy

3.5.1 Cross-Sectional Dependence and Slope Homogeneity

Before conducting the unit root analysis, the study investigates two aspects of the panel data, cross-sectional dependence (CD) and slope homogeneity. This diagnostic phase is very crucial, as the provincial-level units in Pakistan are not statistically independent. Instead, they are jointly influenced by national macroeconomic policies, common tourism demand shocks, and countrywide climatic fluctuations, all of which can generate contemporaneous correlation in the error structure across provinces. If this dependence is not taken into consideration, standard errors are biased, and the standard first-generation panel unit root and cointegration procedures are therefore no longer reliable.

To formally evaluate this question, the Pesaran (2004) cross sectional dependence (CD) test is used under the null hypothesis of weak cross-sectional independence (WCSI). If this null is rejected, there are unobserved common factors affecting all cross-sections. The Pesaran and Yamagata (2008) delta procedure tests for homogeneity of slopes, i.e., whether the response coefficients are common across provinces. The structural diversity in Pakistan, in terms of geography, climate regime, and tourism capacity, implies a priori heterogeneous slopes. If the slope homogeneity is rejected, this further supports the use of second-generation estimation methods suitably designed for heterogeneous dynamics.

3.5.2 Panel Unit Root Tests

Second-generation unit root tests for panel data are used, accounting for both cross-sectional dependence and slope heterogeneity in the data. Specifically, the Cross-sectionally Augmented IPS (CIPS) test of Pesaran (2007) and the Cross-sectionally Augmented Dickey-Fuller (CADF) test are used. Both tests are extensions of ordinary unit root regressions, in which the cross-sectional mean of the series and its lags are added, thereby eliminating the common factor component that accounts for cross-sectional correlation.

The estimation runs for both constant-only and constant-with-trend specifications. Estimations are made for both constant-only and constant-with-trend specifications. If the null hypothesis is accepted, then it is assumed that a unit root exists across all panel members; if the null hypothesis is rejected then it is assumed that the series is stationary. This method considers the dependence structure of the data, meaning it evaluates the integration properties in a context that is compatible with the data dependence.

3.5.3 Panel Cointegration Tests

To assess the presence of a stable long-run equilibrium relationship between the variables, panel cointegration tests are used if the variables are integrated of order one. There are three complementary procedures that are used to increase robustness.

First, the Westerlund (2005) variance ratio test is used, and it is suitable for both homogeneous and heterogeneous cointegrating relationships and is suitable for panels when there is cross sectional dependence. Second, the Pedroni (2004) test framework is applied in which both panel- and group-level statistics are computed using the Phillips–Perron and Augmented Dickey-Fuller formulations. Third, the Kao (1999) residual-based test is applied and yields a demeaned panel cointegration test of the null of no cointegration.

Using more than one test reduces the chances of being sensitive to inferences from any one test. The rejection of the null hypothesis in all tests is a strong indication that the variables are long-run related.

3.5.4 Long-Run Estimation: FMOLS and DOLS

The two estimators, Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) are complementary estimators for cointegrated panel systems and are used in the estimation of long-run coefficients.

FMOLS, as extended by Pedroni (2004) addresses the endogeneity and serial correlation issues by adding non-parametric adjustments to the long-run covariance structure of the residuals. DOLS, following Mark and Sul (2003), attempts to solve these problems by adding leads and lags of the first-differenced regressors to the cointegrating regression, thus enhancing the small-sample properties of the cointegrating regression and reducing simultaneity bias.

The combination of FMOLS and DOLS constitutes a robustness strategy. If the two estimators lead to similar coefficient estimates, the long-run relations are more credible, whereas if the coefficient estimates differ, the long-run relations may be sensitive to the assumptions made by the two estimators.

3.5.5 Panel Causality Analysis

The study uses Dumitrescu and Hurlin (2012) heterogeneous panel non-causality test to determine the direction of influence between the variables. This test generalizes the Wald test for traditional Granger causality to the panel context, where the individual Wald test statistics are averaged across the cross-sections, with the causal structure varying across provinces. W-bar and standardized Z-bar statistics is reported. The null hypothesis is that there is no Granger causality from the explanatory variable to the dependent variable for all Cross Sectional Units. Rejection of this null suggests that there are causal effects in at least a subset of provinces, and therefore evidence of the directionality of causal effects that are consistent with the study's theoretical basis.

3.6 Justification of Methodological Choices

The econometric approach used in this study depends upon the structure of the data as well as the theoretical goal of the analysis. Cross-sectional dependence is not accidental, but rather expected, as all countries in a cross-section are subject to the same policy settings, macroeconomic cycles, and climate related shocks. Failure to recognize this dependence would reduce the statistical validity and render it false inference. Therefore, the application of second generation unit root and cointegration methods, namely the CIPS and CADF tests, is not only preferential, but also methodologically required. They explicitly model cross sectional dependence and slope heterogeneity, consistent with the underlying data generating process.

Likewise, the simultaneous consideration of FMOLS and DOLS yields robustness to endogeneity and serial correlation, which are likely to exist in systems where climate conditions, tourism activity, and economic outcomes are simultaneously determined. The addition of a tourism x climate variable interaction term directly operationalises the core hypothesis of the study—the conditional effect of climate and tourism. The interaction term between tourism and a climatic variable explicitly translates the core hypothesis of the study—the conditional effect of climate and tourism—which can be ignored within additive specifications. Lastly, the Dumitrescu–Hurlin causality framework complements long-run estimation by providing directional relationships among variables and aligning the study's causal research questions with the empirical strategy.

4. RESULTS

4.1 Descriptive Statistics and Correlation Analysis

Descriptive statistics and bivariate correlation structure for all the variables used in the empirical analysis are reported in Table 2. The results show significant differences among the provincial panel members in Pakistan, further supporting the need for a disaggregated analytical structure. The expenditure in provincial areas, as a proxy for economic growth (EG), shows a high degree of dispersion among provinces, with minimum, maximum, and mean values of PKR 24.3 billion, PKR 469.8 billion, and PKR 123.0 billion, respectively, and a standard deviation of PKR 92.3 billion. This vast gap is a result of structural imbalance in the economic scale of the provinces, between the relatively developed province of Punjab and the structurally constrained Balochistan. Spatial variability is also high for climatic variables. The average annual rainfall ranges from 57.1 mm in dry areas of Balochistan to 1017.3 mm in the high rainfall zones of the northern parts of Khyber Pakhtunkhwa province with a mean of 378.8 mm, while the average annual temperature ranges from 12.9°C to 28.1°C, reflecting the marked difference in temperature between northern high altitude tourism corridors and hotter and drier areas of Sindh and Punjab. These gradients are of economic interest, because they influence the productivity of agriculture and the attractiveness of tourism in the provinces. The number of international tourists varies greatly, from 15 to 10,978. This dispersion is due to the uneven development of tourism facilities, accessibility and attractiveness of the destinations by province.

A distributional heterogeneity has been observed, and this constitutes an empirical basis for modelling at the provincial level because the national level would overwhelm the significant spatial differences at the provincial level. The correlation matrix shows patterns generally in line with theoretical predictions of the study. It is observed that the relationships between economic growth and international tourist arrivals, petroleum energy consumption, and population density are positive and significant, with r = 0.56, 0.76, and 0.69, respectively. This indicates that the more economically developed and energy intensive provinces, the more tourists are likely to visit, and population density is likely to be high. The population density has a positive correlation with precipitation (r = 0.69), indicating that historically agricultural activity and settlement has been clustered in areas of relatively high rainfall. There is a strong negative correlation between precipitation and temperature (r = −0.78), which suggests that there is a clear climatic gradient across the provinces; cooler provinces tend to be wetter and warmer provinces drier. This spatial structure is key to understanding how climate risk is exposed and to its effects on the performance of sectors, especially agriculture- and tourism-dependent areas. In general, the descriptive evidence supports the theoretical assumption that the climatic and economic conditions are systematically different between provinces, which requires an empirical analysis based on disaggregation.

Table 2: *Summary Statistics and Correlation Matrix*

Variable	N	Mean	Median	Max	Min	Std. Dev.	Skew	Kurtosis
EG (PKR bn)	52	123.0	106.2	469.8	24.3	92.3	1.81	6.04
P (mm)	52	378.8	324.5	1017.3	57.1	251.4	0.93	2.79
T (°C)	52	22.3	23.9	28.1	12.9	5.3	-0.58	2.21
IT (arrivals)	52	2,284	1,448	10,978	15	2,518	2.07	7.02
PD (p/km²)	52	303.6	334.9	575.4	25.0	177.0	-0.37	2.06
PEC (mt)	52	5,220,000	2,180,000	15,900,000	132,228	4,790,000	1.13	2.94

Note: EG = Economic Growth; P = Annual Precipitation; T = Annual Average Temperature; IT = International Tourist Arrivals; PD = Population Density; PEC = Petroleum Energy Products Consumption. N = 52 province-year observations.

4.2 Cross-Sectional Dependence and Slope Homogeneity

The Pesaran (2004) cross sectional dependence (CD) test results are reported in Table 3 along with the Pesaran and Yamagata (2008) slope homogeneity tests results. The CD test shows that statistical dependence exists between nearly all variables with five variables (EG, P, T, IT, and PD) significant at 1% and PEC at 5%. The results indicate that there is a clear indication of non-cross sectional independence in provincial units of Pakistan. The finding of cross sectional dependence is in line with the structure of Pakistan's economy. Regional economic performance is affected by common macroeconomic trends, national-level policy actions and climate events.

The propagation of climate-induced disruptions across regions, resulting in correlated economic activity, tourism flows and other macroeconomic indicators, have been demonstrated by large-scale extreme weather events such as the floods of 2010 and 2022. Likewise, the national tourism policies and infrastructures create further sources of interdependence between provinces. These slope homogeneity tests also fail to accept the null hypothesis of equal slope coefficients for all the provinces at a conventional significance level (delta = 2.022, p = 0.043; adjusted delta = 2.335 and p = 0.020). This suggests that there is structural heterogeneity among the provinces of Pakistan in terms of their climate and tourism responsiveness of economic growth. Theoretically one would expect such a degree of heterogeneity based on the differences in geographic endowment, climatic exposure, tourism infrastructure and economic structure. Considered collectively, the diagnostic results provide statistical and economic evidence that both cross-sectional dependence and parameter heterogeneity are significant characteristics of the data. The use of second-generation panel econometric methods which explicitly address these characteristics is therefore not only desirable but essential for consistent and reliable inference.

Table 3: *Cross-Sectional Dependence and Slope Homogeneity Tests*

Variable / Test	CD Statistic	p-value
EG	5.76	0.000***
P	5.94	0.000***
T	8.15	0.000***
IT	1.79	0.043**
PD	7.19	0.000***
PEC	-1.32	0.038**
Slope Homogeneity Test	**Delta Statistic**	**p-value**
Standard	2.022	0.043**
Adjusted	2.335	0.020**

*Note: *** p < 0.01, ** p < 0.05, * p < 0.10. CD test null: errors are weakly cross-sectionally independent. Slope homogeneity null: coefficients are homogeneous across provinces.*

4.3 Panel Unit Root Tests

The results of the second generation panel unit root tests, Cross sectionally Augmented IPS (CIPS) and Cross-sectionally Augmented Dickey-Fuller (CADF) procedures are shown in Table 4. Such tests explicitly consider cross-sectional dependence by including the cross sectional averages in the test regressions. Most of the variables do not reject the unit root hypothesis under the constant-only and constant-and-trend specifications at the levels. This means that the level forms of the series are non-stationary.

The behaviour is like macroeconomic and climatic variables that have persistent stochastic trends. Under both deterministic specifications, following the first differencing all variables can reject the unit root null with high significance level, 1%, for both CIPS and CADF tests. This gives strong evidence that all variables are first order auto-regressive (I (1)). Results from two complementary second generation test frameworks are consistent, which increases the confidence in the integration classification. It is important to set up a common level of integration before performing the cointegration test to assure that, if there is a long-run relationship, it is not spurious, but statistically valid.

Table 4: *Pesaran CIPS and CADF Panel Unit Root Test Results*

Test	Var.	Level I(0) Constant	Level I(0) Const.+Trend	1st-Diff. I(1) Constant	1st-Diff. I(1) Const.+Trend
CIPS	**EG**	**-0.644**	**-4.560*** **	**-4.830*** **	**-4.667*** **
	P	-2.221	-2.247	-4.299***	-4.653***
	T	-2.372**	-2.537	-2.947***	-2.884***
	IT	-2.123	-2.152	-3.417***	-3.328***
	PD	-1.533	0.126	-2.503***	-2.240***
	PEC	-1.364	-0.609	-3.346***	-2.952**
CADF	**EG**	**-0.276**	**-1.755**	**-2.396*** **	**-3.612*** **
	P	-0.988	-3.341***	-2.712**	-3.786***
	T	-1.529	-1.529	-5.907***	-5.937***
	IT	-0.588	-2.700	-3.694***	-5.090***
	PD	-2.229	-1.848	-2.359*	-3.450***
	PEC	-1.363	-2.432	-2.690**	-2.952*

Note: **** p < 0.01, ** p < 0.05, * p < 0.10. Blank cells in the Test column continue the preceding test label. ns = not significant.*

4.4 Panel Cointegration Tests

Table 5 summarizes the findings of the three complementary panel cointegration tests that are applied to the economic growth model. Initial evidence of long run co-movement is provided by the Westerlund

(2005) variance ratio test which rejects the null of no cointegration for the 'some panels cointegrated' and 'all panels cointegrated' specifications (VR = 1.285, VR = 1.505, respectively, and both p values below 0.10). The Pedroni (2004) test gives significant results for the Modified Phillips-Perron t statistic (2.994, $p < 0.01$) and Augmented Dickey-Fuller t statistic (−2.738, $p < 0.01$) and the Phillips-Perron t statistic is also significant at the ten percent level. Cointegration is confirmed at the one percent level for all five test statistics in the Kao (1999) test by the use of cross-sectional demeaning. The findings of these three different methodological approaches: Westerlund, Pedroni, and Kao, validate the stable long-run equilibrium relationship between climate change, international tourist arrivals, energy consumption, population density and economic growth in the panel of Pakistan's provinces. Economically, it means that short run fluctuations due to climatic shocks or tourism variations do not permanently change the system but are corrected over time; short run fluctuations are co-moving along a common long run path. This result justifies the use of the FMOLS and DOLS estimators in the analysis which follows.

Table 5: *Results of Panel Cointegration Tests (Economic Growth Model)*

Test and Statistic	Value / Significance
Westerlund (2005) Cointegration — Variance Ratio (VR)	
Some panels are cointegrated (VR)	1.2847*
All panels are cointegrated (VR)	1.5050*
Pedroni (2004) Cointegration	
Modified Phillips-Perron t	2.9937***
Phillips-Perron t	1.4870*
Augmented Dickey-Fuller t	−2.7382***
Kao (1999) Cointegration	
Modified Dickey-Fuller t	−3.6807***
Dickey-Fuller t	−4.3090***
Augmented Dickey-Fuller t	−2.4994***
Unadjusted Modified Dickey-Fuller t	−4.5046***
Unadjusted Dickey-Fuller t	−4.4866***

Note: *VR = variance ratio.* H_0*: no cointegration. **** $p < 0.01$*, *** $p < 0.05$*, ** $p < 0.10$*.*

4.5 Long-Run Estimation: FMOLS and DOLS Results

The long run coefficient estimates derived from Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) are given in Table 6, both with and without the climate–tourism interaction term. The interpretation centers on the interaction specifications that directly relate to the study's main hypotheses. International tourist arrivals (lnIT) have a statistically significant and positive relationship with economic growth in all specifications. The coefficient in the FMOLS interaction model is 0.060 ($p < 0.10$) which means that for every 1% increase in tourist numbers, provincial economic growth increases about 0.06%, keeping all other factors constant. The positive tourism–growth relationship is also statistically robust for the corresponding DOLS estimate of 0.082 ($p < 0.05$). The results confirm the Tourism-Led Growth Hypothesis (TLGH), which was found by previous empirical studies (Brida et al., 2016; Khan et al., 2020), and Hypothesis 4 of this study. The interaction specifications include the coefficient of climate change (CC) with a negative sign, which is statistically significant and has a negative impact on economic performance. The coefficient is −0.116 in the FMOLS model with interaction and is also marginally negative but directionally consistent in the DOLS specification. This finding aligns with the main findings of others that increased climate variability and climate stress are associated with lower output in developing economies (Burke et al., 2015; Diffenbaugh & Burke, 2019) and supports Hypothesis 1. Both FMOLS and DOLS estimations yield a negative and statistically significant interaction term (lnIT × CC). The FMOLS coefficient is −0.015 ($p < 0.01$), while the DOLS coefficient is −0.020 ($p < 0.05$). This is the empirical central contribution of the study. The outcome suggests that climate change is a systematic reduction of the marginal growth contribution of tourism. That is, the greater the climate stress, the less the economic return from expanding tourism, suggesting that the tourism–growth relationship is not fixed but rather contingent upon various levels of climatic stress. This result supports Hypothesis 2 and widens the scope of the literature available by providing evidence of how climate conditions are a structural modifier of the outcomes of tourism-led development. The two control variables do what they're supposed to do. The urbanisation and agglomeration effects of population density (lnPD) is consistently positive and significant for all the specifications ranging from 0.151 to 1.344, indicating the positive role of population density on the provincial economies of Pakistan. In all models, the coefficient of energy use in petroleum (lnPEC) is also positive and significant (range of 0.296 and 0.735), suggesting that energy-related industrial activity has continued to be a significant contributor to the growth of the sample, with results similar to those of the energy-growth literature for developing countries (IEA, 2021).

Table 6: *FMOLS and DOLS Long-Run Estimation Results*

Variable	FMOLS Without Interaction	FMOLS With Interaction	DOLS Without Interaction	DOLS With Interaction
CC	—	-0.116** (0.149)	—	-0.014* (0.141)
lnIT	0.123** (0.052)	0.060* (0.032)	0.118* (0.078)	0.082** (0.860)
lnPD	1.181*** (0.374)	0.151*** (0.001)	1.299** (0.558)	1.344** (0.563)
lnPEC	0.330** (0.142)	0.735*** (0.001)	0.302** (0.215)	0.296* (0.219)
lnIT × CC	—	-0.015*** (0.004)	—	-0.020** (0.022)
Observations	52	47	51	51
Provinces	4	4	4	4

*Note: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Dependent variable: Economic Growth (EG). FMOLS = Fully Modified OLS; DOLS = Dynamic OLS.*

4.6 Panel Causality Results

Table 7 shows the test for Granger-type causality relationships using heterogeneous panel causality tests (Dumitrescu and Hurlin 2012) with the assumption of cross-sectional heterogeneity in causal structure across provinces. The null hypothesis that economic growth (EG) do not Granger-cause international tourist arrivals (IT) is rejected at the 1% significance level (W = 5.341, Z = 6.140, $p < 0.01$). Likewise, the reverse Granger causality of the tourism on the economic growth is also rejected at 1%. The results here agree that there is a bi-directional relationship between tourism and economic growth. The feedback effect between tourism expansion and economic activity seems to be a positive one and the findings are economically significant: a rise in tourism capacity and demand is likely to come from increased income and improved infrastructure, which, in turn, will lead to further tourism development and thereby higher economic activity. This bi-directional relationship aligns with the existing evidence of the tourism–growth relationship within the developing economies (Antonakakis et al., 2019; Brida et al., 2016). Unidirectional causality is found from economic growth to climate change (EG → CC) significant at the 5% level (W = 9.565, Z = 2.219). It implies that the increase in economic activity can be associated with the changes in climatic indicators due to increased energy use and industrial emissions. This broadly matches the initial stages of the Environmental Kuznets Curve (EKC) principle, which suggests that as economies grow, environmental pressures rise, but environmental pressures can begin to subside at higher levels of income.This broadly follows the early stage of Environmental Kuznets Curve (EKC) dynamics: as economies expand, environmental pressure increases, followed by potential environmental pressure reduction at higher income levels (Stern, 2017). There is no statistically significant causality found between either population density and economic growth or vice versa. This suggests that population concentration is not necessarily a growth phenomenon, but rather a phenomenon that takes place through a relationship with other structural factors, like energy consumption, urbanisation processes, and sectoral composition. Last but not least, the results obtained from the bidirectionality test between energy consumption (PEC) and economic growth demonstrated the feedback effect between energy use and economic activity in Pakistan's provinces. The result is in line with the more general energy–growth literature, which sees energy consumption as a cause and an effect of economic growth in developing countries.

Table 7: *Dumitrescu–Hurlin (2012) Panel Granger Non-Causality Test Results*

Null Hypothesis	W-Statistic	Z-Statistic	p-value	Causality Direction
Economic Growth Model				
EG ≠→ IT	5.3413***	6.1395	0.0000	EG ↔ IT (Bidirectional)
IT ≠→ EG	0.5602	-0.6220	0.0000	(see above)
CC ≠→ EG	0.82731	-0.77223	0.4400	EG → CC (Unidirectional)
EG ≠→ CC	9.56456**	2.21852	0.0265	(see above)
PD ≠→ EG	0.7504	-0.3530	0.7241	No Causality
EG ≠→ PD	0.7173	-0.3998	0.6893	(see above)
PEC ≠→ EG	4.8531***	5.4491	0.0019	PEC ↔ EG (Bidirectional)
PEC ≠→ EE	6.2127***	7.3719	0.0000	PEC ↔ EE (Bidirectional)

Note: *≠→ denotes 'does not Granger-cause'. ↔ = bidirectional causality; → = unidirectional causality; ✗ = no causality. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Source: Dumitrescu & Hurlin (2012) D-H test; author computations.*

4.7 Summary of All Empirical Results

Table 7 presents a comprehensive summary of the empirical findings related to each of the four study hypotheses.

Table 7: *Summary of Hypothesis Testing Results*

H	Hypothesis Statement	Test / Method	Key Statistic	Decision
H1	Climate change has a significant negative effect on economic growth	FMOLS & DOLS (with interaction)	CC: −0.116** (FMOLS); −0.014* (DOLS)	Supported
H2	Climate change moderates (attenuates) the tourism–growth relationship	Interaction term FMOLS & DOLS	lnIT×CC: −0.015*** (FMOLS); −0.020** (DOLS)	Supported
H3	Climate change has a significant negative effect on international tourist arrivals	D-H Causality; Correlation (T–IT)	r(T,IT) = 0.4878; CC→EG unidirectional	Partially Supported
H4	International tourist arrivals have a positive effect on economic growth	FMOLS & DOLS; D-H Causality	lnIT: 0.123** to 0.082**; EG↔IT bidirectional	Supported

Note: *H = Hypothesis number. Supported = null hypothesis rejected at conventional significance levels. Partially Supported = directional evidence present but indirect. FMOLS = Fully Modified OLS; DOLS = Dynamic OLS; D-H = Dumitrescu–Hurlin (2012).*

5. DISCUSSION

5.1 Climate Change as a Direct Growth Constraint

The fifth growth factor, Climate Change, is a direct constraint. The empirical evidence suggesting a statistically significant negative effect of climate change on provincial economic growth is consistent with the general macroeconomic literature on climate-induced output losses (Burke et al., 2015; Kahn et al., 2021). In the case of Pakistan, this relationship is understood to result from several reinforcing transmission channels within the heterogeneous economies of the provinces. Over the provinces of

Pakistan, one finds different climatic zones from the high precipitation, glacier-influenced area of Khyber Pakhtunkhwa to the low lying arid and hot area of Sindh and Balochistan. In this spatial arrangement, climate variability is manifested as unequal economic costs. Agriculturally dependent provinces have direct impacts on crop yields and farm income due to changes in the monsoon season, more frequent droughts, and more severe heat stress. Shocks spread through rural economies through households' decreased consumption and lower demand in non-farm sectors, increasing the overall output losses. However, in more industrialised and urbanised provinces, the transmission mechanism is influenced by energy and infrastructure limitations. Warmer temperatures increase cooling needs, which drive up energy costs for homes and businesses, and more extreme precipitation events and flooding cause transport and irrigation systems, as well as urban infrastructure, to wear out quickly. These damages create ongoing budgetary pressures and diminish the productivity of public and private capital. Combining these channels, one can explain the negative climate–growth relationship seen in the data, which is consistent with the findings in developing countries reported in Section 2.1. These findings are further supported by the Pakistani experience. When realised at the macroeconomic scale, the climate risk becomes apparent, as in the 2010 floods, where nearly USD 10 billion in direct damages resulted from the impact on more than 20 million people, as well as serious disruptions to agricultural production and transport connectivity (Government of Pakistan, 2010). In addition to these episodic shocks, the panel results indicate lower-intensity climatic pressures that are more persistent and cause cumulative effects over time, degrading growth performance. A negative correlation between precipitation and temperature across provinces was observed, indicating a strong climatic gradient, and heterogeneous slope estimates suggest that climate effects are not evenly distributed across space. Such spatial asymmetry has direct policy implications for differentiated adaptation policies, especially in areas with concentrated exposure and vulnerability.

5.2 Tourism as a Growth Driver and the Conditional Effect of Climate

The empirical results in this study are quite promising, as the coefficient on international tourist arrivals is consistently positive and statistically significant across all model specifications, supporting the Tourism-Led Growth Hypothesis in the province of Pakistan. Tourism is an important source of economic growth as it creates jobs, stimulates demand for local products and services and brings in foreign exchange. These impacts are especially significant in the provinces where economic diversification is still relatively low and other export-driven industries are undeveloped. The elasticity of tourism to growth (0.06 to 0.12) is economically reasonable, given the relatively small importance of tourism in provincial output. This finding also aligns with panel evidence from other similar developing countries in previous research (Khan et al., 2020), which indicated that although tourism is not the main source of growth, it is a very important one. The most interesting finding from a theoretical perspective is the negative, statistically significant coefficient on the interaction term ($\ln IT \times CC$), indicating that the growth impact of tourism is highly dependent on climatic conditions. It is a finding that cannot be limited to additive specifications, and it shows how climate change has a systematic impact on the marginal contribution to the tourism sector's growth. In the practical sense, in the province where the climate stress is high, the economic benefits per unit of tourism activity are lower than in a province where climate stress is low. The conditionality has implications for the understanding of tourism-led development in environmentally vulnerable contexts. A possible mechanism is infrastructure degradation: if the maintenance and reconstruction costs caused by climate change effects on infrastructure are high enough, the net economic surplus created by tourism activities will be reduced. A second mechanism is linked to visitors' behaviour, as adverse climate conditions can affect the duration of stay, shift consumption patterns, and change the types of activities sought out that are less climate-sensitive, leading to reduce per-visitor spending. A third channel is investment behaviour, in which increased climate uncertainty is associated with reduced long-term private investment in the quality of services and tourism infrastructure, which, in turn, affects backwards and forward linkages to the broader economy. These channels align with the literature on the tourism climate field, showing that tourism systems are sensitive on the demand side and vulnerable on the supply side to climatic stress (Scott et al., 2016; Seetanah & Fauzel, 2019). The present results contribute to this literature by showing not only that climate change affects tourism volume, but also that it affects tourism's macroeconomic productivity and thus its fundamental growth dynamics in tourism-dependent development pathways.

5.3 Bidirectional Causality and Dynamic Feedback

Considering the evidence that economic growth and international tourists affected each other, the long-term relationships identified in the FMOLS and DOLS estimations are further enriched by dynamics. It implies that the relationship between tourism and economic growth is not merely an equilibrium relationship but a self-reinforcing one of mutual causation. The growth of the tourism channel is structurally oriented. Improving provincial income generates more fiscal space for investing in tourism infrastructure, enhances transport connectivity and builds institutional capacity for destination management and promotion. Such enhancements also make it easier and more comfortable to use a province's services, making it more attractive to foreign visitors. The tourism-to-growth channel, on the other hand, reflects the demand-side multiplier effect, in which tourism spending generates employment, increases demand for services, and creates linkages between sectors. Combined, this feedback mechanism means tourism is not a stimulus but an endogenous part of the growth process. This dynamic has important policy implications. Climate-related declines in tourist arrivals can result in an immediate loss of output but can also trigger an overall adjustment process: fewer tourists mean less economic growth, less growth means less investment in infrastructure, and less infrastructure investment means even fewer tourists. In this second respect, climate shocks can start a reinforcing contracting process. Adaptation policies that seek to stabilise tourism flows have the implication that they might yield benefits beyond the tourism sector, such as maintaining broader growth dynamics.

The one-way causality between economic growth and climate change should be interpreted with caution. In a province's developing context, this relationship can be plausibly explained by scale effects related to industrial growth, energy use, and urbanisation, which are linked to local environmental stress and climate variability indicators. It could be due to data and measurement distortions, such as differences in monitoring capacity across provinces, or to unobserved policy or structural factors correlated with economic growth. Although suggestive, the result should be used as an indication, not a conclusion, and should be studied in the future with finer spatial scales, the incorporation of emissions intensity and land-use change indicators.

5.4 Comparison with Existing Literature

The empirical results of this study contribute to the literature in several interrelated ways. First, the results support the Tourism-Led Growth Hypothesis for the provincial economies of Pakistan and extend it by demonstrating that the impact of tourism growth is contingent on climatic conditions. Second, the results confirm the medium-to-long-run nature of tourism's impact on regional economies, implying a cumulative effect. Second, the results substantiate the medium-to-long-run nature of tourism's impact on regional economies, which implies a cumulative effect, and confirm the medium-to-long-run nature of the impact. This interaction effect represents an environmental constraint in a model which is often assumed to be structurally invariant in previous research.

Second, the provincial panel dimension shows a lot of variation that national-level studies don't: the climatic profile of the KPK differs from that of Punjab, Sindh, or Balochistan, and hence it is methodologically incorrect to generalise from any single province or the national average. Third, the methodological rigour of the second-generation econometric approach that incorporates cross-sectional dependence and slope heterogeneity, unit root and cointegration tests, and endogeneity-corrected long-run estimators, greatly surpasses the cross-sectional and first-generation panel methodologies adopted by most previous works in the Pakistan context.

This is in line with the findings of Seetanah and Fauzel (2019), who report on the loss of tourism revenues in island economies due to climate change, and Scott et al. (2016), who highlight the vulnerability of the economic contribution of tourism to climate risks at the destination level. They contribute to this literature by: (i) quantifying this interaction effect in a continental developing-economy setting; (ii) confirming the result with both FMOLS and DOLS estimation; and (iii) providing causality evidence in addition to the long-run coefficient estimates.

6. CONCLUSION

The purpose of the present study was to elucidate the effects of climate change on economic growth in Pakistan over the last 13 years (2009-2021), using the tourism sector across Pakistan's four provinces. The analysis employs a set of second-generation panel econometric methods specifically designed to address the cross-sectional dependence, slope heterogeneity, non-stationarity, and long-run dynamics characteristics of the data, and produces four main empirical results.

Climate change has a statistically significant negative effect on provinces' economic growth, first. It corroborates the already available macroeconomic evidence of climatic-output relations and confirms that climatic variability is a structural constraint, not a transitory shock, that affects provincial economies' performance.

Second, empirical results support the Tourism-Led Growth Hypothesis in the context of Pakistan's provinces, with a positive relationship between international tourist arrivals and economic growth at all specifications. Second, empirical findings suggest a positive relationship between international tourist arrivals and economic growth in the Pakistani provincial context, which becomes stronger under the provocation of the Tourism-Led Growth Hypothesis in Pakistani provinces. Tourism is thus a force that, on the one hand, plays an important but not dominant role in generating regional growth and development.

Thirdly, the climate change–tourism relationship is negative and statistically significant. This is the main result of the study. This implies that the economic value of tourism is sensitive to climate stability, and systematic increases in climate stress systematically reduce the economic contribution of tourism. That is, tourism growth is not constant but depends on the environment.

Fourth, the study reveals a reinforcing dynamic structure as there is a bidirectional relationship between the two variables, tourism and economic growth. The development of tourism promotes growth, and growth further promotes the development of tourism through providing services, investment opportunities and infrastructure. This feedback loop can result in multiple economic losses from a climate shock, since it can not only slow growth momentum, but also decrease tourism receipts.

Overall, all four hypotheses of the study were supported, and both theory refinement and empirical extension were supported. From a theoretical perspective, the results confirm the sustainable tourism development framework regarding sustainability, as observed when environmental stress is present, the economic benefits of tourism are not strong. Thus, the discussion on sustainable tourism becomes a macro-economic constraint rather than a norm. On the empirical side, the study is important because it provides province-level evidence, using a methodologically sound econometric framework that allows for province-specific heterogeneity, dependency structures, and long-run relationships within the same model, thus extending the existing empirical literature for Pakistan.

6.1 Policy Implications

The empirical results yield three sets of policy implications for national and provincial governments in Pakistan with their interlinkages in the context of climate governance, tourism development and regional economic planning at the intersection. Moving from sectoral towards macro-economic priorities is the first step in climate adaptation for tourism infrastructure. The climate change and tourism interaction is identified as negative, implying that inaction on climate change will result in a loss of productivity of the tourism investment contribution to growth. This makes adaptation a growth-preserving strategy, rather than a risk-management choice. Priority interventions include developing climate-resilient transport corridors in northern tourism areas vulnerable to landslides and glacier lake outburst floods, systematic slope stabilisation and drainage infrastructure in high-risk trekking and heritage areas, and the incorporation of multi-hazard early warning systems tailored to tourism operators and tourists. Also important is that tourism infrastructure in climatically sensitive regions is no longer being built, thanks to the integration of climate risk screening into spatial planning processes. Second, governance for sustainable tourism needs to be integrated into the destination development process rather than treated as a separate policy goal. The results showed that environmental degradation not only harms ecological integrity but also affects tourism's economic productivity. Policy instruments should then aim to reduce the sector's environmental impact while sustaining its contribution to growth. This includes measures to meet the energy efficiency requirements of the accommodation and transport systems, to promote the use of renewable energy through public–private partnerships and fiscal measures, and to safeguard natural tourism resources through water and waste management. Credible and province-wide green certification schemes could enable the province to enter international markets and signal the quality of the environment and its sustainability to increasingly climate-conscious tourists.

6.2 Limitations and Future Research Directions

There are several caveats when interpreting the results of this study. First, provincial expenditure is used as a proxy for economic output, which may introduce measurement error, especially for the informal sector, which dominates the rural and tourism-based economies of Pakistan. Second, the small cross-sectional size of the panel (four provinces) imposes restrictions on the degrees of freedom for more complex modelling of the heterogeneity and limits the use of some of the more advanced panel techniques.

Third, the dimension of climate risk is not fully captured when operationalising climate change using average temperature and precipitation, as is often done in macro-panel studies. Extreme weather events, drought intensity and glacial changes – especially significant for the northern tourist areas of Pakistan – are not included in the current specification. Estimated impacts are therefore likely to be conservative estimates of the actual climate–economy relationship.

These limitations can be overcome by future research in a couple of ways. Better spatial resolution would be provided by district-level panel data, facilitating district-specific analysis of climate risks. The further disaggregation of the tourism sector into functional sectors (adventure tourism, cultural tourism, religious tourism, coastal tourism) would make it possible to better understand the different types of tourism sector and climate sensitivity.

Acknowledgements

None.

Conflict of Interest

Authors declared NO conflict of interest.

Funding Source

The authors received NO funding to conduct this study.

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