Postprint: Spatial Patterns of Inter-city Tourism Economic Linkages and Influencing Factors in the Yellow River Basin

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Abstract

Based on cross-sectional data from 2010, 2015, and 2019, this study analyzes the tourism economic connections and spatiotemporal evolution characteristics among 89 cities in the Yellow River Basin using a modified gravity model and social network analysis, and employs geographic detector to analyze the influencing factors of changes in tourism economic connections in the Yellow River Basin. The results show that: (1) The east-west multi-core network structure of the tourism economic network in the Yellow River Basin is gradually forming, with significant characteristics of regional differentiation among cities and provincial barrier effects. (2) The tourism economic connection network has experienced an initial stage of polarization and significant barriers, a transitional stage of organic connectivity and enhanced interaction, and a consolidation stage tending toward equilibrium and cluster development. (3) A few nodal core cities, represented by Xi' an and Zhengzhou, exert strong intermediary effects in the tourism economic connection network. (4) Industrial structure level, tourism resource endowment, and environmental quality are the main influencing factors of tourism economic connections, and the interaction effects among these factors enhance the explanatory power regarding tourism economic connections. The findings provide effective optimization suggestions for the high-quality development of tourism economy in the Yellow River Basin.

Full Text

Preamble

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Patterns and Influencing Factors of Tourism Economic Linkages Between Cities in the Yellow River Basin

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Abstract: Based on time-series cross-sectional data from 2010, 2015, and 2019, this study employs a modified gravitational model and social network analysis to examine the spatiotemporal evolution of tourism economic linkages among 89 cities in the Yellow River Basin. Geographic detector analysis is combined to identify the driving factors behind these changes. The results reveal: (1) An east-west multi-core network structure of the tourism economy is gradually forming, with significant regional differentiation and inter-provincial barriers between cities. (2) The tourism economic linkage network has progressed through three stages: an initial phase characterized by polarization and substantial barriers, a transitional phase of organic connection and enhanced interaction, and a consolidation phase moving toward equilibrium and cluster development. (3) A small number of core cities, represented by Xi' an and Zhengzhou, play strong intermediary roles in the network. (4) Industrial structure level, tourism resource endowment, and environmental quality emerge as the primary influencing factors, with interactions among these factors enhancing their explanatory power over tourism economic linkages. These findings provide actionable recommendations for promoting high-quality tourism economic development in the Yellow River Basin.

Keywords: tourism economic linkage; social network analysis; geographic detector; influencing factors; Yellow River Basin

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Introduction

The Yellow River Basin represents a transitional zone between eastern and western China in terms of physical geography, socio-economics, and ethnic culture, bearing critical responsibilities for ecological security and economic development. Tourism economic linkages constitute a comprehensive manifestation of tourism factor flows, reflecting the spatial attributes and interrelationships of tourism activities as projected onto geographic space. While the basin historically served as a vital economic region, it has gradually declined through historical transformations, with increasingly severe problems including unbalanced regional development, path dependency, and weakening growth momentum.

In October 2021, the State Council issued the *Outline for Ecological Protection and High-Quality Development of the Yellow River Basin*, which calls for promoting integrated cultural and tourism development and establishing the cultural tourism industry as a pillar industry. As a green and environmentally sustainable industry, tourism is crucial for addressing the complex challenges of economic development and ecological protection while fostering high-quality green development in the Yellow River Basin. Implementation of this strategy will inevitably trigger tourism factor flows within the basin and reshape the urban tourism economic linkage network.

Existing research on tourism economic linkages has primarily focused on regional-level geographic perspectives, with studies evolving from static single-time cross-sections to dynamic analyses of linkage processes. Research on the spatial structure and driving mechanisms of tourism economic networks has become a hotspot, commonly employing modified gravity models for quantitative expression and constructing tourism economic linkage matrices. Social network analysis and spatial statistical methods are then used to parse network node structures, while geographic detectors, geographically weighted regression, and other methods detect influencing factors. At the research scale, scholars have advocated expanding the academic perspective from provincial to basin-level units to break administrative economic constraints and examine urban tourism economic networks from a relational perspective.

However, studies on the Yellow River Basin remain limited, with existing research confined to scenic spots, tourism eco-efficiency interactions, spatial differentiation of tourism economies, and high-quality tourism development. Few have examined the evolution of inter-city tourism economic linkages in the basin. Current research indicates that the basin' s economic linkage development pattern shows hierarchical differentiation and increasing polarization, yet insufficient attention has been paid to how tourism economic linkages manifest spatial differentiation patterns in the basin unit. Tourism spatial structure research has emphasized geographic networks while lacking integration with social network approaches, resulting in imprecise identification of tourism spatial structures in the Yellow River Basin. Furthermore, while existing studies have explored development patterns of regional tourism economic linkages, quantitative analysis using geographic detectors to examine natural and social factors influencing these linkages in the Yellow River Basin remains scarce.

This study addresses these gaps by examining 89 cities in the Yellow River Basin, employing social network analysis and spatial statistical methods to dynamically analyze the network structural characteristics of tourism economic linkages from 2010 to 2019, and systematically analyzing influencing factors using geographic detectors.

1.1 Data Sources

This study integrates the research scope delineated in the *Outline* with findings from previous scholars, ultimately selecting 89 prefecture-level cities (including prefectures and leagues) across Shandong, Henan, Shanxi, Shaanxi, Inner Mongolia, Ningxia, Gansu, and Qinghai provinces as research units (Fig. 1). The division of urban agglomerations follows the specifications in the *Outline*. Considering data accuracy and comparability, the analysis focuses on representative years 2010, 2015, and 2019. Data on tourism revenue and visitor numbers are obtained from provincial statistical yearbooks and bulletins, while inter-city shortest highway distances are sourced from the *China Highway and Urban-Rural Road Network Atlas* for corresponding years.

1.2 Methodology

1.2.1 Modified Gravity Model The gravity model has been widely applied in tourism economic linkage research, but it fails to account for asymmetries and inaccuracies in regional tourism economic connections. Constructing a correction coefficient (k) within the tourism economic linkage model effectively addresses these issues. Drawing on the modified model proposed by Wu Zhicai et al., the formula for calculating tourism economic linkage intensity between any two cities is:

$$R_{ij} = \frac{P_{iV}i \cdot P_{jV}j}{D_{ij}^2}, \quad k_{ij} = \frac{P_{iV}i}{P_{iV}i + P_{jV}j}$$

$$C_i = \sum_{j=1}^{n} R_{ij}$$

where R_{ij} represents the tourism economic linkage intensity from city i to city j; k_{ij} is the correction coefficient indicating the linkage weight of city i to city j; P_i and P_j are the total numbers of tourists received by cities i and j respectively; V_i and V_j are the total tourism revenues of cities i and j; D_{ij} is the distance between cities i and j, measured by the shortest highway mileage; C_i is the total outward tourism economic linkages of city i; and n is the number of cities with tourism economic linkages to city i.

1.2.2 Social Network Analysis Social network analysis emphasizes understanding research objects and inter-individual relationships from a relational or structural perspective, enabling quantitative examination of relationships among actors in a network. This study uses Ucinet 6.0 software to process raw data and quantitatively analyze the tourism economic network structure of the Yellow River Basin, focusing on network density, network centrality, and core-periphery structure.

Network Density measures the closeness of tourism economic linkages among cities, with values ranging from 0 to 1. Higher values indicate tighter inter-city connections:

$$D = \frac{m}{n(n-1)}$$

where D is network density, m is the number of actual relationships, and n is the theoretical maximum number of relationships.

Network Centrality indicates a node' s positional weight and centrality in the network structure. This study selects two indicators: point degree centrality and betweenness centrality.

Point degree centrality reflects a city' s centrality through its number of connections with other cities:

$$C_i = \sum_{j=1}^{n} x_{ij}, \quad C_i' = \frac{C_i}{n-1}$$

where C_i is the absolute point degree centrality of city i, C_i' is the relative point degree centrality, and x_{ij} represents connections between cities.

Betweenness centrality measures a city' s ability to act as an intermediary:

$$C_i = \sum_{j<k} \frac{g_{jk}(i)}{g_{jk}}$$

where C_i is the betweenness centrality of city i, g_{jk} is the number of shortest paths between cities j and k, and $g_{jk}(i)$ is the number of those paths passing through city i.

Core-Periphery Structure analysis identifies core and peripheral regions and their relationships by measuring the distribution of different urban nodes within the region, analyzing the evolution of core-periphery structures in the Yellow River Basin.

1.2.3 Geographic Detector Geographic detector is a statistical method for detecting spatial differentiation and revealing underlying driving forces. This study employs its factor detection and interaction detection functions to identify primary factors influencing tourism economic linkage development in the Yellow River Basin.

Factor detection uses a q-value metric:

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

where L is the number of strata for the variable; N and N_h are the number of units in the entire region and stratum h respectively; σ^2 and σ_h^2 are the variances for the entire region and stratum h; and q measures the explanatory power of the detection factor on tourism economic linkages, ranging from 0 to 1. Larger q-values indicate stronger explanatory power.

2.1 Tourism Economic Linkage Analysis

Using the modified gravity model, tourism economic linkages among Yellow River Basin cities were calculated. Cities are treated as network nodes, with connections represented by tourism economic linkage intensities. ArcGIS software visualizes these linkages (Fig. 2). To enhance visualization, the average linkage intensity across all nodes for each year serves as a threshold, retaining only connections above the average for analysis.

The analysis reveals three key characteristics:

First, a significant east-west network trend has emerged. The basin' s tourism economic network exhibits a prominent point-axis spatial pattern. While the original urban linkage framework continues strengthening, multi-core structures have formed with Xi' an, Zhengzhou, Jinan, Qingdao, Taiyuan, and Lanzhou as growth poles radiating to surrounding cities. However, regional differentiation and inter-provincial barriers remain pronounced. In 2010, only 12 city pairs exceeded a linkage value of 100, concentrated in Xi' an-Xianyang, Zhengzhou-Kaifeng, Taiyuan-Jinzhong, and Jinan-Laiwu, with sparse connections elsewhere. By 2015, 31 city pairs exceeded this threshold, with Zhengzhou, Taiyuan, and Jinan significantly enhancing linkages with neighboring cities. In 2019, 45 city pairs surpassed 100, with Lanzhou-Baiyin and Jiayuguan-Jiuquan emerging as breakthrough points connecting central and western regions, reducing the marginalization of central-western cities and rationalizing the network structure.

Second, regional differentiation and inter-provincial barrier effects are significant. Among top-ranking city pairs, adjacent cities linked to Xi' an, Taiyuan, Zhengzhou, Jinan, and Qingdao account for over 70%, forming independent development patterns within each province. In 2010, only Yuncheng-Sanmenxia and Jincheng-Jiaozuo showed cross-provincial linkages, leaving regional differentiation unmitigated. By 2015, intra-provincial and intra-urban agglomeration linkages strengthened, but regional differentiation persisted, with Xi' an, Taiyuan, Zhengzhou, Jinan, and Lanzhou becoming provincial tourism centers forming five tourism circles. In 2019, despite strengthened inter-city linkages, regional differentiation remained unresolved, with these five cities serving as tourism hubs and the pattern of regional differentiation becoming increasingly evident.

Third, multi-core structural features are prominent. In 2010, only four city pairs exceeded 200 in linkage intensity: Xi' an-Xianyang (1,247.63), Zhengzhou-Kaifeng (243.15), Taiyuan-Jinzhong (238.47), and Zhengzhou-Xinxiang (202.17), forming a single-core growth structure centered on Xi' an-Xianyang. By 2015, 12 city pairs exceeded 200, with Zhengzhou, Taiyuan, and Jinan enhancing linkages with surrounding cities, replacing the single-core structure with a "one superpower with multiple strengths" multi-core pattern and gradually equalizing spatial structure. In 2019, 19 city pairs exceeded 200, with overall urban tourism economic linkages significantly improved, further consolidating the multi-core structure.

2.2 Network Spatial Structure Evolution

Based on tourism economic linkage intensity and total volume data, linkage matrices for three years were constructed. To accurately reflect spatial structure, this study uses the average linkage value across all three periods as a cutoff threshold for binarization, following the principle of retaining effective information while ensuring comparability. Using Ucinet 6.0, network density, point degree centrality, and betweenness centrality metrics characterize the spatial network features. Spatial visualization employs ArcGIS Analyst Tools with inverse distance weighting.

2.2.1 Network Density Analysis

Network density changes significantly across the three periods, with structural complexity increasing. Among 89 cities, theoretical linkages total 7,832, while actual linkages grew from 1,116 (2010) to 1,314 (2015) and 1,518 (2019). Research indicates that network density below 0.2 represents weak economic spatial connections. The Yellow River Basin' s network density increased from 0.142 to 0.168 and 0.194, remaining in a weak connection state and requiring structural optimization.

2.2.2 Point Degree Centrality Analysis

Figure 3 shows that point degree centrality is generally low with significant spatial variation. High-value areas appear in the Shandong Peninsula, Central Plains, and Guanzhong Plain urban agglomerations, where Jinan, Qingdao, Zhengzhou, and Xi' an have limited radiation effects confined to surrounding areas, with obvious barriers between agglomerations. Other cities show low values, even zero, primarily in central-western regions, indicating weak node centrality and severely unbalanced networks.

By 2015, point degree centrality values increased universally. High-value areas shifted toward Jinan-centered regions in the Shandong Peninsula, with weakened barrier effects between high-value zones. Radiation and driving capabilities of central cities improved, forming the prototype of a "highland continuous zone."

Low-value areas also increased significantly, particularly Lanzhou and Xining, indicating enhanced node centrality and strengthened organic connections and interaction effects, moderating the two-level differentiation trend.

In 2019, values continued concentrating in Jinan-core regions. Central Plains and Guanzhong Plain agglomerations saw sustained growth, forming three high-value zones that broke regional barriers and achieved organic connections. Lanzhou and adjacent areas showed remarkable increases, as did Jinzhong and other cities. This demonstrates that the tourism economic linkage structure is optimizing toward cluster development, with polarization substantially alleviated and the overall network trending toward equilibrium.

2.2.3 Betweenness Centrality Analysis

Figure 4 reveals that high betweenness centrality zones are concentrated in the Shandong Peninsula and Guanzhong Plain urban agglomerations, where Xi' an, Zhengzhou, Luoyang, Jinan, and Qingdao hold prominent intermediary positions with monopolistic control. Low-value areas appear in northwestern regions, indicating these cities serve as crucial network channels with extreme control over others, resulting in severely imbalanced network structures.

In 2015, Shandong Peninsula' s betweenness centrality concentrated in Jinan-centered areas, while Central Plains and Guanzhong Plain agglomerations saw significant increases, forming new high-value zones with the Yellow River "Ji" character-shaped metropolitan circle. Cities like Jining, Luoyang, and Jiaozuo showed remarkable growth, while western low-value areas generally improved, with Lanzhou showing particularly significant increases. This indicates that control over tourism economic linkage channels is gradually shifting, with network structure trending toward equilibrium and optimization.

By 2019, Shandong Peninsula and Central Plains formed a betweenness centrality low-value zone, with values dropping significantly in all cities except Jinan and Zhengzhou. This reflects these eastern agglomerations' advantages in maritime transport and external tourism connections, resulting in fewer linkages with midstream and downstream cities. Guanzhong Plain remained a high-value zone with diffusion to surrounding areas, where Xi' an' s betweenness centrality reached 28.03, indicating its superior resource transmission advantages and role as a tourism distribution center controlling and influencing other cities. However, the lack of alternative cities may create bottlenecks. In western low-value areas, provincial capitals like Lanzhou, Yinchuan, and Xining showed the highest betweenness centrality values, indicating that crucial channels are gradually shifting westward, equalizing the basin' s network structure.

2.2.4 Core-Periphery Structure Analysis

The core-periphery model clarifies the distribution of core and peripheral cities in the network (Table 1). In 2010, 13 nodes constituted the core area, forming a Shandong Peninsula cluster centered on Qingdao and Jinan, and a midstream cluster centered on Zhengzhou. By 2015, core area members increased to 17 (30.0% growth), with Shanxi adding 53.8% of its cities as new core members showing clustering trends. Henan' s Kaifeng, Pingdingshan, and Anyang became new core areas, with significant growth at the Shanxi-Henan border. By 2019, core area members reached 22 (29.4% growth), with Weinan, Linfen, and Sanmenxia at the Shanxi-Shaanxi-Henan border adding the most new core areas.

Overall, the Yellow River Basin' s tourism economic linkage "core-periphery" structure is gradually forming, with core areas expanding and peripheries contracting. The core is diffusing from traditionally developed tourism economic zones to surrounding cities, spreading from the Shandong Peninsula to the Guanzhong Plain and forming cluster development trends, indicating self-regulation of inter-city tourism economic differences and network structure optimization. The Shandong Peninsula and Central Plains urban agglomerations belong to absolute core areas, while western basin cities remain absolute peripheries.

2.3 Impact Factor Analysis

Changes in Yellow River Basin tourism economic linkages result from multiple interacting factors. Drawing on relevant research and combining spatial pattern conclusions with regional tourism economic development realities, this study establishes indicators from socio-economic and natural environmental factors.

Socio-economic factors include: economic development level (X_1, per capita GDP), industrial structure level (X_2, tertiary industry share), openness level (X_3, total import-export volume), tourism service level (X_4, number of star-rated hotels), transportation development level (X_5, road density), and tourism resource endowment (X_6, comprehensive weight calculated from world heritage sites, national scenic spots, and A-level attractions). Natural factors include: average elevation (X_7), annual precipitation (X_8), annual temperature (X_9), and environmental quality (X_{10}, annual average PM2.5 concentration). Total tourism economic linkages serve as the dependent variable for analysis at three time nodes.

2.3.1 Primary Impact Factor Analysis Table 2 shows that primary influencing factors vary across periods. In 2010, factors ranked by explanatory power (q-value) were: X_6 (0.652) > X_2 (0.481) > X_4 (0.423) > X_{10} (0.387) > X_5 (0.352) > X_3 (0.301) > X_7 (0.245) > X_8 (0.198) > X_9 (0.167) > X_1 (0.142). In 2015, the ranking became X_6 (0.681) > X_2 (0.452) > X_4 (0.398) > X_{10} (0.365) > X_3 (0.378) > X_5 (0.324) > X_1 (0.298) > X_7 (0.267) > X_8 (0.203) > X_9 (0.176). In 2019, it shifted to X_6 (0.634) > X_2 (0.467) > X_{10} (0.421) > X_4 (0.385) > X_3 (0.398) > X_5 (0.341) > X_1 (0.312) > X_7 (0.254) > X_8 (0.189) > X_9 (0.158).

Key factors identified are tourism resource endowment (X_6), industrial structure level (X_2), and environmental quality (X_{10}). Tourism resource endowment shows the most significant impact, with its q-value peaking in 2015 then slightly declining, indicating untapped potential. Industrial structure level' s driving effect weakened across the three periods, likely due to temporary adjustments under China' s economic transformation pressures, suggesting an urgent need for optimization. Tourism service level' s impact also weakened, indicating the basin should enhance star-rated hotel infrastructure and service capacity. Environmental quality' s influence showed a decrease-then-increase trend, demonstrating the need for continued improvement through reducing PM2.5 emissions to create quality tourism environments. Openness level' s significant impact increased notably in 2015, likely due to Silk Road Economic Belt development and China-Europe Railway Express hub construction in Xi' an and Zhengzhou.

2.3.2 Interactive Factor Detection Analysis Interaction detection analysis of factor pairs reveals that all factors exhibit enhanced synergistic effects without any single dominant factor acting alone (Table 3). The interaction between factors better explains tourism economic linkage changes, reflecting the complexity of these dynamics.

In 2010, dominant interactive factors were X_2 X_6 (0.782) and X_4 X_6 (0.764). In 2015, they became X_3 X_6 (0.821) and X_2 X_6 (0.798). In 2019, X_2 X_6 (0.812) and X_{10} X_6 (0.789) dominated. This shows that besides primary factors, tourism economic linkages are also related to economic development level, average elevation, and annual temperature, whose comprehensive interactions promote linkage enhancement.

For example, Shandong and Henan in the lower basin have better economic foundations, complete transportation infrastructure, flat terrain, and suitable temperatures—natural advantages for tourism development that effectively promote capital and population agglomeration, creating strong factor interactions and high linkage intensity. Conversely, upstream regions like Qinghai, Ningxia, and Gansu have weaker economic foundations, lagging tourism infrastructure, plateau-dominated terrain, and cold temperatures that constrain capital and population inflows, resulting in weaker factor interactions and lower tourism economic linkages.

3.1 Conclusions

(1) Tourism economic linkages among Yellow River Basin cities have gradually strengthened over time, developing toward an east-west network orientation. Multi-core structures have formed with Xi' an, Zhengzhou, Jinan, Qingdao, Taiyuan, and Lanzhou as growth poles driving surrounding cities, though significant regional differentiation effects persist between cities.

(2) The evolution of inter-city tourism economic linkages has progressed through three stages: an initial phase of polarization and substantial barriers, a transitional phase of organic connection and enhanced interaction, and a consolidation phase of balanced and cluster development. Control channels for tourism economic linkages are gradually shifting westward, with spatial structures becoming more balanced. The Shandong Peninsula and Central Plains urban agglomerations constitute absolute core areas, while western basin cities remain absolute peripheries.

(3) Industrial structure level, tourism resource endowment, and environmental quality are the primary influencing factors. Enhanced synergistic interactions among factors better explain tourism economic linkage changes, demonstrating the complexity of these dynamics in the Yellow River Basin.

3.2 Recommendations

Based on these findings, we propose the following recommendations to promote high-quality tourism economic development in the Yellow River Basin:

(1) Adopt a "whole basin as one chessboard" perspective to actively break administrative barriers. Leverage the tourism engine and radiation effects of Xi' an, Zhengzhou, Jinan, Taiyuan, and Lanzhou in their respective urban agglomerations. Utilize inter-city transportation networks to achieve axial connectivity and build a collaborative, integrated tourism development pattern.

(2) Western basin cities remain in peripheral positions. These cities should capitalize on comparative advantages in eco-tourism resources, enhance tourism resource endowment orientation to strengthen attractiveness, and utilize core areas' promotional guidance under tourism distribution functions to accelerate tourism flow diffusion westward, achieving balanced network structure development.

(3) Fully exploit the promoting effects of tourism resource endowment and other factors. Given the currently weak driving effect of transportation development, accelerate construction of multi-level transportation networks, especially integrated transport systems in peripheral cities. Improve the basin' s inter-city transportation-tourism linkage development system, using tourism resource advantages to drive transportation infrastructure upgrades and achieve coordinated regional tourism economic development.

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