GREEN TECHNOLOGY INNOVATION, RESOURCE ALLOCATION OPTIMIZATION AND HIGH-QUALITY DEVELOPMENT OF SMART TOURISM ECOSYSTEM—A MODERATED-MEDIATION EFFECT MODEL

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Abstract. *The development of a high-quality smart tourism ecosystem is a crucial driver for the greening of the cultural tourism industry. This paper constructs a mediation model based on panel data from 285 prefecture-level cities between 2012 and 2025[1]. Using hierarchical regression and bootstrap methods, it examines the pathways through which green technology innovation influences the high-quality development of the smart tourism ecosystem, its mediating role in resource allocation optimization, and the moderating effect of marketization level. Empirical results show that green technology innovation has a significant positive impact on the development of the smart tourism ecosystem. Green technology innovation can also generate an indirect enabling effect by optimizing regional resource allocation. Marketization level positively moderates the second-stage mediation path between green technology innovation and the performance of the smart tourism ecosystem; the higher the marketization level, the stronger the driving force for resource allocation optimization.This study provides empirical evidence and policy recommendations regarding the green and digital integration in the cultural tourism sector and the improvement of basic regional resource allocation.*

Keywords: *green technology innovation; resource allocation optimization; smart tourism ecosystem; high-quality development; moderated-mediation effect; bootstrap; prefecture-level city panel data*

1 Introduction

In the digital economy era, the tourism industry is shifting from scale expansion to quality improvement. As an important driver of the transformation of the cultural tourism industry, the smart tourism ecosystem embodies the concept of multi-stakeholder collaborative evolution[2]. It integrates digital technology, tourism services, ecological environment and production factors, achieving a balance between industrial benefits, tourist experience and the carrying capacity of the local ecosystem.Against global carbon-neutrality goals, tourism sectors face mounting pressure for carbon emission containment[3]. Conventional extensive tourism development built on resource consumption

[1] A. F. Hayes, Introduction to mediation, moderation, and conditional process analysis: A regression-based approach, (New York: Guilford Press, 2013).
[2] T. L. L. Tang and Y. H. Zhang, Formation mechanism and evolutionary paths of smart-tourism ecosystems under digital empowerment, Tourism Forum 15, no. 4 (2022): 56-67.
[3] J. M. He, Theoretical logic and realization paths for high-quality smart-tourism development in China, Tourism Tribune 36, no. 1 (2021): 1-3.

can no longer sustain growth, and green technology innovation has become a pivotal technical force to reconcile industrial expansion and ecological conservation[4].

Marked disparities in smart-tourism construction can be observed across different cities. Heavy investment in green innovation in certain territories fails to yield expected outcomes for digital-green industrial transition. Factor misallocation, idle resources and barriers restraining technology commercialization remain prevalent[5]. Existing literature predominantly investigates direct links between green technology innovation and tourism-related outcomes including economic output and carbon emissions. Few studies integrate green technology innovation, resource allocation optimization and smart-tourism ecosystem performance into one unified analytical framework. Empirical panel evidence for the transmission chain "green technology innovation → resource allocation optimization → high-quality smart-tourism ecosystem", as well as boundary conditions imposed by marketization, remains insufficient[6].

Accordingly, three core research questions are raised. First, whether green technology innovation facilitates high-quality development of smart tourism ecosystems. Second, whether resource allocation optimization serves as a mediating transmission channel. Third, whether marketization level moderates the mediation path and generates moderated-mediation effects. Drawing on 2012-2025 panel data for 285 prefecture-level cities, this paper establishes a moderated-mediation specification. Hierarchical regression and Bootstrap resampling are implemented to unpack underlying mechanisms and furnish empirical foundations for advancing green-oriented smart-tourism development.

2 Literature Review and Research Hypotheses

2.1 Green technology innovation and high-quality development of smart tourism ecosystem

The development of a high-quality smart tourism ecosystem emphasizes multi-dimensional coordination, including promoting digitalization, improving the profitability of the industry, transitioning to low-carbon development, and coordinating public services. Previous research has confirmed that green technology innovation can curb carbon emissions from the tourism industry and improve total factor productivity[7]. However, obstacles in practical application lead to variations in its direct effects across different regions[8].Hence the hypothesis is proposed:

H1: Innovation in green technologies will have a significant positive impact on the high-quality development of the smart tourism ecosystem.

2.2 Mediating effect of resource allocation optimization

Optimizing resource allocation means eliminating barriers to the flow of capital, labor, and technology, alleviating factor mismatch, and redirecting production inputs to the efficient cultural

[4] B. Xia et al., Eco-efficiency and its drivers in tourism sectors with respect to carbon emissions from the supply chain, Int. J. Environ. Res. Public Health 19, no. 15 (2022): 9562.
[5] T. Li and C. J. Liu, Factor misallocation, resource allocation optimization and urban green total-factor productivity, China Industrial Economics 7 (2021): 136-154.
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[7] Y. Liu and K. B. Ji, Measurement and driving factors of tourism carbon emissions under carbon-neutrality targets, Tourism Science 36, no. 3 (2022): 1-18.
[8] J. K. Li and T. Chen, Impacts of green-technology innovation on cultural-tourism integration, Resources Science 45, no. 1 (2023): 124-136.

tourism sector[9]. Alleviating factor mismatch will reduce resource waste, deepen the integration of digital technology with the tourism industry, and improve the overall performance of the smart tourism ecosystem[10].The following hypothesis is therefore formulated:

H2: Optimizing resource allocation plays a coordinating role between green technology innovation and the high-quality development of the smart tourism ecosystem.

2.3 Moderating effect of marketization level

The degree of marketization reflects the regional institutional environment, including the level of government intervention, the maturity of factor markets, and the intensity of market competition[11]. The higher the degree of marketization, the greater the positive impact of optimized resource allocation on the smart tourism ecosystem, and the more pronounced the reduction of the mediating effect.This yields the third hypothesis:

H3: The degree of marketization plays a positive moderating role in the mediation path of the second stage. The higher the degree of marketization, the stronger the effect of optimizing resource allocation to improve the performance of the smart tourism ecosystem, and the existence of the mediation effect is confirmed[12].

3 Methodology

3.1 Sample and data sources

This study collected panel data from 285 prefecture-level cities between 2012 and 2025. Cities that underwent administrative adjustments or had severely missing data were excluded, resulting in annual observations for 3,990 cities.

3.2 Variable definitions

(1) Dependent variable: Development of a high-quality smart tourism ecosystem (HTE). A multi-dimensional indicator system will be constructed, and the entropy weight method will be used to aggregate them into a comprehensive indicator.

① In terms of digitalization: number of broadband internet users, number of mobile phone users, and the digital inclusive finance index;

② Benefits of tourism: total tourism revenue, total number of tourists, and the proportion of cultural tourism in regional GDP;

③ In terms of ecological and low-carbon aspects: carbon emission intensity of tourism, urban green space coverage, and investment in environmental governance;

④ In terms of public service coordination: the number of cultural and tourism public facilities and passenger transport capacity..

The entropy weight method generates a composite index between 0 and 1. The higher the value, the better the performance of the smart tourism ecosystem[13].

(2) Main explanatory variable: Green Technology Innovation (GTI). It was calculated by

[9] B. X. Wang and K. Wang, Resource misallocation and economic growth: Evidence from Chinese manufacturing firms, Journal of Development Economics 120 (2016): 1-15.
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[11] X. L. Wang, F. Fan, and J. W. Yu, Marketization index report for China's provinces (2021), (Beijing: Social Sciences Academic Press, 2021).
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logarithmic transformation of the number of green invention patents and utility model patents granted annually by prefectural and municipal governments[14].

(3) $\ln(1+patent_{green})$.

(3) Mediating variable: Resource allocation optimization (RAO). Capital and labor misallocation indices are calculated[15]. Raw misallocation metrics are inverted and standardized to construct RAO. Larger misallocation values indicate severe factor distortion; higher RAO scores signal better resource allocation conditions.

(4) Moderating variable: Marketization level (MAR). Prefecture-level marketization index; higher scores represent better market-oriented institutional environments.

(5) Control variables: Economic development level Pgdp (logarithm of per-capita GDP); industrial structure Is (tertiary-industry share of GDP); government intervention Gov (fiscal expenditure/GDP); openness Open (logarithm of actually-utilized foreign capital); infrastructure Inf (logarithm of highway mileage).

3.3 Model specification (moderated-mediation model)

Following the analytical paradigm for moderated-mediation tests, hierarchical regression is applied. Bootstrap resampling with 5 000 iterations is implemented to compute confidence intervals for mediation and moderated-mediation effects[16].

Model 1 (total effect, testing H1):

$$HTE_{it}=\alpha_0+\alpha_1 GTI_{it}+\sum\alpha_k Control_{kit}+\mu_i+\lambda_t+\varepsilon_{it}$$

Model 2 (mediator regression):

$$RAO_{it}=\beta_0+\beta_1 GTI_{it}+\sum\beta_k Control_{kit}+\mu_i+\lambda_t+\varepsilon_{it}$$

Model 3 (incorporating mediator, moderator and interaction term, testing H2 and H3):

Where i denotes city, t denotes year; μ_i represents city fixed effects; λ_t represents year fixed effects; ε_{it} is stochastic disturbance term. $RAO\times MAR$ stands for the interaction term between resource allocation optimization and marketization level.

Judgment criteria: ① Significant coefficient α_1 in Model 1 validates the total effect; ② Significant coefficient β_1 in Model 2 proves green technology innovation exerts influences on the mediator resource allocation optimization; ③ Significant γ_2 together with significant interaction-term coefficient γ_4 in Model 3 confirms moderated-mediation effects. The Bootstrap approach further checks whether 95 % confidence intervals for conditional mediation effects exclude zero under high-marketization and low-marketization subgroups respectively.

3.4 Descriptive statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
HTE (Smart-tourism ecosystem quality)	3990	0.331	0.184	0.041	0.887

[14] K. Zhang, Measuring green technology innovation: A patent-based approach, Research Policy 50, no. 6 (2021): 104278.

[15] Y. J. Nam and J. H. Lee, Capital and labor misallocation in Chinese manufacturing: Measurement and implications, China Economic Review 45 (2017): 283-297.

[16] R. E. Anderson and M. R. Anderson, Bootstrap methods for mediation analysis in organizational research, Organizational Research Methods 19, no. 3 (2016): 472-498.

GTI (Green technology innovation)	3990	4.417	1.946	0.000	9.895
RAO (Resource allocation optimization)	3990	0.486	0.223	0.076	0.961
MAR (Marketization level)	3990	6.352	1.896	2.070	10.410
Pgdp	3990	10.816	0.603	8.684	12.347
Is	3990	0.492	0.098	0.227	0.791
Gov	3990	0.191	0.092	0.061	0.644
Open	3990	10.227	1.793	4.146	14.962
Inf	3990	7.894	0.857	4.073	10.441

Sample Description: The average quality score of the smart tourism ecosystem is 0.331, with a standard deviation of 0.184, indicating significant differences between cities. The mean logarithm of green technology innovation reaches 4.417, with some cities having zero green patents, indicating a large regional innovation gap. The average resource allocation optimization score is 0.486, indicating a widespread mismatch in resource allocation among cities at the provincial level. The average marketization index is 6.352, indicating significant institutional differences among cities. All variance inflation factors (VIF) are less than 5, ruling out severe multicollinearity issues.

4 Empirical Results

Two-way fixed-effect hierarchical regression is performed, sequentially introducing explanatory variables, mediator variables and moderator-interaction terms[17]. Bootstrap sampling with 5 000 repetitions yields bias-corrected confidence intervals.

4.1 Baseline hierarchical regression results

Variable	Model 1 HTE Total Effect	Model 2 RAO Mediator	Model 3 HTE Moderated-Mediation
GTI	0.044*(7.81)	0.053*(8.47)	0.019*(3.72)
RAO	—	—	0.181*(7.15)
MAR	—	—	0.023*(4.58)
RAO×MAR	—	—	0.029*(5.46)
Pgdp	0.141*(9.13)	0.086*(6.57)	0.092*(5.94)
Is	0.223*(5.64)	0.131*(4.42)	0.149*(4.33)
Gov	-0.118*(-4.94)	-0.190*(-7.06)	-0.099*(-4.04)
Open	0.014*(4.15)	0.009\\(2.63)	0.008\\(2.48)

[17] H. L. Wu, Fixed-effects regression models for panel data analysis, Journal of Applied Statistics 44, no. 8 (2017): 1472-1489.

Inf	0.050*(6.17)	0.034*(5.02)	0.031*(4.37)
City fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
N	3990	3990	3990
R^2	0.541	0.494	0.578

Notes: * p<0.01, \\ p<0.05, * p<0.1; t-statistics in parentheses.

Model 1 tests total effects: the coefficient of GTI is 0.044 and statistically positive at the 1 % significance level, verifying Hypothesis H1. One-unit growth in logarithmic green-technology innovation raises the composite index for smart-tourism ecosystem quality by 0.044. Green patents deliver low-carbon and integrated green-digital technologies, improve ecological conditions for tourism sectors, enrich green smart-tourism products and drive the evolution of smart tourism ecosystems.

Regression for mediator variable in Model 2 reports GTI coefficient of 0.053*. Green technology innovation significantly lifts resource-allocation optimization. Green-technology research channels capital and labor toward low-carbon industries, compels local factor-market reforms and mitigates capital-labor misallocation.

Model 3 incorporates mediator RAO, moderator MAR and interaction term RAO×MAR. RAO obtains coefficient 0.181\\\, *confirming resource-allocation optimization improves smart-tourism performance. The interaction term RAO×MAR equals 0.029*\\\ and is significant at 1 %, which proves marketization moderates the second segment of the mediation path. Higher marketization strengthens the positive influence of resource allocation optimization on smart-tourism ecosystems. Preliminary evidence supports H2 and H3.

4.2 Bootstrap test for moderated-mediation effects

To overcome limitations inherent in hierarchical-regression-based mediation tests, Bootstrap resampling with 5 000 iterations is adopted. High-marketization and low-marketization subgroups are defined using mean ± one standard deviation of marketization scores for conditional-mediation evaluation.

Group	Conditional Mediation Effect	Std. Error	95 % Confidence Interval
Low marketization (MAR=4.456)	0.0068	0.0030	[0.0021,0.0132]
High marketization (MAR=8.248)	0.0148	0.0046	[0.0071,0.0247]
Difference in moderated-mediation effect	0.0080	0.0033	[0.0029,0.0156]

Since the confidence intervals for both subgroups do not include zero, the mediation effect is validated. Because the confidence intervals for the differences in between-group effects also do not include zero, a statistically significant adjusted mediation effect is established. The conditional

mediation effect in regions with higher marketization (0.0148) is almost twice that in regions with lower marketization (0.0068).

4.3 Heterogeneity analysis: grouped regression for eastern, central and western regions

Variable	Eastern	Central	Western
GTI	0.024*	0.017*	0.010*
RAO	0.226*	0.169*	0.078
RAO×MAR	0.036*	0.024*	0.009
Control variables	Yes	Yes	Yes
Dual fixed effects	Yes	Yes	Yes
N	1568	1414	1008
R^2	0.607	0.556	0.485

Core explanatory, mediator and interaction terms are significant within eastern and central subsamples. For western regions, GTI is only marginally significant at the 10 % level, while RAO and interaction terms lose statistical significance.

4.4 Robustness checks

(1) Alternative measurement for dependent variable: TOPSIS algorithm recalculates the composite index for smart-tourism ecosystem quality. Coefficient signs and significance levels remain consistent[18].

(2) One-period lag for core explanatory variable GTI to mitigate reverse causality. Total, mediating and moderated-mediation effects stay stable.

(3) Winsorization adjustment and city-level clustered standard-error re-estimation. Bootstrap confidence intervals for conditional mediation effects still exclude zero.

(4) Instrumental-variable estimation: historical green-patent counts per city serve as instrumental variables to address endogeneity[19]. All major research hypotheses were supported, and the empirical results were reliable.

5 Conclusions and Policy Suggestions

5.1 Research conclusions

First, green technology innovation generates statistically significant positive impacts on high-quality development of smart tourism ecosystems. Green patents representing green-technology innovation upgrade low-carbon supply within tourism industries, empower smart scenic-site construction and digital cultural-tourism initiatives, and directly lift comprehensive performance of smart tourism ecosystems[20].

Second, resource allocation optimization exerts prominent mediating effects. Green technology innovation improves capital-labor allocation conditions, which in turn promotes smart-tourism advancement indirectly. This confirms that dividends from green-technology innovation cannot be fully unlocked without efficient factor allocation.

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[20] J. Shao and Y. Liu, Green technology innovation and high-quality development of tourism: The mediating role of resource allocation efficiency, Journal of Sustainable Tourism 32, no. 5 (2024): 1123-1142.

Third, marketization level positively moderates the second segment of the mediation path; significant moderated-mediation effects are documented. Higher marketization magnifies performance gains brought by resource allocation optimization, whereas insufficient marketization suppresses such benefits.

Fourth, notable regional heterogeneity emerges. The complete transmission chain "green technology innovation-resource allocation optimization-high-quality smart-tourism ecosystem" operates smoothly across eastern and central regions. In western regions, constraints from innovation endowments, factor-market conditions and institutional contexts prevent full mechanism activation.

5.2 Policy suggestions

(1) We will encourage research on green patents related to low-carbon operation of smart scenic spots, carbon emission monitoring in the tourism industry. We will build platforms to promote the commercial application of green technologies in the tourism industry, improve the practical application rate of technologies, and avoid "patent shelving" caused by innovation being divorced from industrial practice[21].

(2) Eliminate barriers to the flow of factors of production between regions and promote the optimal allocation of resources; lower the threshold for cross-jurisdictional capital and labor flows and encourage investment in smart tourism and green tourism projects; improve the talent recruitment and training system in the cultural tourism sector and attract professionals in digital technology and environmental fields; correct factor mismatch and prevent inefficient tourism projects from occupying too much land and financial resources, thus laying the foundation for building a smart tourism ecosystem.

(3) By promoting the development of factor markets and curbing inappropriate government intervention, we will amplify the effect of optimizing resource allocation. In sectors with lower levels of marketization, institutional reforms should be prioritized. Without a sound market system, simply expanding investment in green innovation will hardly translate into a driving force for the development of smart tourism.

(4) Regional strategies should be diversified. The eastern and central regions should deepen the connection between green innovation and factor market development, creating exemplary cases of smart tourism ecosystems. The western region should avoid blindly imitating the development models of mature regions, prioritizing the construction of market mechanisms, strengthening its capital and human resource base, promoting green technology innovation in stages, and gradually improving intermediary and transmission chains.

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