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Research Paper

ESG uncertainty, economic growth, and tourism performance in the United States: A wavelet quantile mediation and moderation analysis

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Abstract

The United States tourism sector faces growing exposure to sustainability-related uncertainty and shifting macroeconomic conditions. This study examines the direct effect of ESG uncertainty (ESGU) on tourist arrivals (TOR) and investigates whether economic growth (ECOG) moderates or mediates this relationship. Using quarterly data for 2002–2025, the analysis applies a wavelet quantile regression framework extended to mediation and moderation, allowing effects to vary across distributional states and short-, medium-, and long-term horizons. The direct effect of ESGU on TOR is nonlinear and horizon-specific: in the short term, ESGU reduces arrivals at the extreme lower quantile ($\tau = 0.01$) but is associated with higher arrivals at the upper tail ($\tau = 0.95$). In the medium term, a positive ESGU effect persists at upper quantiles ($\tau = 0.60–0.80$). Economic growth does not significantly moderate the ESGU-tourism relationship at any quantile or horizon. As a mediator, ESGU affects economic growth positively only at the lower tail in the short term, but negatively at selected quantiles in the medium and long term. Since economic growth supports tourism at medium- and long-term upper and lower tails, the indirect effect of ESGU on tourism through growth is negative and significant in the medium and long term at distributional extremes, though absent in the short term. These findings point to the importance of horizon- and state-specific policy design for managing sustainability-related uncertainty in the U.S. tourism sector.

Keywords: Tourism; ESG Uncertainty; Economic Growth; Sustainable Development Goal; Moderating and Mediating

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** While multiple authors may share the same CRediT roles, the contribution percentages indicate the relative magnitude of each author's contribution to those roles and to the manuscript overall.*

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1. Introduction

Tourism is among the economic sectors most sensitive to uncertainty. Shifts in macroeconomic conditions, geopolitical tensions, and sustainability-related concerns can each alter travel demand, investment flows, and destination competitiveness in ways that are neither uniform nor easily anticipated. In the United States, these pressures are especially pertinent: the sector contributes substantially to employment and GDP, yet tourist arrivals (the most direct measure of performance) can be disrupted by shocks that may not register immediately in aggregate economic indicators. Recent OECD analysis confirms that recovery in major destination economies remains fragile under slow growth, geopolitical instability, and climate-related disruptions (OECD, 2025), and that these factors interact in complex ways over time.

Against this backdrop, a relatively new dimension of uncertainty has received increasing scholarly attention: ESG uncertainty, or the ambiguity surrounding environmental, social, and governance signals, policy direction, and sustainability narratives. Ongan et al. (2025) introduced the ESG-Based Sustainability Uncertainty Index (ESGUI) to quantify this dimension, arguing that it is relevant for investment, planning, and macroeconomic evaluation in ways that differ from conventional economic policy uncertainty. For tourism, the relevance is intuitive: the sector depends on investor confidence, reputational stability, long-horizon planning, and consumer expectations about destination safety and sustainability. When ESGU rises, decisions by operators, investors, and travelers may all be affected, though the direction and magnitude of these effects need not be uniform across economic states or time horizons.

Economic growth enters this picture through two theoretically distinct channels. As a moderator, it may condition how tourism responds to ESGU: stronger macroeconomic performance could, in principle, provide the income, infrastructure, and financing conditions needed to absorb uncertainty-related disruptions, whereas weak growth may amplify them. As a mediator, economic growth may transmit the effect of ESGU to tourism: if sustainability-related uncertainty slows macroeconomic activity, by discouraging investment, complicating long-term planning, or weakening confidence, these growth effects would then propagate to tourism demand. Early evidence from Yıldırım et al. (2025) suggests that ESGU does materially affect economic growth and financial development in developed economies, lending support to this transmission mechanism. Whether the same channel operates in the specific context of U.S. tourism remains untested.

Two gaps motivate this study. First, most existing work on uncertainty and tourism focuses on economic policy uncertainty or geopolitical risk, treating ESG uncertainty as either a financial market variable or a secondary concern. How ESGU specifically shapes tourist arrivals in a major developed destination economy has not been directly examined. Second, the literature has not tested whether economic growth simultaneously moderates and mediates the ESG uncertainty–tourism nexus, particularly across different states of the tourism distribution and at different time horizons. This distinction matters empirically: a shock that is benign under strong growth conditions but damaging under weak conditions calls for different policy responses than one that transmits uniformly through the growth channel regardless of distributional state.

The present study addresses these gaps by applying a wavelet quantile regression framework extended to mediation and moderation (Adebayo, 2026; Adebayo & Özkan, 2024), using quarterly U.S. data from 2002 to 2025. This approach allows us to test whether the effects of ESGU on TOR (direct, moderating, path-a, path-b, and indirect) vary across distributional quantiles and across short-, medium-, and long-term horizons. The contribution is methodological and substantive: the application of wavelet quantile mediation and moderation to ESG uncertainty and tourism in the United States is, to our knowledge, novel in this specific combination, and the results carry implications for tourism risk management, sustainability policy, and macroeconomic coordination.

The remainder of the paper proceeds as follows. Section 2 reviews the relevant literature and develops the study hypotheses. Section 3 describes the data and estimation method. Section 4 presents and interprets the empirical results. Section 5 concludes with policy implications and directions for future research.

2. Literature Review

ESG Uncertainty and Tourism

The literature consistently finds that tourism is sensitive to uncertainty, though the mechanisms and magnitudes differ considerably across studies and contexts. Gozgor and Ongan (2017) established that economic policy uncertainty reduces tourism demand in the United States, and Balli et al. (2018) showed that both global and domestic policy uncertainty depress tourist inflows, particularly when uncertainty shocks are persistent. Evidence from other country contexts reinforces this broad pattern: Kazakova and Kim (2021) reported negative effects of geopolitical risk and economic policy uncertainty on arrivals in South Korea; Papagianni et al. (2024) documented persistent adverse effects of geopolitical tensions on demand in emerging destinations; and Zhang et al. (2025) found that domestic and global uncertainty exert time-varying negative effects on inbound tourism in China. Dimitriadou et al. (2025) further argued that uncertainty has become central to forecasting models precisely because it materially increases demand volatility.

What remains less settled is whether ESG uncertainty behaves in the same way as these broader uncertainty measures. ESGU may shape tourism through channels that differ from conventional economic policy uncertainty: sustainability narratives and ESG-related signals can affect investor confidence, destination reputation, and travelers' expectations about environmental and social conditions at destinations, independently of short-run macroeconomic fluctuations. Previous conceptual research also suggests that sustainability-related pressures and carrying capacity problems may weaken tourism experiences and destination attractiveness when environmental and social systems become overloaded (Karakuş & Erkılıç, 2024).The limited evidence on this point is indirect. Zhang et al. (2025) found asymmetric effects of world uncertainty on outbound tourism, suggesting that distributional heterogeneity matters; and He et al. (2025) showed that ESG engagement can strengthen hospitality-sector resilience under uncertain conditions. However, the specific effect of ESGU (measured as a distinct index) on tourist arrivals in a major developed destination economy has not been directly tested. This study addresses that gap.

Based on this reasoning, the first hypothesis is:

H1: ESG uncertainty has a significant effect on tourist arrivals.

Economic Growth and Tourism

A well-established strand of the literature argues that economic growth supports tourism by raising household income, expanding infrastructure, improving service quality, and enhancing destination competitiveness. Balaguer and Cantavella-Jordá (2002) provided early evidence that tourism acts as a long-run growth factor in Spain, while Katircioglu (2009) documented cointegrating relationships among tourism, trade, and growth in Cyprus. Seghir et al. (2015) extended this to a panel of 49 countries, confirming a causality from tourism spending to growth. More recently, Sun et al. (2025) found that the tourism–growth effect depends on institutional quality, and Liu et al. (2025) reported that economic growth substantially amplifies tourism demand.

At the same time, this literature has grown more cautious about the uniformity and directionality of the tourism-growth nexus. Brida et al. (2020), in a systematic review, concluded that the evidence is mixed across countries and methods, with bidirectional, unidirectional, and null results appearing across different contexts. Antonakakis et al. (2015) showed that the relationship changes over time in both magnitude and direction,

particularly around major economic events. Paudel et al. (2025) also found that the relationship in transition economies is present but not symmetric across states. The collective message is that economic growth can support tourism, but the strength and direction of this effect are conditional on context, time period, and economic state, an observation that motivates testing its role as a moderator.

These considerations motivate two related hypotheses:

H2: Economic growth moderates the impact of ESGU on tourist arrivals.

H3b: Economic growth is positively associated with tourist arrivals when ESG uncertainty is controlled for.

ESG Uncertainty and Economic Growth

The link between ESG uncertainty and macroeconomic performance is relatively new as a research question, but the emerging evidence is informative. Ongan et al. (2025) introduced ESGU as a dedicated sustainability-uncertainty measure, arguing that it captures ambiguity around ESG policy signals in ways that matter for investment and planning. Yıldırım et al. (2025) then found that ESGU significantly affects economic growth and financial development in developed economies, including the United States, establishing a direct empirical link. Qamruzzaman et al. (2025) reported that ESGU constrains green growth in the United States and United Kingdom, although technology and human capital can partially offset this effect. Nawaz and Su (2026) found that ESG uncertainty undermines green investment along the energy transition path, while Nasraoui et al. (2026) showed that policy uncertainty worsens corporate investment efficiency, with stronger ESG practices partially cushioning the damage.

A related strand focuses on ESG information frictions rather than aggregate uncertainty per se. He et al. (2025) showed that ESG rating disagreement raises the cost of equity financing, and Lohmann et al. (2026) found that it constrains the size of the investable universe under ESG consensus rules. Taken together, these findings support a coherent mechanism: ESGU raises ambiguity, distorts valuations, weakens investment quality, and complicates long-horizon planning, thereby slowing economic activity. Since tourism depends heavily on income, employment, infrastructure, and consumer spending capacity, a growth-slowing effect of ESGU would be expected to reach tourism as well. This makes economic growth a plausible mediating variable in the ESGU–tourism relationship.

This reasoning yields two further hypotheses:

H3a: ESG uncertainty has a significant effect on economic growth.

H4: Economic growth mediates the relationship between ESGU and tourist arrivals.

Figure 1 presents the conceptual framework that integrates these four hypotheses.

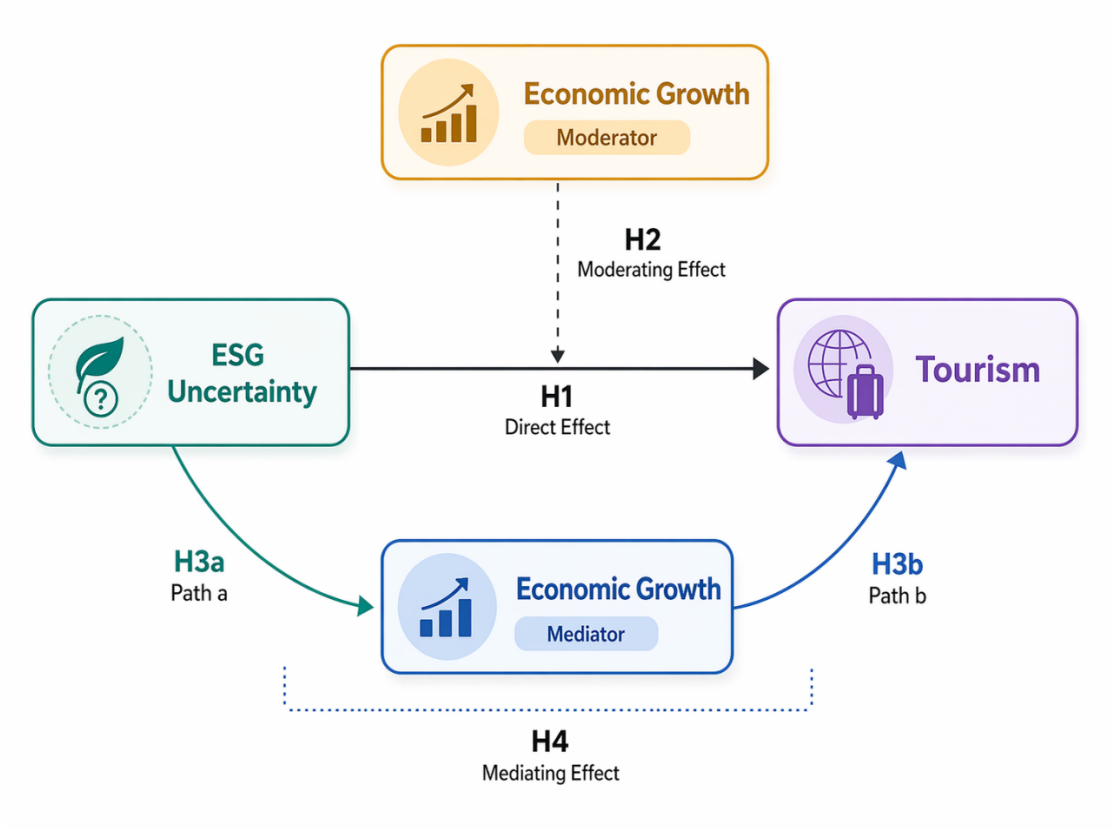


Fig. 1: Conceptual Framework

3. Data and Method

Data

This study uses quarterly data from Q1 2002 to Q4 2025 for the United States. The dependent variable is tourist arrivals (TOR), measured as the number of international tourist arrivals and sourced from Our World in Data (OWID, 2025). The independent variable is ESG uncertainty (ESGU), obtained from the ESG-Based Sustainability Uncertainty Index of Ongan et al. (2025), accessed via the Policy Uncertainty database (PU, 2026). Economic growth (ECOG) is measured as GDP per capita in constant 2015 US dollars, sourced from the Federal Reserve Economic Data database (FRED, 2026). GDP per capita in constant prices captures real income conditions and reflects the economic capacity to sustain tourism demand, infrastructure investment, and service provision. Table 1 summarizes the variables, their measurement, and sources.

All variables are transformed into log differences before estimation. This transformation approximates quarterly growth rates, removes deterministic trends, and addresses potential non-stationarity. Unit root tests in Section 4.2 confirm that the transformed series are stationary. Figure 2 plots the time paths of the log-differenced series over the sample period.

Table 1: Variable Definitions and Data Sources

Abbreviation	Variable	Measurement	Source
TOR	Tourism (Tourist Arrivals)	International tourist arrivals (number)	OWID (2025)
ESGU	ESG Uncertainty	ESG-Based Sustainability Uncertainty Index	PU (2026); Ongan et al. (2025)

ECOG	Economic Growth1	GDP per capita, constant 2015 US$2	FRED (2026)

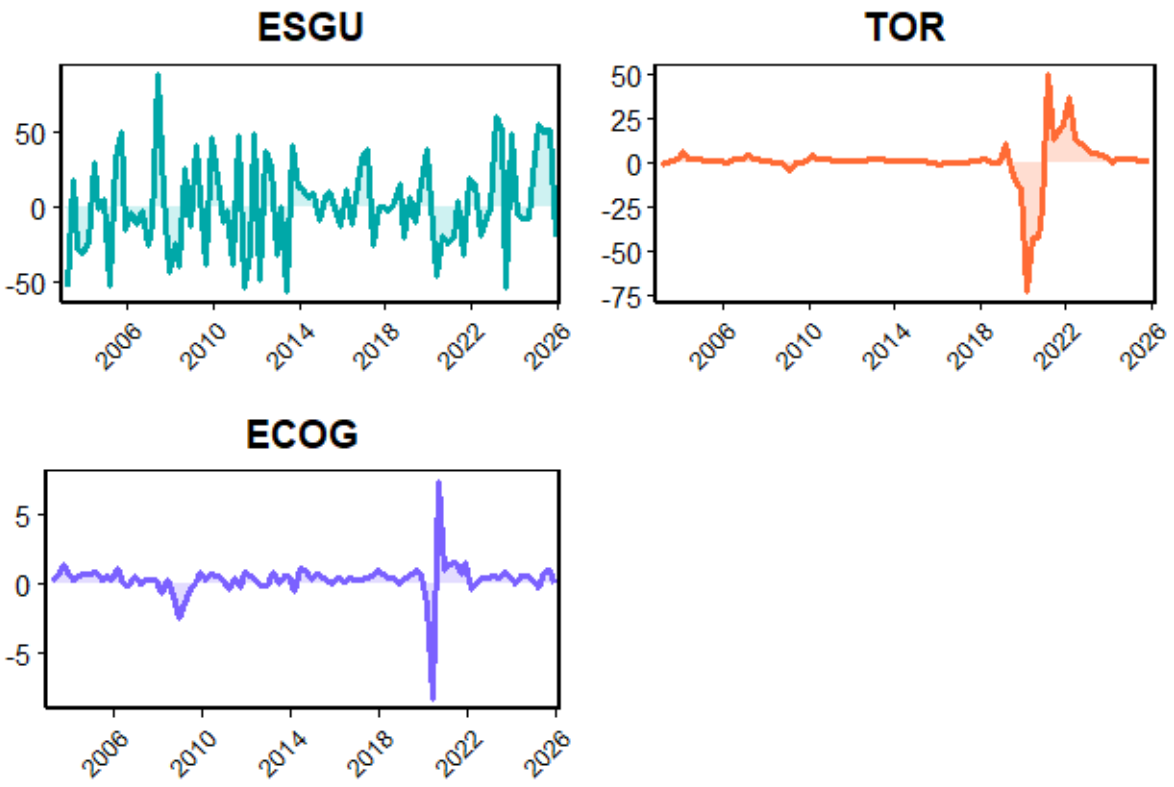


Fig. 2: Trend of Log Difference

4. Method

The estimation strategy proceeds in three steps: standard quantile regression, wavelet decomposition combined with quantile regression, and the extension of the wavelet quantile framework to moderation and mediation. Each step is described below.

Quantile Regression

The standard quantile regression framework, proposed by Koenker and Bassett (1978), models the τ-th conditional quantile of a dependent variable Y given a covariate X as:

$$Q\tau(Y \mid X) = \beta_0(\tau) + \beta_1(\tau)X \quad (1)$$

where $Q\tau(Y \mid X)$ denotes the τ-th conditional quantile of Y, and $\beta_1(\tau)$ captures how the effect of X on Y varies across the distribution of Y. Unlike ordinary least squares, which estimates only the conditional mean, quantile regression yields a complete picture of distributional heterogeneity—a particularly important feature given the non-normality and fat tails evident in the TOR and ECOG series (see Section 4.1).

[1] *Economic growth is measured using GDP per capita in constant 2015 US dollars, which captures the level of real income and reflects the economic capacity that can support tourism demand, investment, and service provision*

[2] *The LA(8) wavelet filter is used because it provides a good balance between smoothness and time localization, making it suitable for decomposing the series into short-, medium-, and long-term dynamics while minimizing boundary distortions*

Wavelet Quantile Regression

Although quantile regression captures distributional heterogeneity, it does not distinguish between effects that operate over different time horizons. To address this, Adebayo and Özkan (2024) developed Wavelet Quantile Regression (WQR), which decomposes each series into scale-specific components before estimating quantile effects at each horizon separately. The decomposition level is determined by $J = \lfloor \log_2(N) - 3 \rfloor$, where N is the sample size. The Least Asymmetric (LA(8)) wavelet filter is applied because it provides a favorable trade-off between smoothness and time localization, making it well-suited for decomposing macroeconomic series into short-, medium-, and long-term dynamics while limiting boundary distortions.

The scale-specific WQR model is expressed as:

$$Q_\tau\left(d_j[Y] \mid d_j[X]\right) = \beta_{0j}(\tau) + \beta_{1j}(\tau) d_j[X] \quad (2)$$

where $d_j[Y]$ and $d_j[X]$ are the wavelet components of Y and X at scale j. The coefficient $\beta_{1j}(\tau)$ captures the effect of X on Y at distributional quantile τ and time horizon j, allowing the researcher to identify, for example, whether ESGU affects TOR differently in the short run than in the long run, and whether this varies across weak versus strong tourism states.

Moderation

To test whether economic growth (ECOG) moderates the ESGU–TOR relationship, the wavelet quantile model is extended to include ECOG as a moderator Z and the wavelet interaction term $d_j[X] \cdot d_j[Z]$:

$$Q_\tau\left(d_j[Y] \mid d_j[X], d_j[Z], d_j[X]d_j[Z]\right) = \beta_{0j}(\tau) + \beta_{1j}(\tau) d_j[X] + \beta_{2j}(\tau) d_j[Z] + \beta_{3j}(\tau)\left(d_j[X]d_j[(Z)\right) \quad (3)$$

A statistically significant $\beta_{3j}(\tau)$ at a given quantile τ and scale j would indicate that economic growth conditions the strength or direction of the ESGU-tourism relationship at that distributional state and horizon. If $\beta_{3j}(\tau)$ is uniformly insignificant, it implies that economic growth does not systematically alter how ESG uncertainty affects tourist arrivals.

Mediation

The mediation analysis follows a two-equation design (Adebayo, 2026). The first equation (path a) captures the effect of ESGU on ECOG:

$$Q_\tau\left(d_j[Z] \mid d_j[X]\right) = \alpha_{0j}(\tau) + \alpha_{1j}(\tau) d_j[X] \quad (4)$$

The second equation (path b) captures the effect of ECOG on TOR while controlling for ESGU:

$$Q_\tau\left(d_j[Y] \mid d_j[X], d_j[Z]\right) = \gamma_{0j}(\tau) + \gamma_{1j}(\tau) d_j[X] + \gamma_{2j}(\tau) d_j[Z] \quad (5)$$

The indirect effect at quantile τ and scale j is then computed as the product of the two path coefficients:

$$\text{Indirect Effect}_{j,\tau} = \alpha_{1j}(\tau) \times \gamma_{2j}(\tau) \quad (6)$$

A significant indirect effect at a given quantile and horizon confirms that ESG uncertainty transmits to tourist arrivals through its prior effect on economic growth, and that this transmission is specific to particular states of the tourism distribution and particular time scales. The full framework thus allows moderation and mediation effects to vary jointly across quantiles and horizons, which is the central methodological contribution of the analysis.

5. Results

Descriptive Statistics

Table 2 summarizes the distributional characteristics of the three variables in log-differenced form. ESGU has the widest spread, with values ranging from −57.39 to 87.79 and a standard deviation of 30.77, reflecting the considerable volatility in sustainability-related uncertainty over the sample. TOR and ECOG exhibit much smaller means (0.69 and 0.36, respectively) but are strongly negatively skewed (particularly TOR (skewness = −1.99) and ECOG (skewness = −1.55)) indicating that extreme declines are more frequent than extreme surges in these series. Both variables also show very high kurtosis values (17.12 for TOR; 30.10 for ECOG), pointing to fat-tailed distributions with a non-trivial probability of extreme observations. The Jarque–Bera statistics confirm strong departures from normality for TOR and ECOG, while ESGU appears relatively closer to a normal distribution.

The correlation results indicate that linear associations among the three variables are weak. ESGU correlates with TOR at 0.056 and with ECOG at 0.065, and the TOR–ECOG correlation is 0.169. These low correlations do not, however, preclude nonlinear or distributional dependencies, which the wavelet quantile framework is designed to capture.

Table 2: Descriptive Statistics and Correlation Matrix

Statistic	ESGU	TOR	ECOG
Minimum	-57.389	-73.011	-8.272
Maximum	87.788	49.369	7.425
Mean	0.904	0.692	0.363
Median	-0.792	1.344	0.451
Std. Dev.	30.767	13.060	1.317
Skewness	0.227	-1.989	-1.552
Kurtosis	2.669	17.119	30.104
Jarque–Bera	1.210	824.779	2853.080
Correlation Matrix			
ESGU	1.000	0.056	0.065
TOR	0.056	1.000	0.169
ECOG	0.065	0.169	1.000

*Note: Variables are in log-differenced form. *** p ≤ 0.01.*

Diagnostic Tests

Table 3 presents the results of nonlinearity, normality, heteroskedasticity, and unit root tests. In terms of nonlinearity (Section A), the BDS test is significant at the 1% level for all three variables, rejecting the hypothesis that the series are independently and identically distributed (i.i.d.) and providing strong evidence of nonlinear dependence. The Keenan test further detects nonlinearity in TOR and ECOG, while the Runs test yields a significant result for TOR. The Mann–Kendall statistics are insignificant for all variables, indicating no dominant monotonic trend. ESGU does not register as nonlinear under the Terasvirta, White, or Keenan tests, suggesting that its nonlinear structure, if present, is of a different form than those captured by these specific tests.

The normality tests (Section B) confirm that ESGU is approximately normally distributed, whereas TOR and ECOG reject normality across all five tests, consistent with the fat tails and asymmetry observed in the descriptive statistics. Section C shows no evidence of heteroskedasticity or ARCH effects for ESGU, but both TOR and ECOG exhibit significant ARCH effects, pointing to volatility clustering. Finally, the unit root tests

in Section D (ADF and PP) show that all three series are stationary at level in log-differenced form. Collectively, the diagnostic results justify the use of a nonlinear, distributional estimation approach: TOR and ECOG are non-normal, conditionally heteroskedastic, and display nonlinear dependence, while all series are stationary.

Table 3: Diagnostic Test Results

Section A: Nonlinearity					
Variable	**Terasvirta**	**White**	**Keenan**	**BDS**	**Mann–Kendall / Runs**
ESGU	0.2617	0.3197	0.5185	0.0000***	0.1265 / 0.4016
TOR	0.3791	0.3635	0.0045***	0.0000***	0.9865 / 0.0000***
ECOG	0.4008	0.5549	0.0000***	0.0001***	0.2701 / 0.6750
Section B: Normality (p-values)					
Variable	**Robust JB**	**Shapiro**	**Skewness**	**Kurtosis**	**SJ**
ESGU	0.6303	0.2655	0.3471	0.6267	0.3558
TOR	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ECOG	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
Section C: Heteroskedasticity (p-values)					
Variable	**White Test**		**ARCH Test**		
ESGU	0.3530		0.2081		
TOR	0.3808		0.0000***		
ECOG	0.4594		0.0000***		
Section D: Unit Root Tests (test statistics)					
Variable	**ADF**			**PP**	
ESGU	-7.7523***			-10.7923***	
TOR	-3.9574***			-5.0273***	
ECOG	-7.7874***			-11.4934***	

*Note: *** p ≤ 0.01, ** p ≤ 0.05, * p ≤ 0.10. ADF = Augmented Dickey–Fuller; PP = Phillips–Perron. All unit root tests are for series in log-differenced form.*

Direct Effect of ESGU on Tourist Arrivals

Figure 3 presents the wavelet quantile coefficients for the direct effect of ESGU on TOR across quantiles and horizons. In the short term, the effect is negative and statistically significant at the extreme lower tail ($\tau = 0.01$), indicating that when tourist arrivals are already at their lowest, an increase in ESG uncertainty further depresses arrivals. A plausible interpretation is that at very low arrival states, operators, investors, and potential travelers may be especially sensitive to any additional source of ambiguity (He et al., 2025). Conversely, at the extreme upper tail ($\tau = 0.95$), the short-term coefficient is positive and significant. This may reflect the possibility that in periods of strong tourism performance, ESGU-related signals are interpreted differently, perhaps as precursors to sustainability-driven repositioning or increased visibility of tourism as an investment category, though this interpretation should be treated cautiously given the correlational nature of the analysis.

In the medium term, the positive effect of ESGU persists at upper quantiles ($\tau = 0.60–0.80$), with weaker significance at $\tau = 0.60–0.70$, suggesting that the directional shift observed at the upper tail in the short term extends to broader upper-distribution states over a medium horizon. No significant direct effects are detected

in the long term. In the medium term, only the lower tail result ($\tau = 0.01$) shifts from negative to insignificant, consistent with the short-run adverse effect dissipating as the economy adjusts. Overall, these patterns confirm H1: ESG uncertainty has a statistically significant, though distributional and horizon-specific, effect on tourist arrivals.

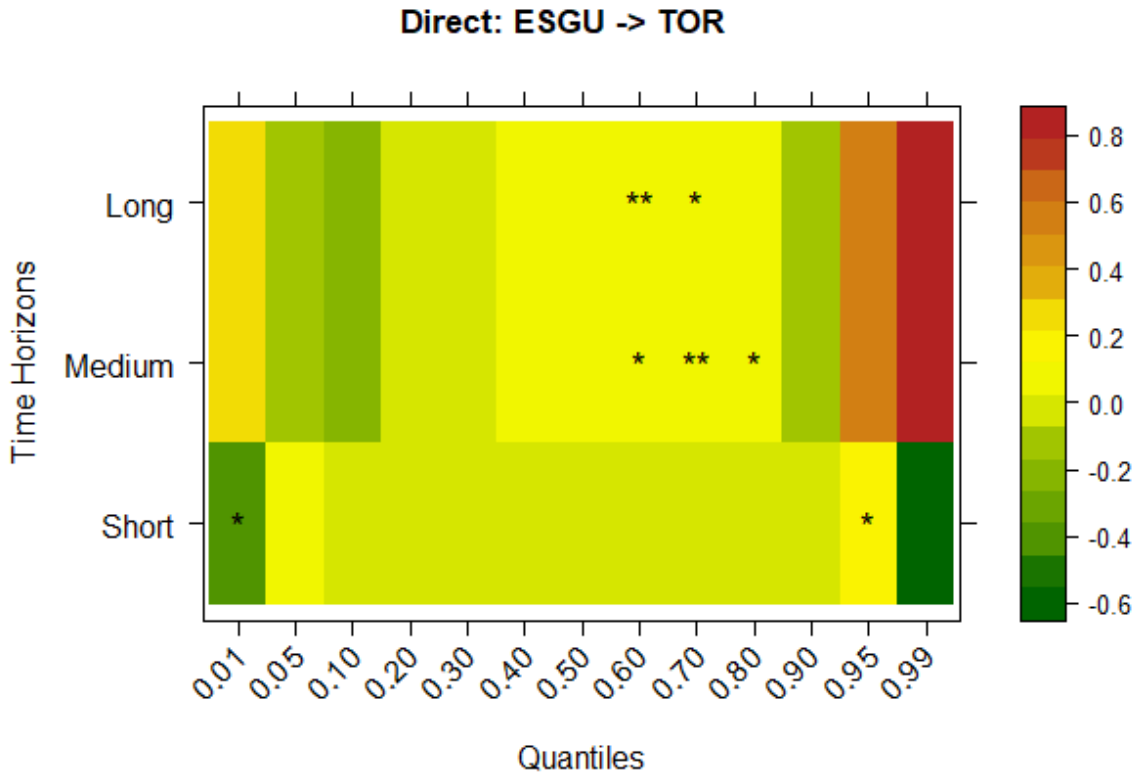


Fig. 3. Impact of ESGU on TOR

Note: Heatmap uses a dark green to red gradient indicating increasing coefficient magnitude. The y-axis represents time horizons (short, medium, long); the x-axis represents quantiles.

Moderating Role of Economic Growth

Figure 4 presents the interaction coefficients ($\beta_{3j}(\tau)$) from the moderation model. These coefficients are uniformly insignificant across all quantiles and time horizons, providing no support for H2. The implication is that economic growth does not systematically condition the strength or direction of the ESGU effect on tourist arrivals, whether growth conditions are weak, moderate, or strong. This result is not entirely unexpected: the relationship between sustainability-related uncertainty and tourism may be driven more by confidence, information, and expectations channels than by aggregate income conditions, and the latter may not be sufficiently granular or responsive to offset uncertainty at the sectoral level. The finding is broadly consistent with evidence that macroeconomic moderators in the tourism context can be context-specific and may not generalize across different types of uncertainty (Romão, 2020; Xu & Xie, 2025).

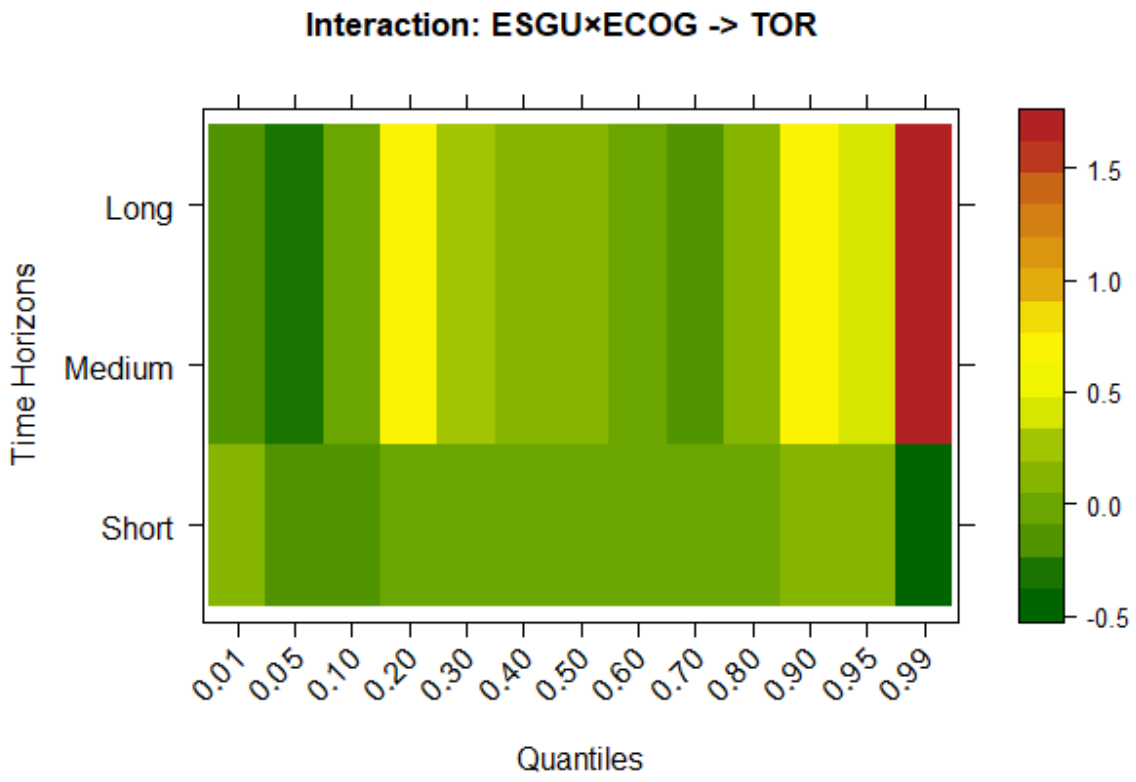


Fig. 4. Moderating role of ECOG on the effect of ESGU on TOR

Note: *A dark green to red gradient is used in the heatmap to indicate the magnitude of increasing slope coefficients, while the y-axis shows time horizons and the x-axis displays quantiles*

Mediation: Path A Effect of ESGU on Economic Growth

Figure 5 presents path-a coefficients (the effect of ESGU on ECOG) from the first mediation equation. In the short term, ESGU has a positive and significant effect only at $\tau = 0.01$, suggesting that under conditions of very weak economic growth, a rise in ESG uncertainty may coincide with some short-term economic adjustment or reallocation. This result could be associated with an initial policy response or portfolio rebalancing in developed settings (Chen et al., 2024; Qamruzzaman et al., 2025), though the direction is surprising given the broader uncertainty literature and should not be interpreted as a robust structural mechanism without further investigation.

In the medium term, the effect of ESGU on ECOG turns negative and significant at the lower tail ($\tau = 0.01$), at middle quantiles ($\tau = 0.50–0.60$), and at the extreme upper tail ($\tau = 0.99$). This pattern, which extends to the lower tails ($\tau = 0.01, 0.10$), middle quantiles ($\tau = 0.50–0.60$), and upper tail ($\tau = 0.99$) in the long term, is more consistent with the prior literature: sustained ESG uncertainty tends to weigh on macroeconomic activity by discouraging investment, complicating long-horizon planning, and creating financing uncertainty (Nawaz & Su, 2026; Nasraoui et al., 2026). The adverse effect is concentrated at distributional extremes and the middle, rather than being uniform, which suggests that the growth-dampening influence of ESGU varies with the state of the economy. These results support H3a.

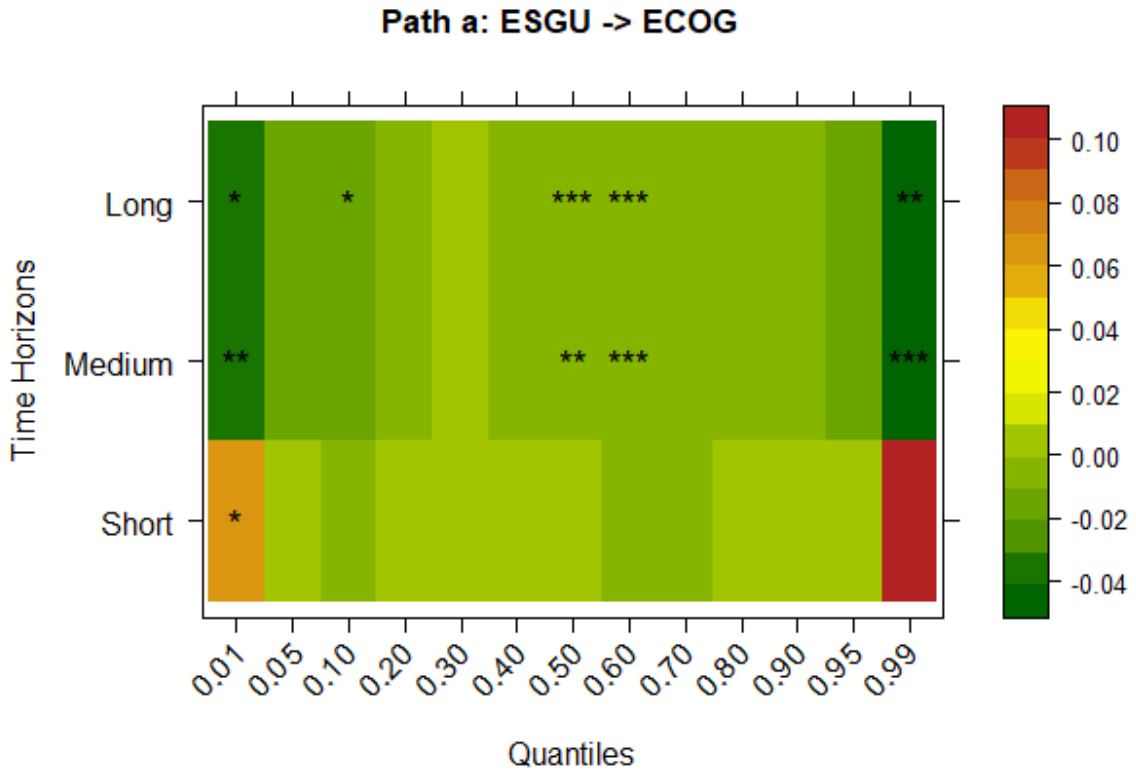


Fig. 5. ESGU on ECOG

Note: *A dark green to red gradient is used in the heatmap to indicate the magnitude of increasing slope coefficients, while the y-axis shows time horizons and the x-axis displays quantiles*

Mediation: Path B — Effect of Economic Growth on Tourist Arrivals

Figure 6 reports path-b coefficients, the effect of ECOG on TOR, controlling for ESGU. In the short term, none of the coefficients are statistically significant, implying that immediate growth fluctuations do not produce a discernible tourism response once ESG uncertainty is held constant. This could reflect the well-known lag between macroeconomic changes and tourism planning decisions, which often involve advance booking, visa processing, and budget allocation over longer horizons.

In the medium term, the ECOG effect on TOR is positive and significant at the lower tails ($\tau = 0.01–0.10$), the middle quantiles ($\tau = 0.60–0.70$), and the upper tails ($\tau = 0.90–0.99$). The same pattern persists in the long term. The result is consistent with theoretical expectations: economic growth raises household income, strengthens destination investment, and improves service capacity over medium and long horizons, effects that are evident across different states of the tourism distribution, though not at the intermediate quantiles ($\tau = 0.20–0.50$). This provides support for H3b and establishes the b-path condition for the mediation test.

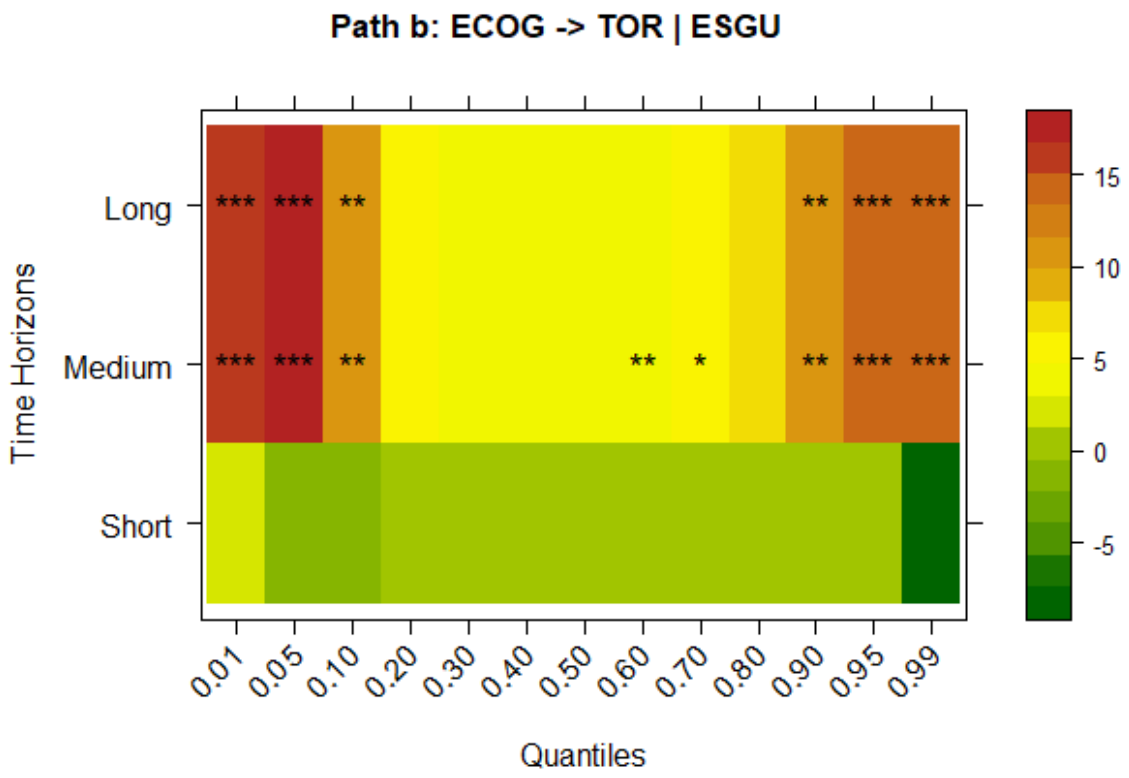


Fig. 6. Effect of ECOG on TOR while controlling ESGU

Note: *A dark green to red gradient is used in the heatmap to indicate the magnitude of increasing slope coefficients, while the y-axis shows time horizons and the x-axis displays quantiles*

Indirect Effect and Mediation

Figure 7 presents the indirect effects (the product $\alpha_{1j}(\tau) \times \gamma_{2j}(\tau)$) which capture the portion of the ESGU effect on TOR that operates through economic growth. In the short term, indirect effects are insignificant across all quantiles, confirming that the ESGU–growth–tourism transmission channel does not materialize immediately. This is consistent with the path-b findings: since growth does not affect tourism in the short term once ESGU is controlled for, the mediation pathway is closed at that horizon regardless of path-a significance.

In the medium term, the indirect effect is negative and significant at $\tau = 0.01$, $\tau = 0.60$, and $\tau = 0.99$. In the long term, negative and significant indirect effects appear at $\tau = 0.01$, $\tau = 0.10$, and $\tau = 0.99$. These results indicate that ESGU dampens tourist arrivals by first slowing economic growth and then propagating that growth effect to tourism demand—but only at distributional extremes and selected middle quantiles, and only over medium and long horizons. The mediation is therefore state-specific and horizon-dependent rather than uniform, which is consistent with the heterogeneous path-a and path-b patterns discussed above. These findings support H4. The absence of short-term indirect effects and the concentration of significant results at distributional extremes suggest that the tourism risk associated with ESG uncertainty is most consequential for destinations or periods already at the tails of the performance distribution.

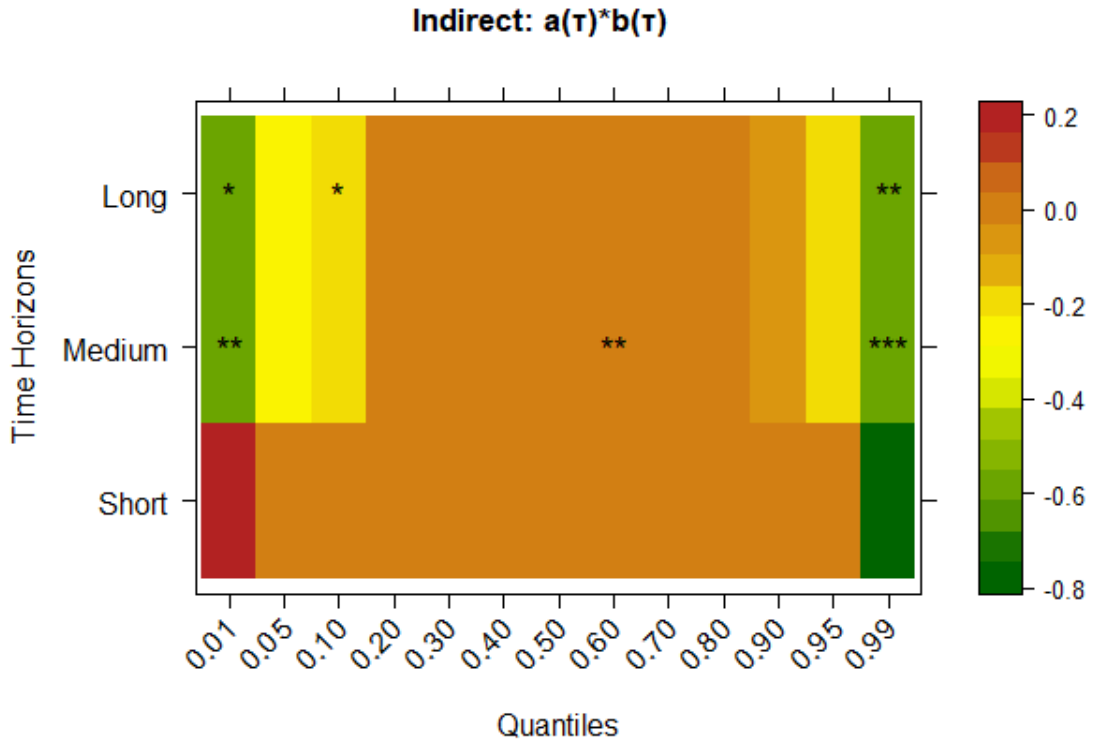


Fig. 7. Mediating role of ECOG on the effect of ESGU on TOR

Note: *A dark green to red gradient is used in the heatmap to indicate the magnitude of increasing slope coefficients, while the y-axis shows time horizons and the x-axis displays quantiles*

6. Conclusion and Policy Recommendations

Conclusion

This study applied a wavelet quantile regression framework extended to mediation and moderation to examine how ESG uncertainty shapes tourist arrivals in the United States, and whether economic growth conditions or transmits this effect. Using quarterly data for 2002–2025 and five analytical steps, direct effects, moderation, path a, path b, and indirect effects, the analysis yields three main findings.

First, ESG uncertainty affects tourist arrivals in a nonlinear and horizon-specific way. In the short term, ESGU reduces arrivals at the extreme lower quantile and is associated with higher arrivals at the upper tail. Medium-term positive effects persist at upper quantiles (τ = 0.60–0.80). These patterns indicate that the direction and magnitude of the ESGU–tourism relationship depend jointly on the distributional state of tourism and the time horizon considered, which cannot be captured by mean-based or single-horizon methods.

Second, economic growth does not significantly moderate the ESGU–tourism nexus at any quantile or horizon. This implies that broader macroeconomic expansion, on its own, does not systematically buffer or amplify how tourism responds to ESG uncertainty. The interaction between the two is more limited than the general uncertainty-growth-tourism literature might suggest.

Third, economic growth mediates the ESGU–tourism relationship, but only over medium and long horizons and at distributional extremes. ESGU affects economic growth positively at the extreme lower tail in the short term, but negatively at selected quantiles in the medium and long term—consistent with the uncertainty-investment literature. Since economic growth, in turn, supports tourist arrivals at medium- and long-term non-central quantiles, the indirect effect of ESGU on tourism through growth is

negative and significant at the distributional extremes in the medium and long term, and absent in the short term.

Together, these findings advance the tourism–uncertainty literature by demonstrating that the channel through which ESG uncertainty reaches tourism performance is distributional and lagged, not immediate or uniform. The study also contributes methodologically by applying the wavelet quantile mediation and moderation framework (previously applied in energy and environmental economics) to the ESG uncertainty-tourism-growth nexus in a major developed tourism economy.

Policy Implications

The results carry implications for tourism policy at the federal and state levels in the United States, though these should be read as directional guidance informed by empirical patterns rather than prescriptive recommendations based on fully identified causal mechanisms.

The first implication concerns tourism risk management. The finding that ESG uncertainty significantly reduces arrivals under weak tourism conditions, and that this adverse indirect effect intensifies over medium and long horizons, suggests that sustainability-related uncertainty should be treated as a material risk to tourism performance, particularly during periods of low demand. Federal and state authorities may benefit from integrating sustainability risk communication and crisis-response protocols into tourism policy frameworks, rather than treating ESG-related signals as purely financial or regulatory matters. This is broadly consistent with the priorities articulated in the U.S. National Travel and Tourism Strategy, which emphasizes sector resilience and sustainability alongside competitiveness (U.S. Department of Commerce, 2022).

The second implication follows from the null moderation finding. The absence of a significant moderating role for economic growth means that broad macroeconomic expansion alone may not be sufficient to protect tourism from sustainability-related uncertainty shocks. Place-based and sector-specific interventions (including investment in resilient transport infrastructure, clean destination services, coastal protection, and support for local tourism businesses in environmentally exposed areas) may be more effective than relying on aggregate growth to absorb uncertainty-related disruptions. The Economic Development Administration's support for travel and outdoor recreation projects and NOAA's coastal resilience programs offer institutional platforms for such interventions (U.S. Economic Development Administration, 2022; NOAA Sea Grant, 2024).

The third implication relates to medium- and long-term policy coordination. Because the indirect effect of ESGU on tourism through growth materializes only over medium and long horizons, policy frameworks that reduce ESG-related ambiguity and provide stable long-term signals on climate, energy, and destination investment may help limit the downstream tourism impact. Greater coordination across commerce, environmental, coastal, and infrastructure agencies could reduce the policy uncertainty component of ESGU, thereby weakening one of the channels through which sustainability uncertainty reaches tourism demand. EPA's Climate Pollution Reduction Grants, which support multi-level government planning and implementation, offer one mechanism for this type of coordinated approach (NOAA Sea Grant, 2024).

Limitations and Future Research

Several limitations qualify the interpretation of these findings. First, the study focuses on the United States as a single destination economy, which limits direct generalizability to other contexts. The role of ESG uncertainty in tourism may differ substantially in economies with different institutional structures, tourism dependencies, or sustainability policy frameworks.

Second, tourist arrivals are used as the sole measure of tourism performance. This captures volume but not value, and aggregates domestic and international tourism in ways that may obscure important

heterogeneity. Future research could examine tourism receipts, bed-nights, or tourism's contribution to GDP, and could separately analyze domestic and inbound international tourism.

Third, several potentially relevant variables, including exchange rates, inflation, energy prices, geopolitical risk, climate-related events, destination safety, and digital tourism development are not incorporated. Their omission means that the ESGU effects estimated here may partly reflect correlated omitted drivers, and robustness checks with extended variable sets would strengthen the conclusions.

Fourth, the wavelet quantile framework identifies distributional and horizon-specific effects but does not pin down the behavioral or institutional mechanisms through which these effects operate. Whether the observed patterns reflect investor reallocation, traveler sentiment, policy signaling, or some combination of these cannot be determined from aggregate time-series evidence alone.

Fifth, the analysis relies on a single uncertainty index (ESGU). Future work could test robustness against alternative uncertainty measures, such as climate policy uncertainty indices or financial market volatility measures or could explore whether different dimensions of ESG uncertainty (environmental, social, governance) affect tourism differently.

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