# A Study of the Relationship between Rapid Transportation, Tourism Economy, and Tourism Eco-efficiency in China Based on a PVAR Model (Postprint)

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## Abstract

The coordinated interaction among rapid transportation, the tourism economy, and tourism eco-efficiency is of great significance for promoting the green transformation of the tourism industry and thereby achieving high-quality development. Based on inter-provincial panel data for China from 2009 to 2022, a panel vector autoregression (PVAR) model is constructed to explore the interaction mechanisms, interrelationships, and heterogeneous characteristics among the three. The results show that: (1) Rapid transportation, the tourism economy, and tourism eco-efficiency all exhibit a relatively positive growth trend, and a benign equilibrium transition supported by the gradual shift from low to high levels of development is the mainstream trend of their coordinated development. (2) There exists a bidirectional Granger causality between rapid transportation and the tourism economy at the national level and in the eastern region; the two demonstrate a benign, positive interactive response, but this effect is not persistent. Rapid transportation displays a pronounced self-reinforcing feature, while the tourism economy, though mainly self-driven, is strongly influenced by rapid transportation. (3) There exists only a unidirectional Granger causality between rapid transportation and tourism eco-efficiency; the positive driving effect of rapid transportation on tourism eco-efficiency tends to fluctuate and decline, and the impact of tourism eco-efficiency on rapid transportation is generally weak. The interaction between the two is evidently unbalanced, with both exhibiting low levels of variance contribution to each other. (4) There exists a bidirectional Granger causality between the tourism economy and tourism eco-efficiency at the national level, characterized by an interaction pattern in which the tourism economy exerts a strong and effective short-term driving effect, whereas the role of tourism eco-efficiency is persistently weak and disorderly. The internal driving force of tourism eco-efficiency is insufficient, and

in the eastern and central regions the tourism economy contributes the largest share to its variance.

## Full Text

## Preamble

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### Research on the Relationship Among Rapid Transportation, Tourism Economy, and Tourism Eco-Efficiency in China Based on a PVAR Model

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**Abstract:** The coordinated interaction among rapid transportation, tourism economy, and tourism eco-efficiency is crucial for promoting the green transformation of tourism and achieving high-quality development. Based on China' s provincial panel data from 2009 to 2022, this study constructs a panel vector autoregression (PVAR) model to explore the interactive mechanisms, dynamic relationships, and regional heterogeneity among these three elements. The findings reveal that: (1) All three variables exhibit positive growth trends, with a mainstream transition toward a benign equilibrium supported by gradual development from lower to higher levels. (2) Bidirectional Granger causality exists between rapid transportation and the tourism economy at both the national and eastern regional levels, implying a positive but short-lived interactive response. Rapid transportation demonstrates strong self-reinforcing characteristics, while the tourism economy is primarily self-driven yet significantly influenced by rapid transportation. (3) Only unidirectional Granger causality is observed between rapid transportation and tourism eco-efficiency. The positive driving effect of rapid transportation on tourism eco-efficiency tends to fluctuate and diminish, while the impact of tourism eco-efficiency on rapid transportation remains weak. Their interaction is notably imbalanced, with low mutual variance contribution rates. (4) Bidirectional Granger causality between the tourism economy and tourism eco-efficiency exists at the national level, characterized by strong and effective short-term driving of the tourism economy, which contrasts with the persistent weakness and disorderly effects of tourism eco-efficiency. Tourism eco-efficiency lacks sufficient endogenous momentum, with the tourism economy contributing the most to its variance in the eastern and central regions.

**Keywords:** rapid transportation; tourism economy; tourism eco-efficiency; PVAR model

## Introduction

According to statistics from the Ministry of Culture and Tourism, China' s tourism industry contributed 11.05% to the national economy in 2023, establishing itself as a strategic pillar industry. However, behind this rapid expansion lies an urgent need to address the ecological costs and efficiency bottlenecks inherent in traditional development models. The *Outline of the National Comprehensive Three-Dimensional Transportation Network* (2021) proposes promoting integrated transportation and tourism development to create a virtuous interactive pattern where transportation drives tourism and tourism stimulates transportation development. As rapid mobility travel patterns emerge, the importance of speed and convenience becomes increasingly prominent. High-speed rail and civil aviation, leveraging superior transport efficiency, meet the demand for rapid spatial transfer and effectively activate tourism development in hub cities [**?**, **?**]. Yet, while rapid transportation plays a 引流 role, massive tourist influxes also threaten tourism eco-efficiency [**?**, **?**]. Therefore, clarifying the complex interactions among tourism economy, tourism eco-efficiency, and rapid transportation is essential for providing decision-making references and practical guidance for deeply integrated transportation-tourism development and sustainable tourism development.

Tourism eco-efficiency, formally introduced into tourism research in 2002, fundamentally aims to achieve maximum tourism economic benefits with minimal environmental costs [**?**, **?**], serving as a crucial tool for quantifying green development in tourism. Existing literature has theoretically and empirically analyzed the relationships among transportation, tourism economy, and tourism eco-efficiency. First, regarding transportation and tourism economy: tourism development significantly depends on transportation, as regional transport infrastructure influences tourist travel choices and distribution patterns [**?**, **?**]. Enhanced transportation accessibility drives the spatial evolution of tourism economic patterns [**?**, **?**], with rapid transportation particularly stimulating tourism development along routes [**?**, **?**] and serving as a core driver for high tourism revenues. Recent research has focused on the impacts of high-speed rail and civil aviation on tourism [**?**, **?**]. Conversely, tourism economy also affects transportation development; for instance, tourism economic growth in Northwest China positively impacts transportation development [**?**], though its theoretical effect on rapid transportation construction requires further verification.

Second, regarding transportation and tourism eco-efficiency: transportation construction optimizes tourism factor allocation efficiency, yet tourism transport carbon emissions can account for 40-60% of total tourism carbon emissions [**?**], significantly affecting green production in tourism [**?**, **?**]. Unreasonable regional transportation infrastructure layout may increase environmental pressure [**?**], while improved accessibility enhances tourism environmental system resilience [**?**]. Existing studies have found nonlinear impacts of rapid transportation on

tourism eco-efficiency [?]. Overall, current research emphasizes unidirectional effects of transportation on sustainable tourism development.

Third, regarding tourism economy and tourism eco-efficiency: tourism eco-efficiency requires tourism economy to maintain growth vitality while reducing negative environmental impacts [?], but tourism activities consume substantial fossil energy [?], inevitably exerting pressure on ecological environments. Limited environmental carrying capacity in tourist destinations [?] has prompted scholars to explore coordinated development between tourism economy and ecological environment [?], with tourism eco-efficiency providing target-driven motivation for high-quality tourism economic development [?].

In summary, complex relationships exist among transportation, tourism economy, and tourism eco-efficiency. Current research limitations include: (1) Content: Most studies focus on pairwise unidirectional relationships, failing to fully reveal interactive mechanisms among all three elements and lacking regional comparisons of their interactive characteristics; (2) Methodology: Ordinary panel regression models inadequately address variable endogeneity and lag effects, unable to effectively characterize complex dynamic interactions; (3) Scale: Most research focuses on small and medium scales such as scenic spots, cities, or regions, limiting overall understanding of national-level interactions; (4) Objects: Rapid transportation studies often examine single modes like high-speed rail or civil aviation with single indicators, requiring more comprehensive evaluation systems integrating multiple rapid transportation modes.

Based on this context, this paper addresses the following scientific questions: What dynamic interactive relationships exist among rapid transportation, tourism economy, and tourism eco-efficiency? Do these relationships exhibit significant spatiotemporal heterogeneity? What mechanisms underlie regional differences? To answer these questions, we construct evaluation indicator systems for rapid transportation, tourism economy, and tourism eco-efficiency, and employ a PVAR model to examine their interactions and regional heterogeneity using provincial panel data (excluding Tibet and Hong Kong, Macao, and Taiwan due to data availability and statistical 口径 differences).

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## 1.1 Data Sources

This study uses panel data from 31 provincial regions in China (excluding Tibet and Hong Kong, Macao, and Taiwan due to significant data gaps and statistical 口径 differences) from 2009 to 2022. Highway data are sourced from the *China Statistical Yearbook* (2010-2023), civil aviation data from the *National Civil Transport Airport Production Statistics Bulletin* (2009-2022), and high-speed rail data from provincial statistical yearbooks, the Ministry of Transport website, and Baidu Baike high-speed rail line information. Tourism economic data are obtained from the *China Statistical Yearbook*, provincial statistical yearbooks, the Ministry of Culture and Tourism website, and supplemented by

national economic and social development statistical bulletins and government work reports. Tourism eco-efficiency data are derived from the *China Culture, Cultural Relics, and Tourism Statistical Yearbook* and the *China Energy Statistical Yearbook*. Missing data are interpolated using adjacent year values.

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## 1.2 Influence Mechanism of Rapid Transportation, Tourism Economy, and Tourism Eco-Efficiency

First, regarding the relationship between rapid transportation and tourism economy: Rapid transportation significantly agglomerates and restructures tourism economy [**?**]. Compared with conventional transportation, rapid transportation based on technological integration innovation can more efficiently break through geographical barriers with superior 时空 compression effects [**?**]. On one hand, rapid transportation stimulates tourism demand and expands source markets by shortening temporal distances, boosting tourism economic benefits. On the other hand, its networked layout drives tourism resource elements to concentrate along transport corridors, forming a "corridor-hub" 联动 spatial structure that significantly enhances tourism economic linkages along routes [**?**]. Additionally, tourism economic growth depends on tourism demand expansion, requiring higher transport efficiency support, thereby generating demand-induced effects that drive rapid transportation toward high-density, intelligent optimization and upgrading, creating a virtuous cycle of "transportation improvement → tourism value-added" (Figure 1).

Second, regarding the relationship between tourism economy and tourism eco-efficiency: Tourism is an environment-dependent industry, and tourism eco-efficiency serves as an important reference for assessing its sustainable development. Through green constraints, tourism eco-efficiency can guide industrial restructuring and ecological transformation during high-quality tourism economic development [**?**]. During extensive growth phases, blind expansion of industrial scale and inefficient resource development increase environmental pressure, threatening limited environmental carrying capacity in tourist destinations [**?**]. When tourism economy transitions toward intensive development, green technology diffusion and strengthened environmental regulations can facilitate environment-friendly practices, boosting tourism eco-efficiency.

Third, regarding the relationship between rapid transportation and tourism eco-efficiency: Rapid transportation has complex dialectical impacts on tourism eco-efficiency, both positive and negative. Improved transportation accessibility positively affects tourism development efficiency [**?**], and rapid transportation' s high efficiency and technological innovation advantages make it more adaptable to green upgrading demands under tourism eco-efficiency targets. By effectively promoting regional tourism resource integration and sharing, attracting high-quality labor, capital, and advanced technology, rapid transportation can enhance value transformation of tourism industry inputs. However, passenger

transport activities are highly energy-consuming, and expanded tourist scale driven by rapid transportation development increases pollution control pressure [?]. Conceptually, tourism eco-efficiency optimization depends on increasing economic value created per tourism input while reducing environmental impacts [?], requiring tourist destinations to improve rapid transportation spatial layout and line connections to stimulate tourism economic benefits, while also requiring daily operations to transform toward green and low-carbon models based on energy structure and carbon emission intensity constraints to mitigate negative environmental impacts from tourism transport activities.

[Figure 1: see original paper]

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## 1.3 Indicator System Construction

**Rapid Transportation:** Compared with conventional railways and highways, rapid transportation effectively shortens spatial distances and time costs through 时空 compression effects [?]. This paper defines rapid transportation as an infrastructure system comprising highways, civil aviation, and high-speed rail that provides fast, comfortable, and convenient services [?]. Referencing existing research [?], we introduce new indicators such as network connectivity, operational (navigation) coverage rates, and construct a comprehensive evaluation indicator system (Table 1) using the entropy weight method.

**Tourism Economy:** Using the entropy weight method, we measure tourism economic development level from two dimensions: economic benefits and market scale, selecting frequently used indicators [?]. The economic benefits dimension includes domestic tourism revenue, inbound tourism revenue, per capita tourism consumption, and tourism output value density. The market scale dimension includes domestic tourist arrivals, inbound tourist arrivals, and tourism spatial density.

**Tourism Eco-Efficiency:** Adopting the super-efficiency SBM model [?] to measure tourism eco-efficiency, we construct an evaluation indicator system from input-output perspectives [?, ?]. Inputs include tertiary industry employment, number of travel agencies, star-rated hotels, and tourism energy consumption. Expected outputs include total tourism revenue and tourist arrivals, while tourism carbon emissions represent unexpected outputs. Tourism energy consumption and carbon emissions are calculated using the energy stripping method [?], with tourism carbon emission coefficients referencing relevant literature [?].

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## 1.4 Model Construction

The PVAR model effectively addresses variable endogeneity issues by placing potentially strongly correlated variables within the same system and revealing

interactive relationships through impulse response and variance decomposition [**?**, **?**]. This paper employs the PVAR model to examine dynamic interactions among rapid transportation, tourism economy, and tourism eco-efficiency. The model is specified as:

$$Y_{it} = \gamma_0 + \sum_{j=1}^{p} \gamma_j Y_{i,t-j} + \alpha_i + \beta_t + \varepsilon_{it}$$

where $Y_{it}$ is the column vector of endogenous variables for province $i$ in year $t$, containing rapid transportation, tourism economy, and tourism eco-efficiency; $Y_{i,t-j}$ is the column vector of endogenous variables lagged by $j$ periods; $\gamma_j$ is the coefficient matrix for lag order $j$; $\gamma_0$ is the intercept term; $\alpha_i$ is individual fixed effects; $\beta_t$ is time fixed effects; and $\varepsilon_{it}$ is the random disturbance term.

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## 2.1 Development Levels of Rapid Transportation, Tourism Economy, and Tourism Eco-Efficiency

First, we calculate the development levels of rapid transportation, tourism economy, and tourism eco-efficiency, all showing positive growth trends. From 2009 to 2022, the average annual growth rates were 9.73%, 5.02%, and 8.55%, respectively. Against the backdrop of COVID-19' s widespread impact on global economic markets, rapid transportation maintained relatively stable development, likely because transportation services providing essential mobility needs exhibit stronger stability, while tourism, as a higher-level spiritual need, is more vulnerable to external shocks.

Second, using tercile classification, we divide the 2009-2022 provincial data into high, medium, and low levels to explore equilibrium characteristics. High-high-high and low-low-low patterns are classified as equilibrium types. In 2009, low-level provinces accounted for 70.00%, with only Beijing showing a high-medium-medium pattern due to its capital advantages. Non-benign equilibrium constrained by low development levels dominated coordinated development among the three elements. By 2019, medium-level provinces accounted for 63.33%, with equilibrium-type provinces comprising 33.33% and low-level provinces dropping to 10.00%. Although the number of equilibrium-type provinces decreased, they remained dominant at 63.33% of the total, showing an evolution characterized by reduced quantity but improved quality, transitioning from low-level to medium/high-level supported equilibrium.

By 2022, high-level provinces increased significantly to 53.33%, 20.00%, and 20.00% respectively. Equilibrium-type provinces declined to 40.00% due to COVID-19 impacts, yet high-level provinces grew rapidly. High-level-based benign equilibrium became the main characteristic of coordinated development. Notably, in 2022, 26.66% of provinces had tourism economy levels below those

of rapid transportation and tourism eco-efficiency, making lagging tourism economy the primary constraint on coordinated development, with boosting tourism recovery becoming an urgent priority.

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### 2.2.1 Panel Unit Root Test

All variables are natural log-transformed to eliminate heteroskedasticity. We employ three unit root test methods—Harris-Tzavalis (HT), Im-Pesaran-Shin (IPS), and Fisher-ADF—to confirm data stationarity (Table 2). Results show that some tests for the tourism eco-efficiency variable are not significant. Therefore, first-difference tests are conducted, with results indicating all variables are stationary series, supporting PVAR model construction.

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### 2.2.2 Optimal Lag Order Selection and Robustness Test

Before formal empirical analysis, optimal lag order must be determined (Table 3). Results show lag order 1 is optimal under all criteria, thus we set the PVAR model to lag 1. Additionally, robustness tests are conducted at national and regional levels to ensure subsequent results' validity. All characteristic roots lie within the unit circle, confirming model stability.

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### 2.2.3 Granger Causality Test

Granger causality tests examine relationships among rapid transportation, tourism economy, and tourism eco-efficiency (Table 4). First, rapid transportation and tourism economy show bidirectional Granger causality at national and eastern regional levels, while in western China, rapid transportation Granger-causes tourism economy, and no causality exists in central China. This indicates more significant and effective interaction in eastern regions, likely due to mature market mechanisms and industrial synergy networks providing favorable environments for transportation-tourism interactions. In western China, tourism development is constrained by remote geographical location, and rapid transportation improvements can effectively stimulate tourism economic growth, but transportation construction is more driven by policy orientation and development strategies, making tourism economy' s feedback effect on rapid transportation relatively weak.

Second, tourism economy and tourism eco-efficiency show bidirectional Granger causality at the national level. In central and western regions, tourism economy Granger-causes tourism eco-efficiency, while no causality exists in eastern regions. Tourism economy' s unidirectional influence is more prominent, possibly because tourism development accompanied by effective growth in revenue and

arrivals increases environmental pressure due to higher tourism activity density, profoundly affecting the balance between economic and environmental benefits. In eastern regions, relatively mature and stable tourism development and multiple factors jointly affecting tourism eco-efficiency make tourism economy' s influence relatively weaker.

Third, rapid transportation Granger-causes tourism eco-efficiency at national and western regional levels, while in central China, tourism eco-efficiency Granger-causes rapid transportation, and no causality exists in eastern regions. No bidirectional causality exists at any level, with rapid transportation' s unidirectional effect being stronger overall. In western China, vast territory and rich but relatively dispersed tourism resources enable rapid transportation to effectively improve local tourism factor mobility and integrated allocation, thereby enhancing tourism eco-efficiency. In central China, geographical location leads to obvious transit flows of tourism elements, which may dilute rapid transportation' s actual impact on local tourism eco-efficiency.

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### 2.2.4 Impulse Response Analysis

We further explore dynamic interactive relationships using Monte Carlo simulations with 500 repetitions to obtain impulse response results (Figure 2 shows national-level results; regional results are omitted due to space limitations).

When tourism economy receives a one-standard-deviation shock from rapid transportation, positive effects are maximized in the current period and decline rapidly at both national and regional levels, showing an "east-strong, west-weak" driving pattern. Eastern regions have strong tourism market demand, and networked high-speed rail and civil aviation effectively divert tourist flows, while western regions' positive driving effects are limited by low population density, dispersed tourism resources, and high travel costs. When rapid transportation receives a one-standard-deviation shock from tourism economy, positive effects show an inverted "U-shaped" change in the short term across all regions. Compared with tourism economy' s response to rapid transportation, rapid transportation' s response to tourism economy is more lagged, possibly because rapid transportation construction involves complex decision-making processes that cannot quickly adjust resource allocation to respond to immediate changes in tourism economic development.

When rapid transportation receives a one-standard-deviation shock from tourism eco-efficiency, it shows weak positive effects nationally, with alternating positive-negative trends in eastern and western regions, and short-term negative effects in central regions. Regional heterogeneity is evident, and tourism eco-efficiency' s influence is generally weak, possibly because tourism industrial structures and development levels vary across regions, with most being in the initial stage of green transformation, providing insufficient feedback signals to transportation investment decisions. When tourism eco-efficiency

receives a one-standard-deviation shock from rapid transportation, positive effects persistently weaken nationally and in western regions, turn from positive to negative in eastern regions, and show an "M-shaped" fluctuation in central regions. Rapid transportation generally positively enables tourism eco-efficiency at all levels, but negative effects emerge in eastern regions in later periods, possibly due to high passenger volumes intensifying the contradiction between intensive tourist transport activities and environmental protection, with negative ecological impacts partially offsetting resource allocation optimization benefits from rapid transportation.

When tourism eco-efficiency receives a one-standard-deviation shock from tourism economy, response processes are highly similar across national and regional levels, with positive effects maximized in the current period and declining rapidly. Conversely, when tourism economy receives a one-standard-deviation shock from tourism eco-efficiency, positive effects are short-term and weak nationally, with alternating positive-negative fluctuations in eastern regions and negative effects in central and western regions. Results indicate that interactive responses feature strong and effective short-term driving by tourism economy, contrasting with persistent weakness and disorderly effects of tourism eco-efficiency. In eastern regions, positive interaction fails to sustain effectively, possibly due to contradictions between immediate pursuit of tourism economic returns and long-term expectations for tourism eco-efficiency improvement, with imperfect interest coordination mechanisms among governments, enterprises, and tourists preventing long-term maintenance of benign interactions. In central and western regions, tourism eco-efficiency may be in an initial adjustment stage that inhibits economic growth, with immature green constraint mechanisms on tourism economy.

[Figure 2: see original paper]

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### 2.2.5 Variance Decomposition

Variance decomposition analyzes the contribution of other structural shocks during variable evolution processes, assessing the relative importance of influencing variables. Results at national and regional levels basically converge by period 10, so we present period 10 results (Table 5).

At the national level, rapid transportation and tourism economy development are primarily self-driven, with self-contribution rates exceeding 92.48% and 99.88%, respectively. Tourism eco-efficiency lacks self-driving capacity, with self-contribution below 50.00%, indicating that tourism eco-efficiency optimization heavily depends on tourism economic development and lacks internal momentum. At the regional level, rapid transportation and tourism economy development remain self-driven, with rapid transportation weakly affected by other variables across regions, while tourism economy is relatively strongly influenced by rapid transportation. Tourism eco-efficiency is self-driven in western regions

(self-contribution > 57.70%), while tourism economy contributes most in eastern and central regions. This may be because western China' s tourism development lags behind with smaller economic scale, making tourism eco-efficiency development more dependent on self-accumulation and improvement. Overall, rapid transportation has the strongest self-development capability, with contributions from tourism economy and tourism eco-efficiency to rapid transportation being far smaller than rapid transportation' s contributions to them.

This result reflects imbalanced interaction between rapid transportation and tourism development, urgently requiring breakthroughs in existing development models to 挖掘 benign interactive feedback with tourism economy and tourism eco-efficiency, and to build a rapid transportation network system with balanced, efficient, and clean tourism passenger transport supply and demand. Tourism eco-efficiency is greatly influenced by external structures but weakly affects tourism economy and rapid transportation, failing to play an effective guiding and regulating role in their development. Exploring development paths for coordinated transportation-tourism interaction under green constraint mechanisms represents an important future direction.

## 4 Conclusions

As the transportation power strategy advances, rapid transportation accelerates tourism development empowerment while potentially inducing extensive tourism economic growth that is detrimental to tourism eco-efficiency optimization [**?**]. Good ecological environments are the foundation for sustainable tourism development, and tourism eco-efficiency improvement also depends on tourism economic benefits [**?**]. Under high-quality development, the urgent need to boost tourism economy and promote industrial green transformation may also create 反作用 on rapid transportation construction. Therefore, clarifying the interactive relationship characteristics among rapid transportation, tourism economy, and tourism eco-efficiency holds important theoretical value and practical significance for leveraging rapid transportation to promote tourism quality and efficiency improvement.

Research shows that the mainstream trend for coordinated development among rapid transportation, tourism economy, and tourism eco-efficiency is the transition from low to high development level-supported benign equilibrium, consistent with many measurement results [**?**, **?**]. All three development levels show overall positive trends with improving coordination status. Regarding their interactions, rapid transportation and tourism economy exhibit benign positive interactive responses, with rapid transportation' s unidirectional effect being stronger, validating research conclusions by Ji Chenyu et al. [**?**] and Wang Xiaowen et al. [**?**]. However, Zhang Yan et al. [**?**] found alternating positive-negative effects of transportation on tourism revenue, possibly due to their use of line density to measure transportation conditions, leading to different re-

sults. For rapid transportation and tourism eco-efficiency, Bai Yang et al. [**?**] found that rapid transportation' s impact on tourism eco-efficiency is initially negative then positive based on a threshold model. This study finds positive impacts at all levels, indicating that when rapid transportation reaches a certain level of development, its positive effects on tourism eco-efficiency can effectively manifest, providing theoretical support for exploring paths to promote high-quality tourism development through optimized regional rapid transportation infrastructure. Tourism eco-efficiency' s weak effect on rapid transportation aligns with Bai Yang et al.' s [**?**] finding that rapid transportation and tourism eco-efficiency mainly show negative decoupling, where tourism eco-efficiency' s relatively weak growth may provide insufficient effective feedback for rapid transportation construction. For tourism economy and tourism eco-efficiency, regional results partially align with previous studies [**?**, **?**], with tourism eco-efficiency' s impact on tourism economy showing alternating positive-negative fluctuations but short duration. Tourism economy' s positive impact on tourism eco-efficiency is maximized in the current period and declines rapidly, consistent with findings that tourism development level' s impact on western China' s tourism eco-efficiency is initially positive then negative [**?**], indicating that early tourism development can effectively improve tourism eco-efficiency, but later intensive development may generate negative effects. Therefore, moderate tourism development based on ecological carrying capacity is necessary.

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*Note: Figure translations are in progress. See original paper for figures.*