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Exploring the efficiency of rural tourism and its drivers to promote high-quality development of rural tourism in Luoyang, China

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Abstract: This study extends classical tourism system models by constructing a "village-scale rural tourism regional system" analytical framework that integrates endogenous industrial momentum, internal village support, and external environmental drivers. Using a sample of 375 tourism-oriented villages in Luoyang City, we employ DEA models, spatial analysis, and quantile regression to systematically investigate the structural characteristics, spatial heterogeneity, and influencing mechanisms of rural tourism efficiency.The findings are as follows: (1) Rural tourism in Luoyang exhibits a structural imbalance characterized by “high technical efficiency but low scale efficiency,” with 41.07% of the tourism villages experiencing capital redundancy, 79.73% facing land idleness, and 64% suffering from insufficient reception capacity. (2) Scale efficiency shows a higher degree of agglomeration than technical and comprehensive efficiency. Tourism efficiency in mountainous areas is primarily constrained by scale efficiency, while in basin areas it is more dependent on technical efficiency. (3) Terrain conditions, agglomeration effects, and government support constitute the core driving factors of efficiency formation; however, their effects exhibit nonlinearity and threshold effects across different efficiency levels, manifesting as three evolutionary patterns: resource supplementation adaptation, management challenge mismatch, and innovative collaborative adaptation. (4) The improvement of rural tourism efficiency relies on the synergistic coupling and dynamic balance among external driving forces, internal supporting factors, and industrial development momentum.Theoretically, this study extends the application of the tourism system model to the village scale, reveals the nonlinear pathways and threshold mechanisms underlying the evolution of rural tourism efficiency, and deepens the understanding of the driving mechanisms of rural tourism development during the transitional period.

Key word：Village Scale; Tourism Efficiency; Spatial Differentiation; Influencing mechanism

1.Introduction

Rural tourism is closely linked to people, space, and industry, exerting a unique influence on rural economic and social development (Yang et al., 2021). Since the 1990s, it has been widely recognized as an important way to promoting rural revitalization (An et al., 2020). In 2017 China proposed the rural revitalization strategy, which take rural tourism by governments at all levels as a vital approach to revitalization. In 2024, rural tourism industry in China welcomed over 3 billion tourists, generating a revenue of 1.5 trillion yuan and creating nearly 18 million job opportunities. However, there is still a large gap between the development of rural tourism development and the goal of common prosperity. In particular, different regions and different groups have multiple gaps in development efficiency, level and ability(Sun et al., 2022). Against this backdrop, accurately assessing the efficiency of rural tourism, especially at the village-scale, is an important issue for promoting high-quality development in rural tourism and the comprehensive rural revitalization(Chen et al., 2024).

Research on tourism efficiency has evolved along two main trajectories: efficiency of tourism industry sector and efficiency of tourism destination (Nurmatov et al., 2021). In recent years, the efficiency of tourism destinations has become an important direction in the field of tourism efficiency research (Wang R. et al., 2021). Commonly used input indicators in such studies include fixed assets and tourism employment, while outputs are typically measured by total tourism revenue

and visitor numbers (Sun et al., 2014). Methodologically, Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA), and super-efficiency SBM models , etc., are widely used research methods (Liu et al., 2021； Nurmatov et al., 2021). Previous studies have examined tourism destinations across various spatial scale, including national, provincial, urban agglomeration, and city (Tang et al., 2022). However, due to the limited availability of data in the rural area and constraints imposed by theoretical analysis frameworks, research on tourism efficiency and influencing factors at the village scale remains inadequate (Xiao et al., 2022).

Rural tourism is a convergence of rural development and tourism development, which are embedded in a wider development context (Shen et al., 2008**)**. However, unlike the urban tourism under full-market conditions, rural tourism typically adopts a development model that combines multiple stakeholders, namely "government + market + community"(Huang et al., 2021).The development of rural tourism not only relies on endogenous conditions such as rural geographical environment, population structure, and economic foundation, but also on exogenous driving factors such as market forces and Government support(Sun et al., 2023). This development model represents a key characteristic of tourism development in the context of China's rural transformation period, which defines the basic context for research on rural tourism efficiency and influencing factors (Lu et al., 2019). Previous researches have primarily focused on administrative units at the county level or above, which have systematic data. However, these researches have deviated from the fundamental spatial unit of rural tourism development and rural revitalization - the village unit. This deviation affects the accuracy of research results and the precision of rural development policies(Sun et al., 2022).

Based on above, this paper attempts to answer the flow questions: How to evaluate tourism efficiency at the village scale? And how is rural tourism efficiency in transitional regions influenced by social, institutional, and geographical contexts in which the tourism is embedded? This research transcends the research on economic efficiency based on medium and large-scale statistical units, focusing on the micro-operational mechanisms of the "human-land relationship regional system" in transitional countries or regions (Li, 2026). In view of this, this study constructs a rural tourism regional system at village scale, integrating the inherent industry development momentum, endogenous rural community factors, and external environment factors into a unified framework. Using 375 tourism villages in different topographical areas of Luoyang as samples, it empirically examines the structural characteristics, spatial heterogeneity, and influencing factors of rural tourism efficiency, reveals the impact mechanism of rural tourism efficiency in transitional economies. The research findings provides micro-empirical support for the research on high-quality development of rural tourism in transitional countries or regions.

2 Theoretical framework and Indicator System

2.1.1 Tourism Regional System

Tourism system is the basic research object of tourism science and the basic theoretical model for studying tourism phenomena (Li et al., 2005).The tourism system is a complex system composed of different subsystems, which emphasizes the comprehensive consideration of the relationship between economy, society, resources, environment and other aspects in the process of tourism development (Xu et al., 2023). From the perspective of the structure-function system, efficiency is manifested as the effectiveness of the interaction and connection among the various elements of the tourism system in achieving its functions (Wu， 1997).Therefore, the tourism system model provides

a fundamental theoretical framework for studying tourism efficiency and its influencing factors.

For the tourism system, the academic community has constructed variously structured tourism system models from multiple perspectives. Gunn (1972) proposed a model that identified five fundamental elements of tourism: tourist population, transportation, attractions, services, and information promotion.Based on the Gunn model, Mill and Morrison (1985) from a marketing perspective combined attractions and services into a "destination subsystem".Wu Bihu (1998) further integrated transportation and promotion into the "travel subsystem", and separated external influencing factors such as policies and regulations into the "support subsystem".Gunn's new model (2002) clearly defined "tourist population" as "the tourism demand subsystem".Finally, the integration of Gunn - mill - Morrison - Wu Bihu model has formed four subsystems of the tourism system: tourism demand, destination (supply), media and support (Figure1). The travel subsystem is the core of the media to connect supply and demand, forming a complete supply and demand cycle (Shi et al., 2020).

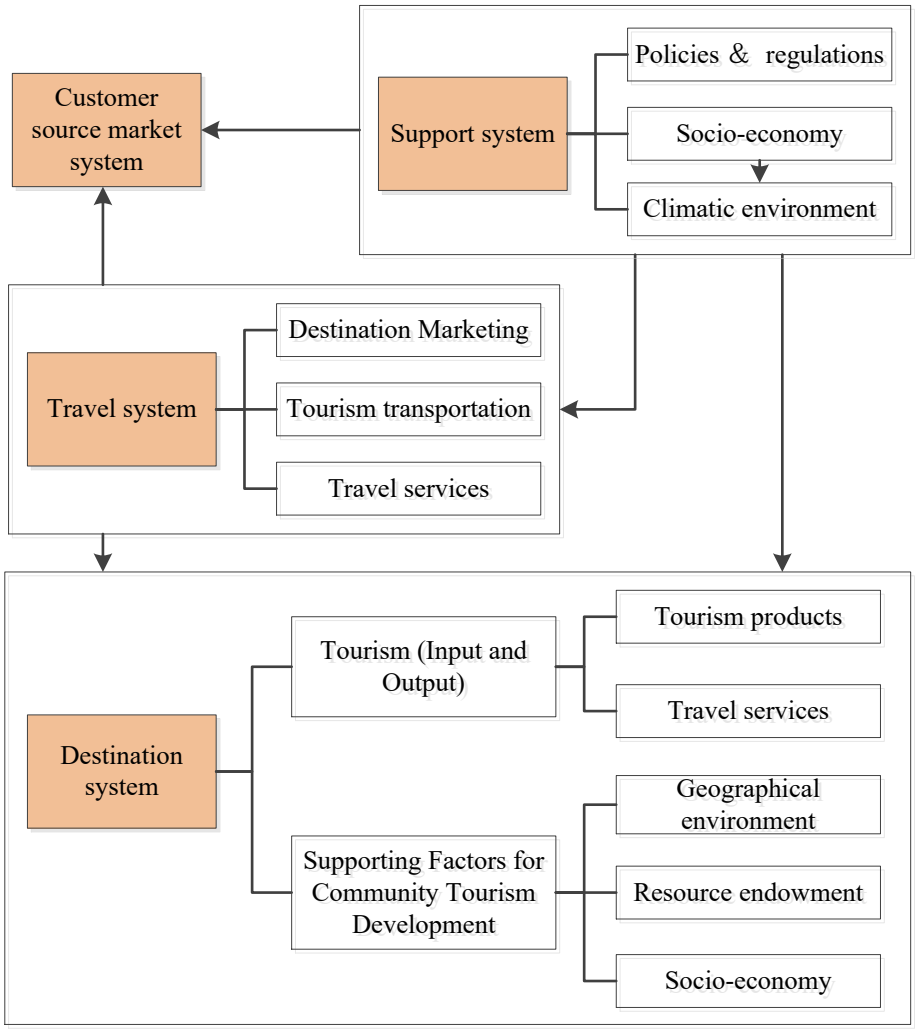


Figure1 Tourism Regional System Model

2.1.2 Rural tourism territorial system model

Under the background of the rural revitalization strategy, the development of rural tourism exhibits distinct characteristics that are different from those of urban tourism and scenic area tourism. These characteristics mainly manifest in the following aspects.

Rural tourism is a combination of rural development and tourism development (Shen et al.,

2008), which is deeply integrated into the rural regional system(Liu, S. et al., 2021). From the perspective of rural regional system, the countryside is an organic whole composed of "people, land, industry" and other elements. As part of the "industry" in the system, the development of rural tourism cannot be separated from rural factors such as local population participation and land space carrying (Ding et al., 2021).Therefore, rural tourism is deeply influenced by the elements and structure of rural regional system in terms of resources, spatial carriers, development goals and other aspects.

On the other hand, the Rural Revitalization Strategy stems from the dilemma of inadequate rural development and insufficient endogenous development capacity（Huang et al., 2021）. In this context, the support and guidance of the government and the market has become the key path to make up for the endogenous weakness of rural areas and activate rural tourism. Therefore, the rural tourism system at the village scale exhibits an evolving characteristic of being driven by multiple forces such as policy guidance, market drive, and community participation (Wang et al., 2023).This implies that the efficiency study at the village scale cannot simply employ the tourism system model at the regional scale. Instead, it is necessary to construct an integrated framework that can incorporate the interaction between "external intervention and internal support".

Based on the above analysis, on the basis of the “Gunn - mill - Morrison - Wu Bihu model”, this study, has constructed a "Rural tourism regional system at village scale " that is more in line with rural tourism practices (Figure 2).The core innovation of the system lies in: The Economies of scale and scope are defined as the internal momentum for industrial development; The Openness of communities, Socioeconomic conditions and Geographical environment are defined as the internal supporting factors for rural tourism; The Government support and Transportation conditions are defined as external driving factors.These three groups of factors are systematically coupled based on the logic of "structure-function"system. This framework adheres to the "structure-function" logic of the classic tourism system model, and further achieves the integration of endogenous industrial momentum, rural internal support, and external environmental driving factors at the village scale. It provides an explanatory theoretical framework for subsequent index construction and empirical analysis.

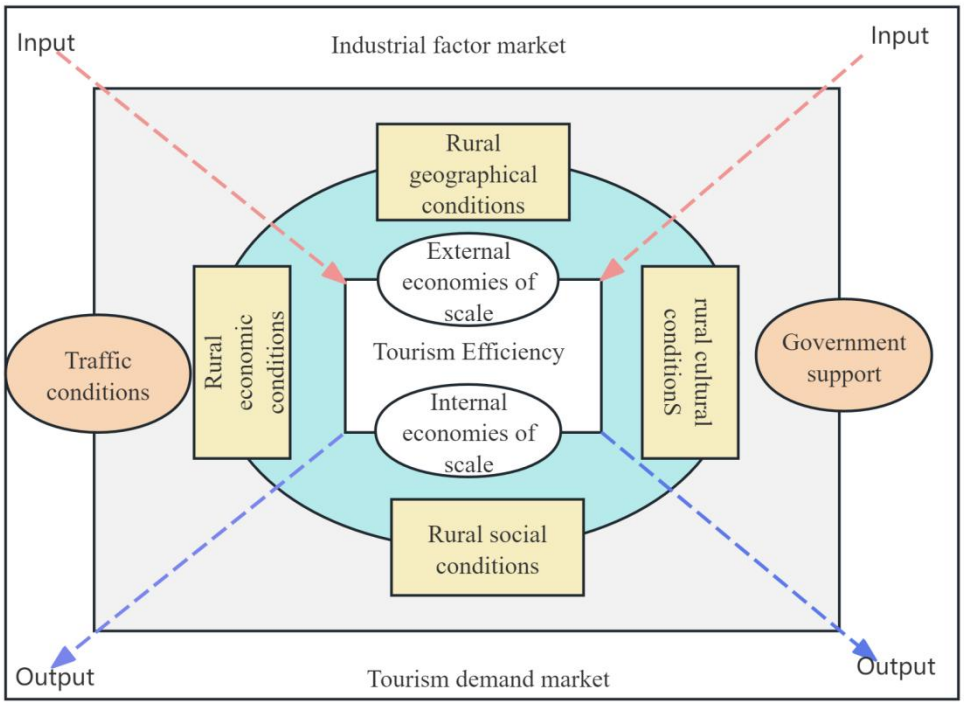


Figure 2 Rural tourism regional system at village scale

2.2 Input-Output Indicators for Tourism Efficiency

From an economic perspective, land, capital, and labor are the most fundamental input factors for production activities (Liu S., 2021), and they also forms the basis for the functioning of the tourism economy (Wang et al., 2023). Land, as the fundamental input element of rural tourism, serves not only as the physical space carrier for tourism infrastructure and service facilities but also as the source of rural core attraction. The farming culture, rural landscape, and ecological texture attached to the land together constitute the "rurality" that tourists seek (Gedecho et al., 2025). Capital not only improves tangible assets such as infrastructure and project construction through fixed assets investment, but also creates a tourism environment through intangible investments such as marketing and promotion, thereby ensuring tourism production and operation and facilitating the large-scale or intensive development of rural tourism (Liu Z. et al., 2021). Human resources, encompassing villagers, managers, service personnel, and craftsmen, are not only the executors of tourism service production and operation, but also transform local resources into deep experiences through emotional interaction and cultural inheritance, endowing tourism products with humanistic warmth (Zhang et al., 2026). Corresponding to the above three elements, and referring to relevant research (Baños-Pino et al., 2024), land area of tourism villages, total tourism investment, and number of tourism employees are selected as input factors of the tourism industry. Drawing on previous studies (Wang R. et al., 2021) , two commonly used indicators, namely tourism revenue and tourism reception volume, are selected to represent tourism output.Based on the above analysis, this paper constructs a village-scale tourism efficiency measurement system that includes three input indicators and two output indicators (Table 1).

Table.1 Input and output index of tourism efficiency in rural tourism

Indicator system	Concrete indexes	Definition/ Unit
Input	Rural Tourism Capital Stock	Ten thousand Yuan

	Scale of Land for Tourism Purposes		Tourism land area（Km2）
	Number of Tourism Practitioners		Average number of employees (Person)
Output	Tourism revenue		Ten thousand Yuan
	Number of tourists		Annual visitor volume

2.3 Factors of Tourism Industry Efficiency

Rural tourism at village scale is the result of the combined effect of multiple internal and external factors, involving dimensions such as geographical environment, resource endowment, economic conditions, transportation conditions, informationization level, resident quality, social openness, and Government support (Liu Z. et al., 2021). Among these, economies of scale are also regarded as a significant industrial development momentum (Wang, R. et al., 2021). Based on the proposed "rural tourism regional system model at village-scale" and previous studies on rural tourism, this paper selects the following six factors from the three dimensions of Endogenous growth momentum, the Internal supporting factors and the External environmental driving factors to explore their effects on rural tourism efficiency. The specific indicators are showed in Table 2.

Endogenous growth momentum refers to the overall growth potential demonstrated by internal integration innovation and optimal allocation within an industry. Among them, External economies of scale and Internal economies of scale are the core drivers of industrial development in the efficiency dimension (Wang, R. et al., 2021). External economies of scale are represented by the number of operating entities, which affect the efficiency of factor allocation through specialized division of labor, diverse heterogeneous element agglomeration and innovation (Li Z. et al., 2022). Internal economies of scale are represented by the size of a single operating entity. The expansion of the Size of single business entity can reduce unit production costs, optimize operational processes, and thereby enhance the efficiency of resource allocation (Zhang Z. et al., 2020). According to the theory of economies of scale, the driving effect of internal economies of scale and external economies of scale can effectively improve the efficiency of the tourism industry only when the scale is maintained within an appropriate range (Jiang et al., 2018).

Community openness reflects a community's acceptance of external information, resources and personnel (Gong, 2022). Community openness can facilitate the introduction of external capital, technology, talents, and management experience, etc., to make up for the deficiencies of local development factors (Liu z., et al., 2021). This helps to promote the development of tourism products, enhance the tourist experience, extend the stay time and increase revenue, thereby improving the efficiency of the tourism economy (Su et al., 2016). However, it is worth noting that excessive openness or dependence on external development resources may weaken the participation, self-development ability and rural nature of local residents, which may have a negative impact on long-term sustainable development (Jiang et al., 2018).

Government support serves as the fundamental driving force for the development of rural tourism. However, the impact of Government support on tourism efficiency remains a subject of debate in field of tourism research. Some studies have pointed out that government support investment in infrastructure construction, financial assistance and institutional guarantee can improve the rural development environment, make up for the lack of rural internal development ability, and help to improve the efficiency of tourism resource allocation (Sun et al., 2022). However, standardized support policies can easily lead to the homogenization of local characteristics, thereby having a negative impact on the effective allocation of tourism resources (Sun et al., 2023). Other

studies have found that the effect of Government support is significantly different due to the characteristics of target regions and the differences in tourism development stages (Yang et al., 2022).

The economic conditions are represented by the proportion of registered poor households. This indicator refers to the ratio of the number of registered poor households in the national poverty alleviation information system to the total number of households in the village. The higher the value, the deeper the poverty level, and the more scarce the human capital and social capital (The World Bank, 2018). This not only restricts the participation of community tourism, the improvement of tourism service quality, and the cultivation of innovation capabilities (Wang et al., 2024), but also hinders the development of emerging business models such as smart tourism (Sun et al., 2025). In addition, regions with a relatively high proportion of poor households who file and register cards often face structural constraints such as a single economic structure and weak investment attraction, which further restricts the extension of the rural tourism industry chain and the construction of the service system (Huang Z. F. et al., 2023).

The rural population density is closely related to the natural utilization and economic status of the community, such as the intensity of the use of natural resources, the level of population development and infrastructure construction (Li J. et al., 2022). Low-density population is conducive to preserving the original landscape and developing high-quality ecological tourism, but it often faces problems such as high infrastructure costs and weak community initiative. In comparison, high-density population may lead to problems such as spatial congestion and excessive ecological load, but it also has advantages in terms of cultural resources and abundant labor force, as well as well-developed infrastructure and service facilities (Buckley et al., 2023). Therefore, the impact of population density on tourism efficiency has multiple possibilities through the dynamic balance relationship among natural ecological preservation, labor supply, and infrastructure investment savings.

The terrain conditions have complex and multi-dimensional impacts on the efficiency of rural tourism. They may either become a resource advantage for development or constitute constraints on development (Wang W. Y., et al., 2017). From a positive perspective, the complexity of the terrain significantly enhances the abundance of tourism resources (Zhang, 2022), facilitating the diversified and integrated development of tourism products, and thereby optimizing the efficiency of rural tourism (Sharpley, 2020). From the perspective of constraints, the complexity of the terrain may increase the investment cost of infrastructure and thereby restrict tourism development. Studies have shown that for every one-unit increase in the index of terrain undulation, the cost of infrastructure construction will increase by 18% to 23% (Zhou et al., 2024). Therefore, the terrain conditions exert a combined influence on the development of rural tourism through tourism resources and infrastructure investment. Given the strong positive correlation between the complexity of the terrain and the altitude in the study area (Zhu et al., 2020), this paper selects the altitude as the proxy indicator for the terrain conditions.

Traffic conditions is an important prerequisite for the prosperity of tourism. Convenient transportation can promote the efficient flow of information, capital and tourists, and promote the optimal allocation of tourism resources and the spatial reconstruction of tourism destinations (Liu, Z. et al., 2021). However, studies have shown that the impact of transportation accessibility on tourism efficiency is not a simple linear relationship. High Traffic accessibility may lead to tourists' quick entry and exit, reducing the duration of their stay, and having a negative effect on tourism

efficiency (Cao et al., 2015). Therefore, there is a threshold effect regarding the impact of transportation accessibility on tourism efficiency.

Table 2 Influencing Factors of Rural Tourism Efficiency

Primary Indicator	Secondary Indicator	Measurement Metric
Endogenous growth momentum	External economies of scale	Number of business units
	Internal economies of scale	Size of single business entity
Internal supporting factors	Community openness	Ratio of Non-local to Total business units
	Terrain conditions	Elevation
	Social conditions	Community population size
	Economic conditions	Community economic conditions
External environmental driving factors	Government support	Government Investment Share
	Traffic conditions	Traffic accessibility

3 Materials and methods

3.1 Study area

Luoyang has a complex terrain, with mountains and hills accounting for 85% of the total area. The per capita arable land is only 0.053 hectares, which is close to the 0.05 hectares per person threshold set by the Food and Agriculture Organization of the United Nations (FAO).In 2014, there were five national poverty-stricken counties, one provincial poverty-stricken county and 669 poverty-stricken villages in the region, with a rural poverty population of 316000. Therefore, the “Plan for Poverty Alleviation Projects for the People in the Taihang Mountain, Funiu Mountain and Dabie Mountain Areas in Henan Province (2014-2020) (YZ [2014] No. 81)” proposes to take ecotourism as an important way for poverty alleviation in the region. By the end of 2025, a total of 435 villages in Luoyang had launched tourism reception services. The total investment in rural tourism throughout the year reached 2.86 billion yuan. There were 3,100 various business units, with an annual tourist reception volume of 28.5 million people and an annual operating income exceeding 3 billion yuan. This directly and indirectly created more than 200,000 jobs.

However, the current development of rural tourism shows a significant polarization. Some tourism villages, such as Chongduogou Village and Tianqiaogou Village, have established a modern tourism industry system, with per capita income exceeding 100,000 yuan. In contrast, tourism villages like Xiexin Village and Yangshuping Village still face problems such as backward products, outdated facilities, and insufficient tourist sources, with per capita tourism income only ranging from 5,000 to 6,000 yuan. Overall, there is still a significant gap between the development of rural tourism resources and the goal of rural revitalization. Different regions and groups have disparities in terms of development efficiency, development level, and participation ability, which hinders the process of common prosperity for rural farmers and the realization of their needs for a better life.

Therefore, the "Implementation Plan for Accelerating the High-Quality Development of Vunuo Mountain Rural Tourism in Luoyang City (2025)" clearly proposes to promote the quality and efficiency of rural tourism by optimizing industrial layout, innovating industrial formats, improving service quality and other measures, so as to help the rural revitalization. In this context, based on the industrial development practice and systematic data of rural tourism development in Luoyang, this study focuses on evaluating the efficiency of the tourism industry, exploring the influencing factors and mechanisms, so as to provide theoretical reference for the high-quality development of

rural tourism and the comprehensive revitalization of rural areas in this region and other regions in China.

3.2 Data sources

The terrain of Luoyang is diverse and complex, with mountains, hills and plains accounting for 45.51%, 40.73% and 13.8% of the total area respectively. To enhance the representatives of the sample, this study selected 375 tourism villages distributed in the three types of land-forms as case villages, including 145 mountain villages, 151 hill villages and 79 plain villages. The socioeconomic, tourism development and land use data of the sample village were obtained from field survey jointly carried out by the research team and "Luoyang Municipal Bureau of culture, radio, television and tourism" in 2025. The elevation data used to characterize the human settlement ecological environment is derived from the 1:1000 scale digital elevation model provided by Luoyang natural resources and Planning Bureau.The Traffic accessibility data is derived from the road network of Luoyang City and was extracted based on the "Map Book of Highway Mileage in Henan Province and Huanghuai Region (2023)" published by China Map Publishing House. Among them, the driving speed and time cost for different levels of roads are determined in accordance with the "Technical Standards for Highway Engineering in China (JTGB01-2003)" and related studies (Pan et al., 2021).

3.3 Evaluation of tourism efficiency

Data Envelopment Analysis (DEA) is a systematic approach used to evaluate the relative efficiency of decision-making units (DMUs) or to solve multi-objective decision problems by applying operational research principles. It serves as a key mathematical method for analyzing input-output relationships in production systems. Assume there are K DMUs to be evaluated, each with L types of input indicators and M types of output indicators. Let $x_{jl}\lambda_j$ denote the amount of the 1-th input resource for the j -th DMU, and y_{jm} represent the amount of the m-th output of the j -th DMU. For the n-th DMU (n=1, 2…, K)：

$$\begin{cases} min\left(\theta-\varepsilon\left(e_1^T s^- + e_2^T s^+\right)\right) & \\ s.t.\ \sum_{j=1}^{k} x_{jl}\lambda_j + s^- = \theta x_l^n & l=1,2,\cdots,L \\ \sum_{j=1}^{k} y_{jm} - s^+ = y_m^n & m=1,2,\cdots,m \\ \lambda \geq 0 & n=1,2,\cdots,m \end{cases} \quad (1)$$

In formulation (1), θ ($0 < \theta \leq 1$) represents Comprehensive efficiency; λ_j ($\lambda_j \geq 0$) denotes the weight variable; s^- ($s^- \geq 0$) and s^+ ($s^+ \geq 0$) are slack and surplus variables, respectively; ε is a non-Archimedean infinitesimal; $e_1^T = (1, 1...,1) \in E^m$ and $e_2^T = (1, 1...,1) \in E^k$ represent unit vector spaces of dimensions m and κ. By introducing the constraint $\sum_{j=1}^{k} \lambda j = 1$ into Equation (1), the model is transformed into a variable return to scale (VRS) formulation. Here, θ_b denotes Technical efficiency ($0 < \theta_b \leq 1$), and Scale efficiency is defined as $SE=\theta/\theta b$ ($0 < SE \leq 1$). When $\theta_b=1$ or SE = 1, it indicates optimal Technical efficiency or optimal Scale efficiency, respectively.

3.5 Spatial autocorrelation model

Global Moran's. The ESDA method can provide an effective tool for measuring correlation of any feature between neighboring spatial units. The Moran's I index represents spatial autocorrelation among unit attribute values. The formula is as follows (Liu S. et al., 2021):

$$I=\frac{N\sum_{i=1}^{n}\sum_{j=1}^{n}(x_i-\bar{x})\cdot(x_j-\bar{x})}{\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}(x_i-\bar{x})^2} \quad (2)$$

where n denotes the number of spatial units; x_i and x_j are the tourism efficiencies at the

spatial position i and j, respectively; and wij is the spatial weight matrix. The global Moran's index is in the range of [-1,1]. $I>0$ suggests positive correlation while $I<0$ suggests negative correlation. A larger value of I suggests more similar attributes and higher accumulation degree. A smaller value of I indicates more different attributes and higher agglomeration degree. There is no spatial auto-correlation when I = 0.

Empirical Bayesian Kriging (EBK) interpolated rural tourism efficiency, generating a continuous surface from discrete village data. It estimates semivariogram parameters via restricted maximum likelihood (REML), accounting for uncertainty. The value at unmeasured point X_0 is a linear combination of n neighboring observed values (Hu et al., 2020).

$$Z(X_0)=\sum_{i=1}^{n}\lambda_i Z(X_i) \quad (3)$$

In formula (3), $Z(X_0)$ represents the estimated tourism efficiency at any target point X_0, while $Z(X_i)$ denotes the known tourism efficiency at observed point X_i. Based on the variogram, semivariance values are incorporated into the kriging equations to determine the weight coefficients λ_i for each known $Z(X_i)$, with the constraint that the sum of all weights equals 1.

3.6 Regression Model of Influencing Factors

（1）Tobit Regression Analysis

The Tobit Regression Model was proposed by Tobin (Díaz-Villavicencio, et al., 2017). And mainly addressed the construction problem of limited or truncated dependent variables (Zhang J. et al.,2020). Thus, the efficiency measured by the Data Envelope Analysis in this study is a cutoff value between 0 and 1, so a Tobit Regression Model can be used to identify the driving factors that affect spatial differentiation of regional tourism eco-efficiency (Wang R. et al., 2021). This model was expressed as follows:

$$y_i^*=\beta_0+\beta_1 x_i+\varepsilon_i \quad (4)$$

$$y_i=\begin{cases} y_i^*, & y_i^*>0 \\ 0, & y_i^*\le 0 \end{cases} \quad (5)$$

In this expression, y_i^* represents the latent variable (rural tourism efficiency). The observed dependent variable y_i^* equals y_i when the latent variable is positive, and is censored at 0 otherwise. Here, x_i denotes the factors influencing rural tourism efficiency, β_0 is the constant term, and β_1 reflects the magnitude of the factors' impact on efficiency across different quantile levels. The term ε_i represents the random disturbance.

（2）Quantile regression model

Traditional OLS regression usually only reflects the results of the effect of homogenization between variables without capturing the differences in the influence of the explanatory variables at different levels of the explained variables. The quantile regression model proposed by Koenker and Bassett (1978) can reflect the relationship between the optimization of the tourism industry structure and the digital economy under different quartiles and alleviate the problem of the results being interfered for the extreme data values. Therefore, the quantile regression model (2) is as follows:

$$Q_q(TE_i|FS_i)=\beta_0+\beta_1 FS_i+\sigma_i \quad (6)$$

Where *TE* represent the tourism efficiency index; *FS* is the factors affecting tourism efficiency; β_0 is the constant term； β_1 denotes the extent of the impact of the factors on the efficiency of rural tourism at different quantile levels; σ_i is a random perturbation term. The quantile regression coefficient β is estimated using the bootstrap method with put back sampling to obtain the confidence interval of the sample and then estimate the regression coefficients of the model.

4 Empirical results

4.1 Status and Structural Features of rural tourism efficiency

Based on DEA efficiency classification criteria in relevant literature (Nurmatov et al., 2021), the levels are divided into three grades: high (0.89,1], medium (0.69 - 0.89], and low (0, 0.69] (Table 3). For the mean value, Technical efficiency is greater than Scale efficiency and Comprehensive efficiency. Regarding the structure, 79.2% of the tourist villages have a Technical efficiency of above 0.89, which means that most of the rural tourism villages can make full use of the existing inputs to generate tourism-related outputs. In comparison, only 38.7% of the tourism villages have high-Scale efficiency, and only 30.13% (90 villages) also have high-Scale efficiency among the villages with high Technical efficiency. As a result, 41.07% of the tourist villages have excess funds, 79.73% have idle land, and 64% have insufficient tourist reception capacity. The above findings suggest that "efficient management but unbalanced scale" is the core bottleneck restricting the Comprehensive efficiency.

Table 3. Rural Tourism Efficiency: Levels and Structural Characteristics

Efficiency dimension	Low-efficient	Moderately-efficient	Highly-efficient	Mean Value	variance
Overall Efficiency	27.2%	47.5%	25.3%	0.784	0.019
Scale efficiency	16.5%	44.8%	38.7%	0.831	0.015
Technical efficiency	5.6%	15.2%	79.2%	0.945	0.011

4.2 Spatial Features of rural tourism efficiency

Table 4 presents the results of Moran's I, Z-scores, and P-values. All Moran's I indices exceed the critical value of 0.0027, indicating significant spatial clustering in the comprehensive, pure technical, and Scale efficiency of tourism villages. Among them, the Moran's I values for comprehensive and Technical efficiency are below 0.2, while that for Scale efficiency exceeds 0.2. This suggests that rural tourism efficiency and its components in Luoyang exhibit significant spatial aggregation at the regional scale, with Scale efficiency demonstrating a higher degree of spatial concentration than pure technical and Comprehensive efficiency.

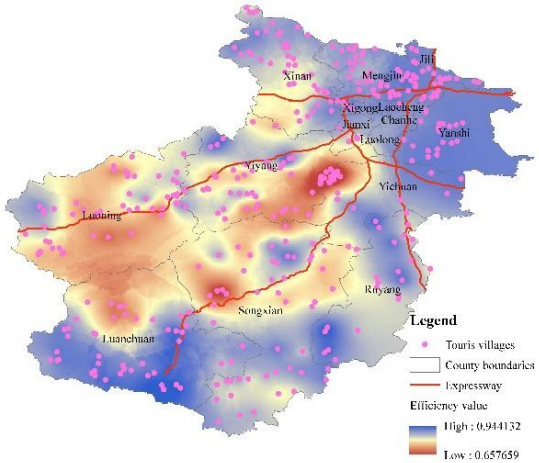
Table 4 Spatial autocorrelation analysis result of tourism efficiency

Efficiency dimension	Moran's I index	Var(I)	Z-value	P-value
Overall Efficiency	0.194719	0.001087	5.988276	0.000000
Scale efficiency	0.156358	0.001071	4.859197	0.000001
Technical efficiency	0.253312	0.001088	7.759560	0.000000

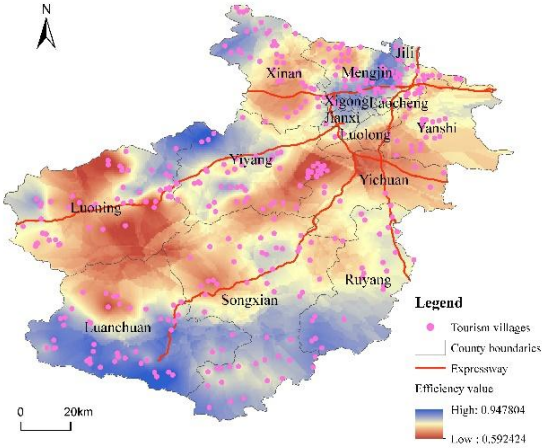
Global spatial autocorrelation reveals significant clustering of rural tourism efficiency in Luoyang. To further identify the specific extent, location, and spatial evolution patterns of these clusters, Empirical Bayesian Kriging (EBK) in the ArcGIS 10.5 Geostatistical Analyst module was applied to interpolate sample point data, delineating the agglomeration distribution pattern of tourism village efficiency. The spatial interpolation output is shown in the accompanying Figure3.

The villages with high Comprehensive efficiency are mainly distributed in two regions, the southern mountainous area (the southern parts of Luanchuan, Songxian, and Ruyang counties) and the western mountainous area (western part of Yiyang, the western part of Xinan, northeastern part of Luoning, and the strip area connecting Jianxi, Xigong, Mengjin, and Jili). The villages with high Scale efficiency are mainly located in the southern mountainous areas (in the south of Luanchuan, Songxian and Ruyang counties) and the Luoyang Basin. Compared with the former two, the

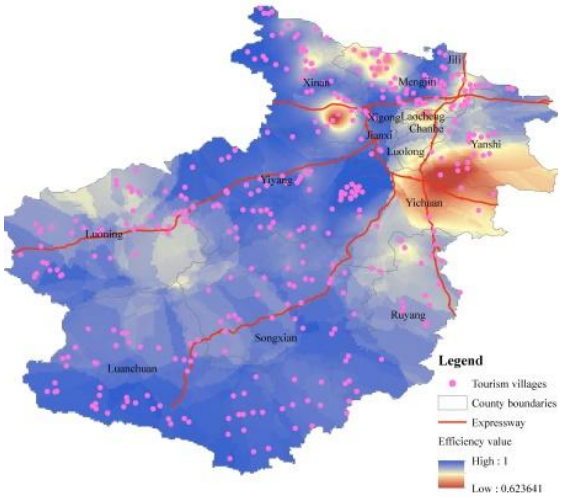
distribution of pure technical high values is more balanced. The low-value villages are mainly located in the southeastern part of the Luoyang Basin (in the south of Yanshi and the north of Yichuan). By comparing the spatial distribution patterns of the three types of efficiency, it can be found that the distribution of high and low values of Comprehensive efficiency and Scale efficiency shows a high degree of spatial overlap in the mountainous area. While in the Luoyang Basin, the spatial overlap degree between Comprehensive efficiency and Technical efficiency is relatively high. The finding suggest that the constraining factors of rural tourism efficiency exhibit spatial heterogeneity. In underdeveloped mountains areas, the efficiency is mainly affected by the scale effect. However, the efficiency is more affected by the level of technology and management, in the plain basin area with better economic foundation.



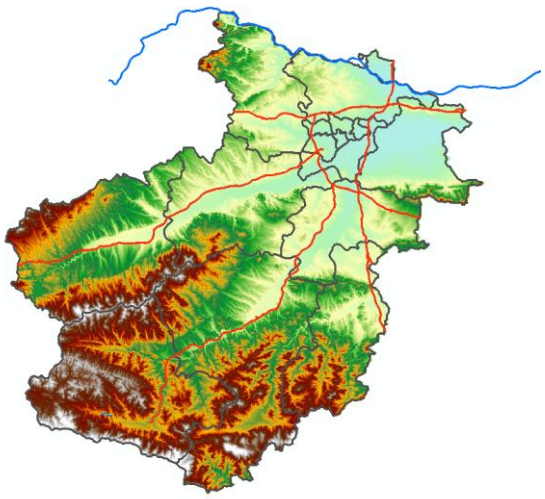
2-a Comprehensive efficiency



2-b Scale efficiency



2-c Technical efficiency



2-d DEM Elevation Map of the Study Area

Figure3 Spatial distribution map of Comprehensive efficiency(2-a), Scale efficiency(2-c) and Technical efficiency(2-b) of Rural Tourism

4.3 Influencing factors of rural tourism efficiency

4.3.1 Benchmark model

The Tobit regression model passed the significance test (P=0.000), which confirmed that the model was reasonable and effective (Table5). The regression results show that the efficiency of rural

tourism is significantly influenced by multiple factors. Among them, topographical conditions, agglomeration effects, and Government support constitute the core driving factors. Community openness and Traffic accessibility constitute the secondary important factors affecting tourism efficiency. The scale of business units, community population and community economy have a weak influence on tourism efficiency.

Table5 Tobit Regression Results of factors influencing tourism efficiency

Explanatory variable	Regression Coefficients(Z)
Intercept	0.920**(32.101)
Number of business units	0.257*** (8.500)
Size of single business entity	0.093*(1.859)
Community openness	0.213*** (2.297)
Traffic conditions	0.178*** (1.863)
Terrain conditions	0.492**(-33.548)
Community population size	0.011** (0.341)
Community economic conditions	0.068**(0.294)
Government support	0.233*** (3.548)
Log (Sigma)	-2.725**(-74.526)
R^2	-1.364

Note：***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively; z -statistics in parentheses

4.3.2 Robustness test

Due to the significant differences in geographical environment and urban-rural relations among the case villages, there may be some extreme values in the sample efficiency level, which could lead to deviations in the empirical results. This study employs tail trimming for robustness testing. The main variables involved in the model are truncated and replaced at the 1% and 99% levels, and then regression processing is conducted.

The efficiency values of rural tourism based on the DEA method have a boundary of [0,1] and a left-skewed characteristic. Direct OLS is prone to be disturbed by extreme values. By shifting (Eadj = E + 0.001) to ensure positive values and then taking the logarithm, it not only corrects the distribution skewness to meet the normal assumption of OLS, but also conforms to the marginal decreasing law of "input-output" in rural tourism. This method offers an elastic interpretation and forms complementary verification with the distribution assumption of the benchmark Tobit model.

The results of tail-cutting processing and "OLS + logarithmic shift transformation" regression show that the signs and significance of the core variables are consistent with the baseline conclusion (Table 6). This shows that the test results of the seven variables affecting rural tourism efficiency are not disturbed by the model function form and boundary problems.

Table 6. Robustness Tests

Explanatory variable	Regression coefficients from winsorized data	Regression coefficients from OLS with a log-shift transformation
Intercept	0.921**(32.129)	-0.233(-1.541)
Number of business units	0.461*** (7.031)	0.629*** (4.098)
Size of single business entity	0.061* (1.933)	0.101** (1.606)
Community openness	0.776***(32.905)	0.418*** (3.826)
Traffic conditions	0.083**(3.948)	0.326** (3.711)

Terrain conditions	0.208*** (5.282)	1.206*** (9.667)
Community population size	0.047** (2.187)	0.031* (2.108)
Community economic conditions	0.056*** (3.392)	0.074** (2.249)
Government support	0.375** (2.592)	0.517*** (4.006)
Log (Sigma)	375	375
R2	0.778	0.239

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively; t-statistics in parentheses

4.3.3 Quantile Regression Results

At the 0.25, 0.5 and 0.75 quantiles (Table 7), the Number of business units significantly affects the efficiency of rural tourism. This is in line with the basic principles of professional village development proposed by Li et al. (2009), which states that the external economies of scale and scope formed by the professional division of labor and network connections among multiple business entities are the key factors in the formation of professional villages. However, it is worth noting that with the improvement of tourism efficiency, the impact of the number of business units on Tourism efficiency present a variation of "positive - negative - positive". At the 0.5 quantile, the Number of business units negatively affects the tourism efficiency, indicating that the negative effects such as excessive competition and environmental consumption brought about by clustering are particularly prominent during the Moderately-efficient stage.The finding suggests that the concentration of business units is a "double-edged sword" for tourism efficiency depend on whether a dynamic balance can be achieved between external diseconomies of scale and innovation vitality (Liu Z. et al., 2021).

At the 0.25, 0.5 and 0.75 quantiles, the impact of the Size of Single business entity on the efficiency of rural tourism undergoes changes from a significantly negative effect, no significant effect, to a significantly positive effect (Table 7). This indicates that internal scale economies have a restraining effect on the tourism development of Low Efficient villages, while they have a promoting effect on the tourism development of Highly-efficient villages. This result is highly consistent with the "moderate scale" threshold effect discovered by Li et al. (2022) in the development of rural tourism. They believe that only when the scale of the operating unit is compatible with the development stage and resource conditions of the tourist village can it have a positive impact on efficiency. The possible reason is that as the efficiency of tourism has improved, the management capabilities and customer acquisition capabilities of the operating units have also been enhanced. This has led to a transformation in the relationship between the operating capabilities and Size of Single business entity from non-coupling to coupling, which lead the transition of the impact from inhibiting to promoting (Wang et al., 2024).

At the 0.25, 0.5 and 0.75 quantiles, the Community openness significantly affects the efficiency, but the direction of the influence undergoes a change of "positive - negative - positive". This indicates that Community openness helps to introduce external development resources to make up for the shortage of internal development resources in Tourism Villages at the primary stage of development, thus positively improving the efficiency of resource allocation (Zha et al., 2020). During the mid-stage of rural tourism development (at the 0.5th percentile), the external resources brought about by openness are prone to lead to excessive expansion of business scale and the number of business units, and intensify competition, which will have a negative impact on the efficiency of tourism resource allocation (Rao et al., 2022).With the continuous improvement of the operation ability of business units, cooperation network and rural governance level, Highly-efficient villages

can effectively coordinate external resources, internal conditions and the relationships among operating entities, converting the external resources introduced under an open environment into the comprehensive development capabilities of rural tourism, so as to promote a improvement of tourism efficiency（Bao et al., 2021）.

At the 0.25, 0.5 and 0.75 quantiles, Traffic accessibility significantly affected the tourism efficiency, and the coefficients were 0.147, -0.011 and 0.065, respectively. The "positive-negative-positive" change in the direction of influence coefficient reflects that transportation accessibility has multiple functions such as enhancing the proximity and accessibility of the market and accelerating the tourist flow. However, with the changes in the contradiction between supply and demand quantity and structure, its effects vary significantly (Wang et al., 2023). In the Low-efficient stage, the market proximity and accessibility brought by Traffic accessibility promote the formation of supply scale and market scale, thus promoting the improvement of tourism resource allocation efficiency. With the development of rural tourism, the market proximity advantage brought by transportation accessibility and the scale promotion effect have shown a marginal decline. At the same time, supply structure issues such as insufficient business innovation and poor retention capacity have become the main constraints on tourism development, leading to increasingly severe "retention effects" on tourists (Xu et al, 2018). As a result, the growth of tourism efficiency has slowed down or even declined. During the Highly-efficient stage, the village effectively transformed the tourist flow into increased consumption by addressing the supply structure problems fed back in the early stage, highlighting the market proximity and access advantage brought by accessibility.

At the 0.25, 0.5 and 0.75 quantiles, Terrain conditions significantly affect the efficiency of rural tourism, with coefficients of -0.211, 0.075 and 0.149 respectively, indicating a phased gradient change in the degree and direction of the impact.This indicates that from Low-efficient to Highly-efficient tourism villages, the constraint effect of Terrain conditions (such as increasing construction and operation costs and tourist tourism costs) gradually weakens, while the positive effect (such as improving landscape diversity) significantly increases.This result differs from the findings of Cao et al. (2015), who contend that the effectiveness of tourism resources endowment on tourism development diminishes as the tourism destination progresses. However, Liu et al. (2020) provided a more systematic explanation for this finding, arguing that the contribution of tourism resources to the high-quality development of the tourism industry varies due to the type of tourist destination, its stage of development, and its industrial structure

At the 0.25 and 0.5 quantiles (the low - Moderate efficiency range), Community population size has a positive impact on tourism efficiency. However, at the 0.75 quantile (the high efficiency range), its impact on tourism efficiency is not significant. During the Low and Moderately efficient range, the perfect infrastructure and public services corresponding to big Community population help to save non productive investment and concentrate the development factors to the direct production field. It forms a development path of low input, high output and high efficiency. However, during the Highly-efficient stage, the infrastructure advantage brought by Community population size is weakened, while the environmental quality and business innovation become the main driving force for development. At this time, the restriction effects such as resource and environment consumption caused by overpopulation are more prominent. In this regard, Pan et al. (2021) pointed out that high Community population size and its development demands would consume the natural ecological environment and restrict the development of high-end tourism, easily leading to a "rural-style mass tourism model - impacting the living environment - restricting high-end models - low investment

return rate - relying on mass tourism" low-value cycle.

The Government support shows significant positive effect on rural tourism efficiency. However, in the Low and Moderately efficient range (0.25 and 0.5 quantiles), Government support has a negative impact on efficiency. While in the Highly-efficient range (0.75 quantile), Government support shows a positive promoting effect on rural tourism efficiency. The possible reason is that the government mainly supports direct investment, which greatly improves the development environment of medium and low efficiency tourism villages. However, due to insufficient capacity in tourism product and market development, it often adopts a large-scale development model, leading to the phenomenon that government investment reduces economic efficiency. This does not negate the research findings of Cao et al. (2015) that Government support has a positive impact on tourism development. During Highly-efficient stage, Government support has shifted from direct investment to development guidance. Along with the optimization of the investment structure and resource allocation capabilities in community tourism, the government's effect on enhancing tourism efficiency became more prominent. Along with the optimization of the community tourism investment structure and resource allocation capabilities, the government's promotion effect on the intensive development of rural tourism became increasingly prominent.The above nonlinear relationship between Government support and tourism efficiency has been confirmed by Liu et al. (2020) at the macro scale, pointing out that the institutional environment has a significant role in promoting the tourism economy in the Middle East, while the impact on the western region is not significant.

At the 0.25, 0.5 and 0.75 quantiles, the Community economic conditions shows a significant impact on the efficiency of rural tourism, but the impact coefficient shows a decreasing trend. The reason might be that as the efficiency and development capabilities of tourism improve, the integration of resources in rural tourism development increasingly extends beyond the rural area (such as labor force, infrastructure and investment), and integrates into the economic cycle across urban-rural and regional boundaries（Pan et al., 2021）. In this regard, Yue et al. (2021) found in the macro scale research that the impact of per capita GDP on Regional Tourism efficiency is nonlinear.

Table 7. Quantile Regression Results

Explanatory variable	Q=0.25	Q=0.5	Q=0.75
Intercept	0.999**(0.009)	0.985** (0.011)	0.971**(0.022)
Number of business units	0.164***(0.000)	-0.131**(0.000)	0.030*(0.000)
Size of single business entity	-0.003*(0.003)	0.107(0.000)	0.057*(0.000)
Community openness	0.957**(0.006)	-0.102** (0.009)	0.327**(0.021)
Traffic conditions	0.147***(0.002)	-0.011** (0.009)	0.065** (0.005)
Terrain conditions	-0.211***(0.001)	0.075**(0.002)	0.249*** (0.003)
Community population size	0.017**(0.000)	0.003(0.000)	-0.041***(0.000)
Community economic conditions	0.059*** (0.004)	0.031** (0.004)	0.006 (0.010)
Government support	0.152***(0.006)	0.104**(0.007)	0.075**(0.016)

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively; standard errors are shown in parentheses for the quantile regression.

5 Discussions and conclusions

5.1 Theoretical implications

(1) Structural Disparities and Spatial Heterogeneity of Rural Tourism Inefficiency

The low efficiency of rural tourism asset conversion and its insufficient contribution to rural revitalization constitute a key challenge in tourism-led rural development (Sun et al., 2023). The result of this study reveals that the efficiency of rural tourism asset conversion is a structurally and spatially heterogeneous issue, as it objectively reflects spatial disparities in geographical conditions and tourism development capacities (Sun et al., 2025).

The statistical results indicate that the development of rural tourism faces a structural imbalance between "High-tec efficiency" and "Low Scale efficiency". 79.2% of the tourist villages have good resource management and operation capabilities, while 61.3% show medium-low Scale efficiency. Only 30.13% of the high-tech efficiency villages also have High Scale efficiency, and 41.07% and 79.73% of the tourist villages have Redundant investment in capital and land factors.The results of "efficient management but inappropriate scale" is partly attributed to the seasonal nature of rural tourism products, which leads to the seasonal idleness of assets (Wang Y., 2021). It also reflects the phased structural friction issues faced by rural tourism during its transformation from "lax investment" to "precise operation" (Bao et al., 2021). Under the rural tourism development system of "Government led, Market operation and Community participation", the structural friction is manifested in two dimension. First, in the process of development transformation, policy incentives remain on the track of "scale preference", solidified into the behavioral inertia of "focusing on input and ignoring output", which is misplaced with the efficiency priority transformation. Second, there is a time lag between the large-scale injection of government and market resources guided by policies and the cultivation of endogenous capacity in rural areas, forming a capacity fault of "blood transfusion first, hematopoiesis lagging" (Yang et al., 2025). Meanwhile, the resource allocation pattern formed during the rapid expansion period leads to path dependence, causing the rural tourism system to exhibit structural rigidity when facing transformation pressures. This make it is difficult to break through the lock-in effect of the existing institutional arrangements (Wang R et al., 2020). It can be seen that the current problem faced by rural tourism is not a single Scale efficiency problem, but a structural transformation dilemma caused by the deep mismatch between external intervention and endogenous response. It is this structural friction that determines the nonlinearity and differentiation of the efficiency improvement path.

At the spatial level, the tourism efficiency in mountainous areas is mainly affected by the scale effect, while the tourism efficiency in basin is more significantly affected by the Technical efficiency. This is consistent with the research of Ding et al. (2021) based on Wuling Mountain Area in Western Hunan, which found that the topographic conditions play a fundamental role in shaping the efficiency and structure of rural tourism. From the perspective of the regional system of human-environment relationship, the terrain gradient differences in the efficiency of rural tourism are clearly not solely determined by the spatial differentiation of ecological resource attractiveness based on differences in terrain conditions. The spatial differences in transportation accessibility, market reachability, and community development capabilities, which are influenced by terrain conditions, also affect the efficiency of rural tourism by shaping the development models and paths of rural tourism resources (Lobsang, 2025). In the mountainous areas, the terrain's topography has created conditions such as superior resource endowment, high entry costs for factors, small market radius, and insufficient endogenous development capabilities. These factors have led to a

development model characterized by external support dependence, resource foundation, and scale expansion. This also results in an efficiency bottleneck due to insufficient Technical efficiency. In contrast, the basin area often develops an endogenous intensive development model under the environmental conditions of land and other resource constraints, good proximity to the tourism market and factor availability, and higher endogenous development capacity, which also leads to the development bottleneck of insufficient Scale efficiency.This analytical framework incorporates static topographical conditions into the dynamic framework of human-environment relationship analysis, revealing how the topographical gradient, by restricting the flow of elements and the carrying capacity of the economy and society, indirectly affects the path of efficiency improvement.It provides a spatial differentiation mechanism for the efficiency of rural tourism from the perspective of the "human-environment relationship regional system".

（2）The evolution of rural tourism efficiency follows a nonlinear path

Quantile regression reveals that the same factor shows different degrees and even different directions of influence at three efficiency levels. This suggests that there is a significant threshold effect in the evolution process of rural tourism efficiency. Once the efficiency crosses a specific threshold, the development path, driving mechanism, and effects will undergo fundamental changes. Relevant studies have also found that the impact of rural tourism development on Rural Revitalization exhibits a phased and non-linear characteristic (Liu et al., 2025). Some studies also confirm that the effect of agricultural tourism integration on rural tourism production efficiency showed nonlinear characteristics. Once the new paradigm was established, the direction of the impact of various factors on efficiency was reversed (Mo et al., 2026). This shows that the dynamic evolution of rural tourism efficiency is essentially a continuous reconstruction process of reconfiguration of the matching state among external driving forces (government, market), internal support ability (community) and industrial response ability (enterprise) (Chen et al., 2026).

The Low-efficient stage is characterized by "resource complementary adaptation", where external resources are injected to make up for the shortage of local factors. At this time, factors such as the number of enterprises and the openness of communities play a positive role, promoting a scale-oriented and extensive development model. During the medium-efficiency stage, there is a disconnection between external intervention, community support capabilities, and industrial response capabilities. This results the "management challenge mismatch" among scale development under external support, insufficient community elements and governance support, and insufficient enterprise resource integration ability. This leads to a diminishing marginal output effect of resource input. Entering the high-efficiency stage, the system achieves "innovative collaborative adaptation" through feedback from both internal and external factors. At this point, external support, internal support, and internal vitality form a deep coupling, and technological optimization and quality improvement become new sources of efficiency growth.

（3）Influencing mechanism of rural tourism efficiency

By the results above, the improvement of rural tourism efficiency depends on the coupling and synergy of the three factors of "External environmental driving factors - Internal supporting factors - Endogenous growth momentum" (Luo et al., 2025) (Figure 4). Among them, the Endogenous growth momentum (such as economies of scale and economies of scope) are the direct driving force for efficiency improvement. However, their effect does not occur in isolation. Instead, it relies on the the support of rural internal support (such as the community population, culture, economy and resources) to bear the scale and structure of the industry and to provide support for the coordination

among organizations. The effectiveness of the intervention of the external driving factors (government and market) depends on the transformation and bearing of the internal supporting forces (population, resources, culture, etc.) of the community. Communities use their community endowments (such as population capacity and resource base) to internalize the development support of the government and the efficient resource allocation mechanism of the market into the internal development momentum of industrial development, so as to realize the industrialization of factors and the continuous optimization of industrial structure (Yang et al., 2025).

The interaction among factors at three levels of has a clear threshold boundary, leading to the nonlinear evolution of efficiency. The expansion of industrial scale needs to be adapted to the external market capacity and the endowment conditions of the community. Excessive expansion will lead to dis-economies of scale. Industrial agglomeration needs to be constrained by the social-cultural synergy and the comprehensive carrying capacity of the social ecology. Excessive agglomeration will result in internal competition, decline in efficiency, and excessive consumption of resources and the environment (Rao et al., 2024). Moderate government intervention can enhance the internal development momentum of rural areas. However, excessive intervention will suppress the vitality of communities, leading to government-driven development and deviation from the optimal market allocation mechanism of resources.Therefore, the mechanism for optimizing the efficiency of rural tourism lies in the dynamic balance among the three elements. The external driving force needs to be adapted to the actual carrying capacity of the rural area and the resource integration ability of the operating entities. The expansion of the industry scale needs to follow the critical threshold of the supporting environment both within and outside the rural area.Therefore, the core of optimizing the efficiency of rural tourism lies in achieving the coordinated evolution and threshold matching of three factors: the degree of external driving force intervention, the internal carrying capacity and transformation ability of the rural area, and the integration ability of industrial assets. Only when external intervention, local implementation and industrial integration form synergy in a dynamic process, can the system break free from the predicament of low efficiency and transition to a higher-level equilibrium state (Wang, 2024). A case study by Li et al. (2025) with Jianhe village in Yancheng City confirmed that the rural industrial spatial governance follows the evolution path from "endogenous governance" to "exogenous governance", and finally realizes the equilibrium state of "internal and external linkage symbiosis" through the in-depth adjustment of internal and external resources.

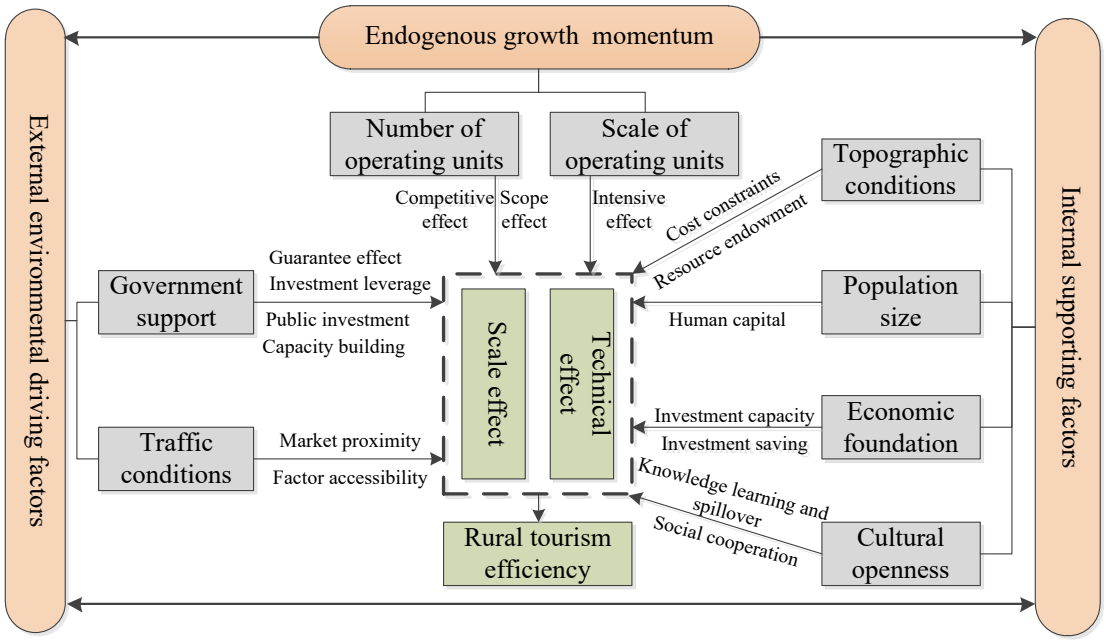


Figure 4 The Tripartite Conjugate Mechanism of "External driving, Village Support, and Endogenous growth momentum" in the Formation of Rural Tourism Efficiency

5.2 Practical implications

This study reveals that the influencing mechanism of rural tourism efficiency exhibits significant characteristics of threshold, stage, and spatial heterogeneity. To promote the high-quality development of rural tourism, differentiated intervention strategies adapted to the development stage and geographical contexts should be adopted. Specifically as follows:

For Low-efficient tourism villages, the core of industrial development governance should be "cultivation of foundation and precise empowerment". First of all, They should enhance the openness of the community to attract external capital and business entities to make up for their own resource and capacity deficiencies, thereby promoting the development of a comprehensive product system and the clustering of the industrial chain. Secondly, these villages should pay attention to the optimization of Traffic accessibility, so as to connect with the main source markets and regional core cities. Furthermore, they should carry out marketing promotion for tourists and investment in the main source markets and regional core cities, so as to improve the market and external investment. Thirdly, government support should focus on tourism infrastructure construction, service capacity training, marketing and investment environment optimization, management system construction, etc., to improve the development conditions of rural tourism and activate the internal vitality of rural development.

For Moderately-efficient tourism villages, the key to the governance of tourism industry lies in resolving the development bottlenecks of "inefficient agglomeration and lagging management". Firstly, they should strengthen the cultivation of innovation ability, encourage differentiated innovation and value co creation and sharing of business entities, so as to alleviate the vicious competition caused by excessive agglomeration and promote the value creation ability based on new products and new formats. Secondly, they should enrich tourism formats and consumption scenes through industrial integration, so as to transform the tourist flow into consumption scale, so as to eliminate the "transit effect" caused by traffic convenience.Thirdly, the role of the government should shift from direct intervention to fostering the capacity of communities, promoting the growth

of local business entities, facilitating the formation of an internally coordinated division of labor system, and enhancing the community's control and retention capabilities over development benefits.

The development of Highly-efficient villages should take "innovation driven, collaborative symbiosis" as the core development orientation. Firstly, they should guide the differentiated innovation of various enterprises, promote enterprises to move from competition to cooperation and value creation, extend the industrial chain and cultivate an industrial innovation ecosystem. Secondly, they should utilize Community openness to introduce high-end factors and new business formats, and strengthen cross-regional resource integration.Thirdly, they should explore cluster development by integrating resources, products, and service facilities among neighboring rural areas, in order to enhance the overall carrying capacity and external scale effects.

Tourism villages in the Luoyang Basin should explore moderate economies of scale based on industrial chain organization and spatial optimization, while continuing to strengthen their management and innovation capabilities. They should promote the refinement and digital upgrading of existing facilities and services, strengthen business innovation and product differentiation, optimize service quality, etc., in order to enhance the core driving role of technological efficiency. Meanwhile, within the tourism village, they should promote modular innovation of product formats and scenario based collaboration of business entities around consumption scenarios, in order to promote the construction and extension of characteristic industrial chains and strengthen the scope economic effects. At the spatial level, they should promote the linkage and integration of neighboring villages, explore the sharing and co construction of marketing promotion, route organization, resource sharing, and new business development, and promote the cluster development of tourist villages to leverage the benefits of agglomeration economy.

The core of rural tourism governance in mountainous areas lies in breaking through the bottleneck of "Exogenous scale driven" development and exploring intensive development based on endogenous capacity enhancement. Firstly,while moderately opening up to introduce external development resources, they should focus on cultivating local human capital and community participation capabilities, to bridge the gap of "receiving external assistance first, but developing internal capabilities later", to effectively convert the external funds and information into internal development vitality. Secondly, they no longer simply pursue the growth of the number and scale of business entities, but focus on guiding the extension of the industrial chain, innovation of product formats, and improvement of service governance to avoid homogeneous agglomeration and internal competition, thus achieving intensive development.

5.3 Limitations and future research

This study still has several limitations. Firstly, since the countryside is not a complete statistical unit, it leads to the lack of historical data recording for the rural tourism system. The single-point data used in this study has limitations in revealing the dynamic changes of tourism efficiency and its influencing factors. Secondly, due to the complexity of rural tourism and the integration of input factors, as well as the non-complete economic rationality of government and farmers' tourism investments, it is difficult to fully quantify the input and output factors. This may result in a deviation between the calculation efficiency and the actual operation of the rural tourism system. Future research should conduct participatory social surveys to deeply analyze the production functions of different-scale rural tourism operating units, and improve the design of input-output indicators in order to enhance the scientifically of efficiency measurement. Thirdly, in the context of rural revitalization and sustainable development, the output of rural tourism should not only include

income but also encompass various benefits such as employment opportunities, cultural prosperity, and ecological protection.Future research should incorporate tools such as ecological efficiency models to comprehensively assess the multi-dimensional outputs of rural tourism.

5.4 Conclusions

This study expands the classic tourism system model and constructs the "village-scale rural tourism regional system" model. This model integrates external driving factors, rural internal supporting factors, and industrial development momentum into a unified analytical framework, providing a basic theoretical reference for examining the high-quality development of rural tourism and its influencing factors. Based on this model, the study uses quantile regression to reveal the coupling or imbalance between external driving factors, internal rural support factors, and industrial development momentum - how they collectively lead to non-linear and threshold effects in efficiency improvement.The main conclusions are as follows:

(1) Structural imbalance between Technical efficiency and Scale efficiency.

Rural tourism in Luoyang exhibits a distinct pattern of "high Technical efficiency but low Scale efficiency." As a result, 41.07% of the tourist villages have excess funds, 79.73% have idle land, and 64% have insufficient tourist reception capacity.

(2) The terrain gradient shapes the spatial heterogeneity of rural tourism efficiency. The spatial agglomeration of Scale efficiency is higher than Technical efficiency and Comprehensive efficiency, reflecting significant spillover effects of rural tourism scale.The tourism efficiency in mountainous areas is mainly influenced by Scale efficiency and shows a significant exogenous-driven development. Technical efficiency is the main bottleneck for efficiency improvement.In the basin region, the development of rural tourism presents a significant endogenous driving force, and moderate scale is the key to improving Comprehensive efficiency.

(3) The factors on efficiency exhibits non-linearity and threshold effects. The efficiency of rural tourism is influenced by multiple factors including external driving forces, community support factors, and industrial development momentum. Among them, Topographical conditions, Agglomeration effects, and Government support constitute the core driving factors. However, the impact of the same factor at different efficiency levels showed varying levels or even opposite directions.This reveals the phased and non-linear nature of the driving mechanism for rural tourism development, indicating that rural tourism governance must adopt more precise and differentiated approaches.

(4) The internal and external synergy mechanism for efficiency formation. The improvement of rural tourism efficiency is essentially a dynamic reconstruction process of the adaptation state between external driving forces (government, market), internal support capabilities, and industrial development momentum. Specifically, it manifests as a phased development model of "resource replenishment adaptation" in the low efficiency stage, "management challenge mismatch" in the medium efficiency stage, and "innovative collaborative adaptation" in the high efficiency stage.

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