Spatiotemporal Evolution and Influencing Factors of Coordinated Development between Tourism Economy and Ecological Environment in the Yellow River Basin: Postprint

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Abstract

Based on panel data of the tourism economic system and ecological environment system for 66 central cities (municipalities, prefectures, autonomous prefectures, and leagues) in the Yellow River Basin, and employing methods such as the coupling coordination model, spatial autocorrelation analysis, and geographic detector, with 2008, 2013, and 2018 as time nodes, this study examines the spatio-temporal evolution characteristics and influencing factors of the coupling coordination level between the tourism economic system and ecological environment system in the Yellow River Basin. The results show: (1) In 2008, 95% of central cities in the Yellow River Basin had coupling coordination levels between the tourism economic system and ecological environment system at or above the moderate coordination grade; in 2013, over 60% of central cities in the Yellow River Basin adjusted the coupling coordination level of the two systems to the high coordination grade, with the basin overall exhibiting a non-uniform distribution pattern of "high in the east and low in the west"; in 2018, over 88% of central cities in the Yellow River Basin had coupling coordination levels of the two systems at or above the high coordination grade. (2) The spatial clustering of coordinated development between the tourism economic system and ecological environment system in the Yellow River Basin adjusted year by year, with cold spot significant areas in upstream provinces (autonomous regions) of the basin continuously contracting and clustering in eastern Qinghai Province, central Gansu Province, and other regions; hot spot significant areas in midstream and downstream provinces (autonomous regions) continuously moving and converging toward central Henan Province, western Shandong Province, and other regions. (3) Government support for the tourism industry and efforts in ecological environment protection and remediation, as well as the average annual growth rate of energy conservation and environmental protection expenditure over the past 3 years, are sequentially the most important driving forces affecting the coordinated development of the two systems in the Yellow River Basin; the influence effect of driving factors such as the number of invention patents per 10,000 people and taxi ownership shows a trend of gradual increase followed by weakening; the element of scientific and technological quality education, represented by the proportion of Research and Development (R&D) expenditure to Gross Domestic Product (GDP), has a relatively insignificant impact on the coordinated development of the two systems in the Yellow River Basin. This study explores the path of coordinated development between tourism economy and ecological environment in the Yellow River Basin, providing theoretical reference for further enhancing the high-quality development level of the Yellow River ecological economic belt.

Full Text

Abstract

Based on panel data from the tourism economic system and ecological environment system across 66 central cities (municipalities, prefectures, autonomous prefectures, and leagues) in the Yellow River Basin, this study employs the coupling coordination model, spatial autocorrelation analysis, and geographic detector methods to examine the spatiotemporal evolution characteristics and influencing factors of the coupling coordination level between tourism economy and ecological environment systems in the Yellow River Basin, using the years 2008, 2013, and 2018 as key time nodes. The results indicate that: (1) In 2008, 95% of central cities in the Yellow River Basin exhibited a moderate coupling coordination level or above between tourism economy and ecological environment systems. By 2013, over 60% of central cities had adjusted to a high coordination level, with the basin displaying a non-uniform distribution pattern of "high in the east, low in the west." By 2018, more than 88% of central cities had achieved a high coupling coordination level or above. (2) The spatial clustering of coordinated development between tourism economy and ecological environment systems in the Yellow River Basin adjusted annually. Cold spot significant areas in upstream provinces continuously contracted and clustered, forming groups in eastern Qinghai and central Gansu. Meanwhile, hot spot significant areas in midstream and downstream provinces consistently moved toward and converged in central Henan and western Shandong. (3) Government support for tourism and ecological environment protection and remediation, as well as the average annual growth rate of energy conservation and environmental protection expenditure, emerged as the most critical driving forces affecting coordinated development of the two systems. The influence of driving factors such as invention patents per 10,000 people and taxi ownership increased slowly before weakening. The impact of science and technology quality education, represented by the proportion of research and development expenditure in GDP, on coordinated development of the two systems was relatively insignificant. This study explores pathways for coordinated development between tourism economy and ecological environment in the Yellow River Basin, providing theoretical references for further enhancing high-quality development of the Yellow River Ecological Economic Belt.

Keywords: tourism economy; ecological environment; spatiotemporal evolution; Yellow River Basin

1. Introduction

The ecological protection and high-quality development of the Yellow River Basin has been elevated to a national strategy, making the investigation of coordinated development between tourism economy and ecological environment in this region profoundly significant. Tourism economy represents a novel economic development model and a new driving force for economic transformation and high-quality development. The ecological environment serves as the carrier for human survival and development, constituting a core element in human-environment relationship research. The tourism economy and ecological environment are interconnected systems that integrate regional and comprehensive characteristics under specific human-environment relationships, representing outcomes driven by multiple factors. Under the combined influence of economic development theories and environmental values, the coordination mechanism between tourism economy and ecological environment has gradually become a central research topic among scholars worldwide.

International scholars have extensively explored the relationship between tourism economy and ecological environment. Moulin and Boniface proposed the concept of integrating tourism industry with ecosystem development, while Konan argued that tourism economic growth could alleviate ecological pressure burdens, suggesting that the relationship between tourism economy and ecological environment represents outcomes under dual influences and multi-factor intersections. Drawing upon China' s unique natural endowments and cultural foundations, domestic scholars have continuously explored new measurement methods and analytical approaches while focusing on the coordination principles and mechanisms between tourism economic and ecological environment systems. Guo et al. employed the Attribute Hierarchical Model (AHM) combining subjective and entropy weights to analyze spatial differences and evolution characteristics of coordinated development between tourism economy and ecological environment in China. Zhou et al. utilized the weighted TOPSIS method and grey prediction model GM(1,1) to evaluate and forecast the coordination mechanism among regional economy, ecological environment, and tourism industry in provinces along the Yangtze Economic Zone. Wu et al. applied entropy and cluster analysis methods to examine coordinated development between public service resource spatial allocation and urban-rural interaction in Xinjiang. Wang et al. predicted future tourism economic development trends in the Yellow River Basin using rescaled range analysis (R/S analysis) based on previous research regarding ecological environment dimensions.

In summary, existing research on coordination mechanisms between tourism economy and ecological environment exhibits diversified and scientific characteristics, with research perspectives transitioning from qualitative to quantitative approaches and research value shifting from level measurement to multi-factor exploration and future development forecasting. However, current research still presents certain limitations, particularly the emphasis on measuring coordination levels and spatiotemporal patterns while insufficiently investigating spatiotemporal evolution effects and driving factors of coordinated development. Therefore, this study examines the coordination relationship between tourism economy and ecological environment across 66 central cities in the Yellow River Basin, exploring the spatiotemporal evolution and influencing factors of their coupling coordination. Guided by the "Two Mountains" theory and oriented toward coordinated promotion and high-quality development, this research seeks pathways suitable for high-quality coordinated development between ecological environment and tourism economy in the Yellow River Basin.

2. Data and Methods

2.1 Data Sources and Indicator Selection

Tourism economy and ecological environment constitute complex systems. The tourism economic system represents a comprehensive manifestation of tourism benefits and tourism scale, where tourism benefits characterize the input-output comparison of tourism economy as crucial support for stable system operation, and tourism scale reflects the interactive features between tourism carrying capacity and development scope as the strength guarantee of the tourism economic system. The ecological environment system comprises a combination of ecological resources and environmental governance, where ecological resources represent the main manifestation of natural resource endowments and environmental governance serves as the core guarantee for ecological environment system operation.

Based on accessibility and factor endowment theory, this study constructs an evaluation index system for the coupling coordination degree between tourism economic system and ecological environment system in the Yellow River Basin (Table 1). To clarify internal element differences between the two systems, the system divides tourism economic and ecological environment systems into four dimensions: tourism benefits, tourism scale, ecological resources, and environmental governance, selecting 15 indicators to form the evaluation index system. Original data were obtained from the *China City Statistical Yearbook* and *Yellow River Yearbook* for 2008-2018. Given missing data for certain years, some central cities' statistical yearbooks and statistical bulletins were also consulted (http://www.cnstats.org/). The 66 selected central cities (municipalities, prefectures, autonomous prefectures, and leagues) correspond to those listed in the *Yellow River Yearbook*. Since the evaluation system comprises multiple levels and indicators, the entropy method was employed to determine indicator weights.

2.2 Methods

2.2.1 Coupling Coordination Degree Model After establishing indicator weights, the coupling coordination degree model for tourism economy and ecological environment subsystems was constructed. The formulas for calculating coupling degree (C) and coupling coordination degree (D) are as follows:

$$C = \frac{U \times G}{\sqrt{(U+G)^2}}$$

$$D = \sqrt{C \times T}$$

$$T = \alpha U + \beta G$$

where: C represents coupling degree, indicating the degree of mutual influence between two systems through interactive coupling factors; U and G represent comprehensive evaluation indices of tourism economic system and ecological environment system, respectively; D represents coupling coordination degree, reflecting the overall synergistic effect of the two subsystems; T represents the comprehensive evaluation index reflecting the overall synergistic effect of the two subsystems, where α and β are weights of the subsystems. According to the coupling coordination degree values, the two systems can be classified into 10 grades (Table 2).

2.2.2 Spatial Autocorrelation Method To more intuitively analyze spatial pattern characteristics of coupling coordination between tourism economy and ecological environment in the Yellow River Basin, the Getis-Ord Gi* statistic was used to identify high-value and low-value clusters in different regions, exploring local spatial correlation degrees and spatial distribution patterns of coordinated development efficiency, as well as spatial dependencies among research units. The calculation formula is:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{ij} x_j}{\sum_{j=1}^{n} x_j}$$

When spatial weight matrix w_{ij} is determined by adjacency criteria, the standardized form of Gi* is:

$$Z[G_i^*] = \frac{G_i^* - E[G_i^*]}{\sqrt{Var[G_i^*]}}$$

where: G_i^* is the spatial correlation value; d is spatial distance; n is the number of spatial units; w_{ij} is the spatial weight matrix; x_j is the attribute value of spatial unit j; Z[G_i^*] is the standardized result; E[G_i^*] is the mathematical expectation; Var[G_i^*] is the variance. If Z[G_i^*] is positive and significant, it indicates high values around location i, belonging to high-value spatial clustering (hot spot area). If Z[G_i^*] is negative and significant, it indicates low values around location i, belonging to low-value spatial clustering (cold spot area).

2.2.3 Geographic Detector To explore the coordinated development relationship between tourism economic system and ecological environment system in the Yellow River Basin, the factor detector in geographic detector was employed to analyze influencing factors through geographic stratification of different factors. The q-statistic measures the degree of spatial stratified heterogeneity of variable Y and how much factor X explains the spatial differentiation of variable Y:

$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2} = 1 - \frac{SSW}{SST}$$

where: L is the stratification of variable Y or factor X (i.e., classification or zoning); N_h and N are the unit numbers in layer h and the entire region, respectively; σ_h^2 and σ^2 are variances of variable Y in layer h and the entire region, respectively; SSW and SST are the within-layer sum of squares and total sum of squares. The q-value ranges from [0,1]; a larger q-value indicates more obvious spatial differentiation of variable Y. If stratification is generated by independent variable X, a larger q-value indicates greater consistency between X and Y spatial distributions, implying stronger explanatory power of independent variable X on attribute Y, and vice versa.

3. Results Analysis

3.1 Spatial Distribution Characteristics of Coupling Coordination Degree

To further investigate spatiotemporal evolution characteristics of coordinated development between tourism economic and ecological environment systems in the Yellow River Basin, coupling coordination degree model data were calculated for three time nodes and classified into five grades to map spatial distributions (Figure 1). The coupling coordination degree grades between tourism economic and ecological environment systems in the Yellow River Basin showed annual optimization. In 2008, except for some downstream cities exhibiting low-level disharmony, other central cities in the basin maintained moderate to high coordination levels, with overall moderate differences and general comprehensive performance. After five years of adjustment and development, all central cities except Baiyin City achieved moderate coordination or above. By 2018, the development and optimization rate of the two systems became prominent, with 55 central cities reaching high coordination or above. Overall, except for Yushu, Guoluo, and Huangnan prefectures in the upper reaches where system indicators developed relatively slowly, and Puyang, Hebi, and Laiwu cities limited by small administrative areas resulting in lower tourism economic and ecological environment indicators, coupling coordination degrees in other central cities showed optimization trends.

3.2 Spatial Autocorrelation Analysis

3.2.1 Global Spatial Autocorrelation To further analyze spatial clustering and evolution characteristics of coupling coordination between tourism economy and ecological environment in the Yellow River Basin, global Moran' s I and Getis-Ord Gi* indices were calculated (Table 3). The global Moran' s I index for coupling coordination level between tourism economic and ecological environment systems in the Yellow River Basin was positive for all sample years, with all indices passing significance tests at $P < 0.05$ (where P is the significance probability value and Z is the test statistic, with $|Z| \geq 1.96$ indicating significance), demonstrating obvious spatial autocorrelation. The global Gi value showed an overall trend of "rising—stable—slight decline" over the years, indicating that the spatial clustering trend of coupling coordination level fluctuated significantly, presenting a pattern of "first clustering then weakening."

3.2.2 Local Spatial Autocorrelation Based on the above global autocorrelation analysis, local spatial heterogeneity, evolution degree, and internal element autocorrelation were further explored. Using Formula (6) with three years as time nodes, local Getis-Ord Gi* values were calculated and classified into seven types using the natural breaks method in ArcGIS 10.2: cold spot high-significance area, cold spot medium-significance area, cold spot low-significance area, random distribution area, hot spot low-significance area, hot spot medium-significance area, and hot spot high-significance area, mapping spatial pattern evolution (Figure 2). As years progressed, the local spatial pattern of coupling coordination level showed a stepped distribution of "cold in the west, hot in the east." Cold spot significant areas in upstream provinces continuously concentrated in Huangnan and Haibei prefectures due to fragile environments and underdeveloped economies. Meanwhile, hot spot significant areas in midstream and downstream provinces consistently moved toward and gathered in central Shaanxi, northern Henan, and western Shandong, with radiation effects from provincial capitals like Xi' an, Jinan, Zhengzhou, and Taiyuan strengthening annually.

3.3 Influencing Factors Analysis

3.3.1 Selection of Influencing Factors Coordinated development between tourism economic and ecological environment systems results from multiple influencing factors. Using geographic detector methods, this study selected 13 indicators from five dimensions as influencing factors: economic development level, industrial structure, science and technology quality education, transportation conditions, and policy factors. Economic development level was represented by per capita GDP and per capita disposable income; industrial structure by tertiary industry proportion and average annual growth rate of energy conservation and environmental protection expenditure; science and technology quality education by R&D personnel per 10,000 people, R&D expenditure proportion of GDP, and invention patents per 10,000 people; transportation conditions by public passenger volume, taxi ownership, and highway network density; and policy factors by frequency of "tourism" and "environment" mentions in government work reports. Original data for influencing factors primarily came from the 2008-2018 *China City Statistical Yearbook*, with transportation data from *China Transportation Statistical Yearbook*, disposable income data from national economic and social development statistical bulletins, and policy factor data from government work reports of each central city.

3.3.2 Analysis of Influencing Factors Table 4 shows that from 2008 to 2018, q-values for 11 influencing factors—including per capita disposable income, tertiary industry proportion, energy conservation and environmental protection expenditure growth rate, R&D personnel per 10,000 people, public passenger volume, highway network density, and government report mentions of "tourism" and "environment"—showed positive correlation growth over time. Based on this analysis and practical conditions of coordinated development in the Yellow River Basin, five driving factors were examined:

(1) **Economic development level** is the dominant factor balancing coordinated development. Per capita GDP and disposable income are important measurement standards. From 2008 to 2018, q-values for per capita GDP showed steady increase then slow increase, while per capita disposable income q-values continued rising but with smaller base values, indicating relatively weaker driving effects.

(2) **Industrial structure** provides strength support for coordinated development. Tertiary industry proportion and energy conservation and environmental protection expenditure growth rate q-values both floated upward, with the latter's growth rate being particularly prominent, demonstrating enhanced industrial structure effects.

(3) **Science and technology quality education** provides intellectual and innovation support. Among three indicators, R&D personnel per 10,000 people q-values rose steadily, while R&D expenditure proportion and invention patents per 10,000 people q-values showed initial increase followed by relative decline, indicating weakening driving effects.

(4) **Transportation conditions** serve as the "main artery" connecting coordinated development. From 2008 to 2018, q-values for public passenger volume, taxi ownership, and highway network density all increased. However, taxi ownership q-values slowed after 2013 due to transportation mode shifts and ride-hailing platforms, while public passenger volume and

highway density effects strengthened significantly.

(5) **Policy factors** constitute the core driving force. Based on government work report analysis, q-values for "tourism" and "environment" mentions continuously rose, reaching the top rank among all factors by 2018, indicating increasing government emphasis on coordinated development.

4. Conclusions and Recommendations

4.1 Conclusions

Based on tourism economic and ecological environment systems of 66 central cities in the Yellow River Basin, this study constructed an evaluation index system and examined spatiotemporal evolution characteristics and driving factors of coupling coordination using three time sections through coupling coordination model, spatial autocorrelation analysis, and geographic detector. The conclusions are:

(1) From 2008 to 2018, coupling coordination degrees between tourism economic and ecological environment systems across 66 central cities in the Yellow River Basin showed overall improvement. In 2008, coordination levels included low, moderate, and high grades; by 2013, low coordination disappeared; by 2018, extreme coordination emerged.

(2) In spatial clustering and evolution mechanisms, cold and hot spot groups gradually formed. Cold spot significant areas in upstream provinces continuously contracted toward Qinghai and Gansu, forming collaborative groups. Hot spot significant areas in midstream and downstream provinces gathered toward central Shaanxi, northern Henan, and western Shandong, forming significant hot spot groups with increasingly prominent radiation effects.

(3) Regarding driving factors of coordination degree, policy factors, industrial structure, economic development level, transportation conditions, and science and technology quality education are important driving factors in descending order. After a decade of development, policy factors became the most significant driving force; industrial structure effects continuously strengthened; economic development level effects were relatively unstable; transportation conditions had relatively large impacts; and science and technology quality education effects were relatively weak.

4.2 Recommendations

Based on these conclusions and the strategic 方针 of ecological protection and high-quality development in the Yellow River Basin, recommendations are proposed for upstream, midstream, and downstream regions:

(1) **Upstream region**: Addressing heavy reliance on mineral and water resources, deeply promote ecological protection and restoration projects to

facilitate transformation and upgrading of ecologically fragile and energy-rich areas. Popularize clean energy construction, pilot green high-quality development in resource-depleted cities like Baiyin and Shizuishan, and integrate tourism resources with economic industries to promote high-quality tourism economic development.

(2) **Midstream region**: Playing a connecting role in basin ecological protection and high-quality development, midstream areas should focus on solving soil erosion and pollution problems. Center on environmental protection and governance, rely on Guanzhong and Taiyuan urban agglomerations, transform cultural resource endowments into emerging industrial momentum, and promote construction of cultural and tourism economic belts along the Yellow River.

(3) **Downstream region**: Limited by objective constraints and rapid industrialization, downstream areas face prominent contradictions between ecological environment and economic development. Strengthen ecological protection and restoration using the Yellow River Delta wetland as a model, promote dual development of pollution control and environmental protection, enhance economic radiation effects of provincial capitals like Zhengzhou and Jinan, and integrate industrial economy with tourism resources in ancient capital cities like Luoyang and Kaifeng to improve coordinated development capacity of tourism economy.

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