A Study on the Spatiotemporal Patterns and Spatial Spillover Effects of Cultural Industry Clusters in the Yellow River Basin (Postprint)

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Abstract

Based on panel data from 62 cities in the Yellow River Basin from 2005 to 2020, this study constructs an indicator system for cultural industry cluster levels from three dimensions—cluster scale, connectivity, and specialization—and employs Moran's I and the spatial Durbin model to investigate the spatiotemporal patterns of cultural industry clusters in the Yellow River Basin and the influencing factors of spatial spillover effects, based on clarifying the mechanisms and pathways of spatial spillover effects. The results show that: (1) From 2005 to 2020, the mean value of the cultural industry cluster index in the Yellow River Basin increased from 0.07 to 0.21, exhibiting an overall "positive triangle" distribution pattern. (2) The development levels of cultural industry clusters among cities are unbalanced, with a significant "siphon effect" evident, and the impact of each explanatory variable on spillover effects varies substantially. (3) Spatial spillover effects exhibit a significant correlation with geographic distance; when geographic distance reaches 500 km, positive spatial spillover effects are strongest, and when exceeding 850 km, spatial spillover effects gradually disappear, showing an overall inverted "U-shaped" trend. Based on the above analysis, to accelerate the development of cultural industry clusters in the Yellow River Basin, enhance regional competitiveness, and narrow regional development gaps, recommendations are proposed including strengthening regional collaborative cooperation, grasping the urban renewal process, and avoiding homogeneous competition.

Full Text

Spatiotemporal Pattern and Spatial Spillover Effect of Cultural Industry Clusters in the Yellow River Basin

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Abstract

Based on a comprehensive understanding of the industrial cluster concept, this study constructs an evaluation index system for cultural industry cluster levels. Employing Moran's I and the Spatial Durbin Model, and clarifying the mechanisms and pathways of spatial spillover effects, we investigate the spatiotemporal patterns of cultural industry clusters in the Yellow River Basin and the factors influencing their spatial spillover effects. Using panel data from 62 cities in the basin from 2005 to 2020, we measure cluster levels across three dimensions: scale, connectivity, and specialization. Results indicate that: (1) The average cultural industry cluster index in the Yellow River Basin increased from 0.07 to 0.21 between 2005 and 2020, exhibiting an overall "positive triangle" distribution pattern. (2) Development levels among cities are unbalanced, with a significant "siphon effect" evident, and various explanatory variables demonstrate markedly different impacts on spillover effects. (3) Spatial spillover effects show clear correlation with geographic distance; the positive spillover effect is strongest at a geographic distance of 500 km, gradually diminishing beyond 850 km and displaying an inverted "U" shape trend. Based on these findings, we propose recommendations to accelerate cultural industry cluster development in the Yellow River Basin, enhance regional competitiveness, and narrow development gaps, including strengthening regional collaborative cooperation, leveraging urban renewal processes, and avoiding homogenous competition.

Keywords: Yellow River Basin; cultural industry; cluster level; influencing factors; spatial spillover effect

Introduction

As China's economy enters a high-quality development phase, it is currently in a critical period of optimizing economic structure and transforming growth drivers. The cultural industry is recognized as a new growth point for economic development, and cultural industry clusters have become an important phenomenon in cultural industry development. The "14th Five-Year Plan for Cultural Development" issued in 2021 explicitly proposes promoting high-quality development, with culture serving as a crucial fulcrum requiring further expansion of the cultural industry. In recent years, with increased national emphasis on and development of the cultural industry, both the level and scale of cultural industry clusters have improved significantly. The Yellow River Basin, as an important pilot zone for high-quality development, possesses rich historical and cultural resources. However, due to geographical constraints and other factors, its economic development has lagged behind other regions for years, with prominent inter-regional imbalances. As an organizational form of the cultural industry, clusters play a vital role in promoting regional economic growth. Studying the spatiotemporal patterns and spatial spillover effects of cultural industry clusters in the Yellow River Basin is an urgent need to accelerate the basin's high-quality development transformation, promote balanced regional development, and enhance cultural soft power.

According to the industrial cluster concept, a cultural industry cluster is a specialized industrial organization formed by cultural enterprises and related institutions aggregating in a specific region and collaborating with one another. Current scholars have conducted extensive research on cultural industry clusters. Regarding cluster models, they can be categorized into specialized clusters, diversified clusters, and competitive clusters. Specialized and diversified clusters promote cultural industry cluster development by reducing market risks and enhancing inter-industry complementarity, and these two models generate complementary trends. In terms of influence mechanisms, they promote regional innovation, knowledge spillovers, generate competition that drives technological progress and productivity improvements, enhance upstream-downstream collaboration, and reduce factor acquisition costs. Moreover, the clustering process enables production processes to integrate with geographical environments, creating cumulative circular effects that further elevate cultural industry cluster levels. However, China's cultural industry clusters are still in the early development stage, where crowding effects may occur, making it difficult for positive effects to manifest.

Regarding spatial distribution, studies have been conducted at national, provincial, and municipal scales, revealing significant regional differences in cultural industry cluster levels and an overall pattern of "local concentration and overall dispersion." Empirical research has found that cultural industry clusters exhibit spatial dependence and significant spatial spillover effects. As spatial effects are constrained by geographic distance, the compression of spatiotemporal distances gradually enables cluster spillover effects to transcend geographical limitations.

Currently, domestic and international research on cultural industry clusters has yielded relatively rich results, but studies on influencing factors of spatial spillover effects remain limited, particularly lacking research at the municipal administrative scale within the Yellow River Basin. Existing cluster level index systems lack objectivity and authenticity, and analyses of spatial spillover effect pathways are relatively rare, with overly simplistic selection of influencing factors. Finally, with advancements in transportation and communication technologies, spillover effects may have changed, yet research on how these effects vary across different distances and their attenuation characteristics is particularly scarce.

Based on this context, this study first reconstructs the cultural industry cluster level index system to measure urban cultural industry cluster levels. Second, it employs Moran's I to analyze spatial correlation. Third, it constructs multiple spatial weight matrices and uses spatial econometric methods to conduct empirical analysis on influencing factors of cluster level spillover effects in the Yellow River Basin from 2005 to 2020. Finally, it constructs a geographic threshold weight matrix to examine spillover effect attenuation characteristics. The marginal contributions of this research are threefold: First, based on understanding the connotation and extension of industrial clusters, it reconstructs the evaluation index system for cultural industry cluster levels. Second, it explores how different factors influence spillover effects, providing references for central cities in the Yellow River Basin to drive cluster development in peripheral cities, enhance regional integration, and accelerate high-quality economic development. Third, it provides empirical evidence that cultural industry cluster spillover effects have transcended geographical constraints.

1. Methodology

1.1 Study Area Overview

Based on the natural basin delineated by the Yellow River Conservancy Commission of the Ministry of Water Resources, the Yellow River Basin covers an area of 79.5$×10^{4}$ km^2. As a crucial origin of Chinese civilization, the high-quality development of the Yellow River Basin is vital not only to the modernization process of the basin itself but also to the pace of national modernization. The basin is rich in cultural heritage. According to statistics, it possesses 1,274 national-level intangible cultural heritage items, accounting for 53.7% of the national total, and 1,451 key national cultural heritage protection units, with a distribution density 1.69 times the national average.

1.2 Data Sources

Taking 62 cities in the Yellow River Basin as research samples and maintaining complete municipal administrative boundaries, the study period spans 2005–2020. Data primarily originate from the *China City Statistical Yearbook* (2006–2021). Missing data for individual years were supplemented using interpolation methods. The number of cultural industry entities was obtained through the Aiqicha enterprise information query platform (https://aiqicha.baidu.com/?from=pz).

1.3 Construction of Cultural Industry Cluster Level Index System

Existing index systems struggle to clearly depict regional cultural industry cluster levels. Based on previous research, we further construct a cultural industry cluster level index system:

1) **Cluster Scale**: Represented by the number of "cultural industry entities."

2) **Cluster Connectivity**: As cultural enterprises are predominantly small and medium-sized, making inter-firm connections difficult to measure directly, we use the "Average Nearest Neighbor Index" as a metric, calculated as follows:

$$\text{ANN} = \frac{\bar{D}_o}{\bar{D}_e}$$

where $\bar{D}_o$ is the average distance between enterprises and their nearest neighbor, and $\bar{D}_e$ is the average distance under random distribution.

3) **Cluster Specialization Level**: Measured by "location quotient," calculated as:

$$\text{LQ}_{ij} = \frac{q_{ij}/q_j}{q_i/q}$$

where LQ_{ij} is the location quotient of cultural industry i in city j; q_{ij} is the number of employees in cultural industry i in city j; q_j is the total number of employees across all industries in city j; q_i is the number of employees in cultural industry i nationwide; and q is the total number of employees across all industries nationwide.

Numerous methods exist for assigning indicator weights, but data indicators are fraught with uncertainty. Therefore, based on the connotation and characteristics of the concept, we assign weights of 0.4, 0.3, and 0.3 to the three dimension indicators, respectively. Finally, the urban cultural industry cluster level (CICI) is obtained by summing the three indicators:

$$\text{CICI} = 0.4 \times N + 0.3 \times \frac{1}{\text{ANN}} + 0.3 \times \text{LQ}$$

where N is the number of cultural industry entities; ANN is the average nearest neighbor index of cultural enterprises; and LQ is the location quotient.

1.4 Variable Selection

To thoroughly investigate the spatial spillover effects of cultural industry cluster levels and examine the pathways and mechanisms of these effects, we select influencing factors from three dimensions: physical spatial environment, socio-economic environment, and infrastructure level. After standardization, the entropy weight method is used to determine indicator weights (Table 2). According to the *Classification of Cultural and Related Industries (2018)*, cultural enterprises are categorized into eight types: news information services, content creation and production, creative design services, cultural communication channels, cultural investment operations, cultural entertainment and leisure services, cultural auxiliary production and intermediary services, and cultural equipment manufacturing.

Spatial spillover depends on factors such as human resources, information, and infrastructure, with primary mechanisms and pathways including:

1) **Knowledge Spillover Effect**: "Learning by doing" serves as the main form of knowledge spillover, relying on information exchange among enterprise research and management personnel to facilitate inter-firm knowledge sharing.
2) **Competition Effect**: Competition stimulates innovation, enhancing productivity levels through innovation. Simultaneously, competitive pressure transfers to less competitive areas, promoting development in lagging regions.
3) **Synergy and Complementarity Effect**: Cluster enterprises improve resource allocation efficiency and reduce factor acquisition costs through mutual exchange and collaboration, thereby generating spillover effects.

1.5 Spatial Analysis Methods

Moran's I is an important indicator for measuring spatial correlation. We employ univariate global Moran's I (I_{global}) and bivariate global Moran's I (I_{global}) to examine spatial correlation patterns from a global perspective. Local Moran's I (I_{local}) is used to investigate local spatial correlation patterns. The calculation formulas are as follows:

$$I_{\text{global}} = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij}(x_i - \bar{x})(y_j - \bar{y})}{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} \sum_{i=1}^{n} (x_i - \bar{x})^2}$$

$$I_{\text{local}} = \frac{(x_i - \bar{x})}{S^2} \sum_{j=1}^{n} W_{ij}(y_j - \bar{y})$$

where n is the number of cities; i and j are city indices; W_{ij} is the spatial weight matrix between cities i and j; x_i, y_i, and y_j are the values of explanatory variable x and explained variable y in cities i and j, respectively; $\bar{x}$ and $\bar{y}$ are the mean values of explanatory variable x and explained variable y; and S^2 is the sample variance. The Moran's I value ranges between [-1, 1].

1.6 Spatial Econometric Model

Traditional econometric models overlook the interdependence of influencing factors across time and space, leading to model specification bias and resulting in incomplete, unscientific research findings that lack explanatory power. Spatial econometric models effectively address statistical biases caused by spatial and temporal correlation among observations, primarily including the Spatial Lag Model (SLM), Spatial Error Model (SEM), and Spatial Durbin Model (SDM).

The **Spatial Lag Model** is primarily used to explore spatial interactions among explained variables in neighboring regions, calculated as:

$$y = \rho W y + X\beta + \varepsilon$$

where y is the explained variable; ρ is the spatial lag term coefficient; Wy is the spatial lag term of the explained variable; β is the regression coefficient; X is the explanatory variable; and ε is the random error term.

The **Spatial Error Model** verifies that when a shock occurs in one region, its spillover impact on neighboring regions is reflected through the spatial error term:

$$y = X\beta + \mu, \quad \mu = \lambda W \mu + \varepsilon$$

where y is the explained variable; β is the regression coefficient; X is the explanatory variable; μ is the disturbance term; λ is the spatial error term coefficient; $W\mu$ is the spatial error term; and ε is the random error term.

The **Spatial Durbin Model** serves as the standard framework for capturing various spatial spillover effects:

$$y = \rho W y + X\beta + W X\theta + \varepsilon$$

where y is the explained variable; ρ and θ are spatial lag term coefficients; Wy is the spatial lag term of the explained variable; β is the regression coefficient; X is the explanatory variable; WX is the spatial lag term of the explanatory variable; and ε is the random error term.

Spatial weight matrix specification significantly impacts model results. To ensure research reliability, we construct three types of spatial weight matrices:

1) **Geographic Distance Spatial Weight Matrix**: $W_{\text{dis}} = 1/d_{ij}^2$, where d_{ij} is the geographic distance between cities (km).
2) **Economic Weight Matrix**: $W_{\text{eco}} = 1/|E_i - E_j|$, where E_i and E_j are per capita GDP (yuan) of cities i and j.
3) **Economic-Geographic Spatial Weight Matrix**: $W_{\text{gra}} = W_{\text{dis}} \times \text{diag}(\bar{E}_i/\bar{E})$, where E_i is per capita GDP of city i and $\bar{E}$ is the average per capita GDP of the study area. Considering substantial economic disparities among cities, the impact effects vary across different economic scales, so we construct an economic distance nested spatial weight matrix to reflect the interaction effects among cities of different economic sizes.

2. Results

2.1 Spatial Distribution and Correlation Analysis of Cultural Industry Cluster Levels

2.1.1 Spatial Distribution Characteristics of Cultural Industry Cluster Levels We calculated urban cultural industry cluster levels using the CICI formula and visualized them using the natural breaks method (Figure 2). Results show that the average cultural industry cluster index increased from 0.07 in 2005 to 0.21 in 2020. In terms of spatial distribution, cluster levels in central and eastern regions are significantly higher than in western regions. High-level areas are mainly concentrated in provincial capitals such as Jinan, Zhengzhou, and Yinchuan. Southern Gansu and northern Shanxi exhibit lower cluster levels. Regarding the distribution of cities across different levels, the number of high-level cities is small while low-level cities are numerous. Overall, the distribution pattern of cluster levels remains largely unchanged, but growth rates vary significantly across cities.

2.1.2 Spatial Correlation Analysis of Cultural Industry Cluster Levels Using data from 2005, 2010, 2015, and 2020, we calculated global Moran's I (I_{global}) and local Moran's I (I_{local}). Results show that I_{global} is negative and passes significance tests at the 1% level, indicating an increasingly evident "siphon effect" among cities in the Yellow River Basin. Furthermore, using cultural industry cluster level as the central variable and various influencing factors as peripheral variables, we calculated bivariate global Moran's I, which is also basically negative, suggesting a negative correlation between cultural industry cluster levels and various influencing factors. Local Moran's I is consistently negative, further verifying the "siphon effect" phenomenon among cities, with consistent trend patterns to global Moran's I.

To more intuitively demonstrate spatial association types, we used Moran's I scatter plots to conduct significance tests on regions where $P < 0.05$. Results indicate that high-high agglomeration areas are mainly concentrated in central Shanxi, central Inner Mongolia, and Zhengzhou and Luoyang in Henan. Low-low agglomeration areas are primarily located in the upper reaches of the Yellow River, indicating generally low cultural industry cluster levels in this region. Overall, the number of cities in high-high agglomeration mode increased by 8 from 2005 to 2020, while low-low agglomeration cities increased by 12, demonstrating increasingly severe regional imbalance.

[Figure 3: see original paper]

2.2 Spatial Spillover Effects of Cultural Industry Cluster Levels and Influencing Factors

2.2.1 Model Estimation and Testing Before model analysis, we first conducted multicollinearity tests on influencing factors. The variance inflation factor (VIF) values are all below 10, indicating no collinearity issues. Second, we tested different spatial models. Robust Lagrange Multiplier (LM) test results are significant at the 1% level, indicating spatial correlation exists in both error and lag terms. Wald and Likelihood Ratio (LR) tests reject the null hypothesis, suggesting SDM should not be simplified to SLM or SEM. Combined with Hausman test results that reject the null hypothesis, we compared fixed-effects models under different matrices. The time fixed-effects regression coefficient (ρ) under the economic-geographic spatial weight matrix is -0.24, with goodness-of-fit (R^2) of 0.81 and large log-likelihood value (Table 4). We ultimately adopted the SDM under time fixed effects with economic-geographic spatial weight matrix.

2.2.2 Spatial Spillover Effect Analysis Table 4 shows that the regression coefficient is -0.24, indicating significant negative spillover effects of cultural industry cluster levels. A 1% increase in local cluster level leads to a 0.24% decrease in neighboring cities' cluster levels.

2.2.3 Spatial Spillover Effect Decomposition If the coefficient of the explained variable's spatial lag term is non-zero, the total effects of explanatory variables will be biased, requiring decomposition using partial differential methods (Table 5). Overall, direct effects of all explanatory variables are positive, while indirect effects are only positive for per capita GDP and number of teachers in regular institutions of higher education.

1) **Ecological environment quality, economic development level, proportion of tertiary industry, and public library collections** show positive direct effects significant at the 1% level. This likely occurs because these factors enhance urban attractiveness to population, promote industrial structure optimization and transformation, and foster urban cultural atmosphere, directly driving rapid cluster level development.

2) **Urban road area, built-up area green coverage rate, total nighttime light, and proportion of tertiary industry** show negative indirect effect coefficients, significant at the 1% or 5% level. Urban infrastructure, green coverage, and urban development level enhance a city's attractiveness, particularly for high-end talent, reducing cultural industry demand in neighboring cities. A city's own industrial structure adjustment and optimization may lead to industrial transfer, with cities more inclined to transfer low-quality, low-efficiency industries to neighboring cities, causing high energy consumption and environmental quality deterioration in those cities, thereby inhibiting cluster level improvement.

Per capita GDP and number of teachers in regular institutions of higher education have significant positive direct and indirect effects on cultural industry cluster level improvement. Per capita GDP reflects labor productivity differences, while teacher numbers reflect labor quality. Improvements in labor efficiency and quality promote local cultural industry rapid development. Meanwhile, geographic proximity reduces the cost of talent and resource factor mobility, enabling more high-quality resources to concentrate in central cities and generating obvious "core-periphery" effects.

2.2.4 Spatial Spillover Effect Attenuation To examine the attenuation boundary of spatial spillover effects, we established threshold geographic weight matrices with an initial threshold of 100 km, increasing geographic distance by 100 km increments (Equation 12). Regression analysis using these matrices can eliminate the influence of cities beyond threshold values.

$$W_{ij} = \begin{cases} 1/d_{ij}^2 & \text{if } d_{ij} \le d \\ 0 & \text{if } d_{ij} > d \end{cases}$$

where W_{ij} is the distance between cities i and j (km); d is the set distance threshold.

Regression results show that as distance continuously increases, spatial spillover effects exhibit an inverted "U" shape trend (Figure 4), indicating:

1) When the threshold is less than 250 km, negative spatial spillover effects occur, manifesting as a "nearby darkening" phenomenon. This may be because geographic proximity lowers talent and resource factor mobility costs, causing more high-quality resources to concentrate in central cities and generating obvious "agglomeration shadow" effects.
2) When the threshold is between 250–850 km, the spatial spillover effect becomes positive and passes significance tests. At a geographic distance of 500 km, the spatial spillover effect peaks at 0.18, indicating that central cities have more significant driving effects on cluster levels in peripheral cities within the province. This is likely because peripheral cities have lower cluster levels and thus stronger dependence on central cities, while spatiotemporal compression effects facilitate more convenient resource flows to peripheral cities.
3) When distance exceeds 850 km, the effect rapidly diminishes and fails significance tests, indicating that cities beyond this threshold are almost unaffected by spillover effects.

[Figure 4: see original paper]

3. Discussion

This study uses 62 municipal administrative units in the Yellow River Basin from 2005 to 2020 to reconstruct the cultural industry cluster level index system, clearly depicting regional urban cluster levels. Using Moran's I, we investigate spatial correlation of cluster levels. Results show that cultural industry cluster levels in the Yellow River Basin have significantly increased but with marked regional differences, consistent with previous research. Studies using provincial spatial scales struggle to reveal more accurate spatial correlations and spillover effects. Therefore, by examining the municipal spatial scale, this study discovers that:

1) The overall cultural industry cluster index in the Yellow River Basin is relatively low and extremely unevenly distributed, presenting an "east-high, west-low" development pattern. The distribution of cities across different levels shows a "positive triangle" pattern.

2) Cultural industry cluster levels in the Yellow River Basin exhibit increasingly significant negative spatial spillover effects, showing a "solo pleasure" development trend. Over time, more cities belong to the high-high agglomeration mode, with a severe "Matthew effect."

3) When geographic distance is less than 250 km, spatial spillover effects are significantly negative. However, as distance increases, negative spatial spillover effects gradually transform into positive promotion effects, with cross-administrative division promotion emerging. At approximately 850 km, spatial spillover effects gradually weaken.

The development of cultural industry clusters in the Yellow River Basin is crucial for promoting rapid regional economic development and even driving high-quality basin development. Based on our findings, we propose the following recommendations: (1) Establish a theoretical concept of synergistic development by clarifying the "big relationship" among upper, middle, and lower basin developments and grasping the "small relationship" between central and peripheral cities to construct development models at different spatial scales and promote balanced regional development. (2) Actively seize opportunities in urban renewal by improving urban ecological quality, strengthening infrastructure construction, ensuring basic medical service facilities, and enhancing urban attractiveness to population. (3) Guide the development of cultural industry cluster models according to local conditions to avoid homogenous competition.

Using the average nearest neighbor index of cultural enterprises to describe inter-firm connectivity is more reasonable and scientific compared to existing research, though room for expansion remains. Due to data availability limitations, the examination of knowledge and economic factor connections in constructing the cultural industry cluster index is insufficient. Future research should strengthen quantitative studies of knowledge and economic connections among enterprises.

In studying influencing factors of spillover effects, we reselected factors based on a deep understanding of industrial cluster concepts and spatial spillover effect pathways and mechanisms. Results show that only labor efficiency and labor quality generate positive spillover effects, while other factors produce negative spillover effects, partially differing from other regional studies. This may be because the overall development level of the Yellow River Basin is relatively low, with inadequate policy perfection and talent mobility, causing some influencing factors to exert negative effects on spillover effects.

Finally, using a spatial threshold geographic weight matrix, we find that spatial spillover effects significantly correlate with geographic distance, indicating that cultural industry cluster level spillover effects have transcended geographical distance constraints.

4. Conclusions and Recommendations

This study further constructs a cultural industry cluster level evaluation index system. By analyzing the mechanisms and pathways of spatial spillover effects, it employs the spatial Durbin model to analyze influencing factors of spatial spillover effects and constructs a geographic threshold matrix to characterize spillover effect attenuation patterns. The following conclusions are drawn:

1) From 2005 to 2020, the average cultural industry cluster index in the Yellow River Basin increased from 0.07 to 0.21. However, the distribution is extremely uneven, showing an "east-high, west-low" development pattern, with city-level distributions displaying a "positive triangle" pattern.

2) Cultural industry cluster levels in the Yellow River Basin exhibit significant negative spatial spillover effects, with a severe "Matthew effect." Over time, the number of cities in high-high agglomeration mode increased by 8, while low-low agglomeration cities increased by 12, indicating increasingly severe regional imbalance.

3) Decomposition of spatial spillover effects reveals that selected influencing factors have negative spillover effects on cultural industry cluster levels in neighboring cities. Only labor efficiency and labor quality show positive spillover effects, while other factors exhibit negative spillover effects.

4) Spatial spillover effects show a notable correlation with spatial distance. The positive spatial spillover effect is strongest at a geographic distance of 500 km, gradually diminishing as distances exceed 850 km, exhibiting an inverted "U" shape trend.

The study reveals a distinct "cluster shadow" phenomenon among cities in the Yellow River Basin, with weak positive spillover effects. Therefore, to accelerate cultural industry cluster development, improve regional competitiveness, and narrow development gaps, establishing theoretical concepts of synergistic development, leveraging urban renewal opportunities, and adopting context-specific development models are crucial for contributing to the high-quality development of the Yellow River Basin.

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