Postprint of "Coordinated Development and Impact Pathways of China's 'Ecology-Tourism-Culture' System"

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Abstract

The three subsystems of ecology, tourism, and culture constitute a complex system of interactions, and the coordinated development of this system is of great significance for promoting regional sustainable development. Based on panel data for 31 provincial-level regions in China from 2011 to 2022, this study constructs an evaluation index system for the comprehensive development of the "ecology-tourism-culture" system, and employs the comprehensive evaluation function model, the coupling coordination degree model, and fuzzy-set qualitative comparative analysis (fsQCA) to explore the spatio-temporal differentiation and influencing pathways of coordinated system development. The results show that: (1) The trends in the comprehensive development levels of each subsystem differ, and the comparative ranking of the mean index values is natural ecology > ecology > social ecology > culture > tourism, indicating that the ecological subsystem still has remaining carrying capacity. (2) The overall coupling coordination degree of the "ecology-tourism-culture" system presents a cyclical pattern of alternating decline and rise, fluctuating upward from 0.507 in 2011 to 0

Full Text

Coordinated Development and Influence Paths of the "Ecology-Tourism-Culture" System in China

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Abstract

The three subsystems of ecology, tourism, and culture constitute an interactive complex system, whose coordinated development holds significant importance for promoting regional sustainability. Based on panel data from 31 Chinese provinces (excluding Hong Kong, Macau, and Taiwan) from 2011 to 2022, this study constructs a comprehensive development evaluation index system for the "ecology-tourism-culture" system. Employing a comprehensive evaluation function model, coupling coordination degree model, and fuzzy-set qualitative comparative analysis (fsQCA), we investigate the spatiotemporal differentiation and influence paths of system coordinated development. Results indicate: (1) The comprehensive development levels of the three subsystems exhibit divergent trends, with index means ranking as natural ecology > ecology > social ecology > culture > tourism. The ecological subsystem retains carrying capacity, while the tourism subsystem consistently lags behind. (2) The overall coupling coordination degree of the "ecology-tourism-culture" system displays a cyclical "decline-increase" pattern, rising from 0.507 in 2011 to 0.526 in 2022 and fluctuating between near-imbalance and barely-coordinated levels. Regional coupling coordination follows the order eastern > central > northeastern > western regions, showing a "high in southeast, low in northwest" distribution pattern. (3) High-coordination development types include diversified development, government-led industry, and economy-market-technology driven models, whereas non-high coordination development is constrained by government and technology limitations.

Keywords: "ecology-tourism-culture" system; coordinated development; influence paths; China

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1. Data and Methods

1.1 Data Sources

This study utilizes panel data from 31 Chinese provinces (excluding Hong Kong, Macau, and Taiwan) spanning 2011–2022. Data were obtained from the *China Statistical Yearbook*, *China Environmental Statistics Yearbook*, *China Tourism Statistics Yearbook*, *China Culture and Tourism Statistics Yearbook*, *China Culture and Related Industries Statistics Yearbook*, and *China Trade and Foreign Economic Statistics Yearbook* (2012–2023 editions). Additional sources include the National Cultural Heritage Administration (http://www.ncha.gov.cn), National Bureau of Statistics (https://www.stats.gov.cn), Ministry of Housing and Urban-Rural Development (https://www.mohurd.gov.cn), provincial culture and tourism department websites, CEIC Data (China Economic Database),

and provincial statistical yearbooks. Missing data were supplemented using provincial national economic and social development statistical bulletins and linear interpolation. The grey prediction model GM(1,1) was employed to estimate missing wastewater discharge data for 2011, with parameters a = -0.073 and relative error of 0.001, indicating good fit quality.

1.2 Coordination Mechanism of the "Ecology-Tourism-Culture" System

The "ecology-tourism-culture" system represents a complex system with extensive coupling relationships among its three subsystems. Coordinated development among these subsystems is crucial for regional sustainability. The coordination mechanism is constructed as follows (Figure 1): The ecological subsystem comprises natural and social ecology, serving as the foundation for coordinated development. Natural ecology includes geology, hydrology, land, soil, and ecological conditions, while social ecology encompasses living environment, employment opportunities, social security, and safety. The social-ecological system represents the organic integration of human society and its environment within specific spatiotemporal contexts, with humans as the principal element. Socioeconomic development requires material resources from natural ecosystems, whose stability depends on human maintenance and protection. Overexploitation destabilizes the system and constrains sustainable socioeconomic development.

The tourism subsystem encompasses tourism resources, enterprises, facilities, and products, acting as the coordination carrier. The cultural subsystem includes cultural institutions, facilities, resources, and products, serving as the value core. As the material foundation, the ecological subsystem provides natural resources (water, land, minerals) and social resources (human capital, social organizations) to support tourism and cultural development. Quality environments attract tourists, facilitate cultural dissemination, and 反哺 regional economies through ecological compensation mechanisms, forming a virtuous cycle. Regional coordinated development strategies provide financial guarantees for ecological restoration through fiscal transfers and infrastructure co-construction.

As the core carrier, the tourism subsystem creates employment, optimizes industrial structure, and drives rapid economic growth and social harmony. Low-carbon tourism concepts and ecological technologies strengthen environmental awareness among residents and tourists. Tourism-generated funds and advanced technologies support cultural preservation, while culture-tourism integration continuously expands cultural industries. Regional coordinated development promotes tourism upgrading and high-quality development.

As the value core, the cultural subsystem provides philosophical guidance for ecological transformation through concepts like "unity of heaven and humanity" to achieve harmonious human-nature coexistence. Market mechanisms enable

deep integration of diverse cultural characteristics with tourism experiences, generating new products and consumption experiences. Regional coordinated development creates favorable conditions for cultural inheritance through policy coordination and resource integration, forming a cultural-led multi-industry development effect.

1.3 Index System Construction

Following systematic, scientific, and accessibility principles, we selected panel data from 31 provinces as research samples. Based on the National Bureau of Statistics' classification of eastern, central, western, and northeastern regions, and drawing on relevant studies [22-25,29,32], we initially selected 52 indicators. Principal component analysis screened core indicators, constructing a comprehensive evaluation index system covering 3 primary indicators and 24 secondary indicators (Table 1).

Table 1 Evaluation index system for comprehensive development of the system

1.4 Research Methods

1.4.1 Comprehensive Evaluation Function Model The comprehensive evaluation function model calculates subsystem development indices using:

$$U_i = \sum_{j=1}^{m} A_j x_{ij}, \quad i = 1, 2, 3$$

where U_i represents the comprehensive evaluation function for subsystem i; m is the number of indicators; x_{ij} is the standardized value of indicator j for province i; and A_j is the weight of indicator j.

1.4.2 Coupling Coordination Degree Model To reflect the coordinated development effect of interactions among the three subsystems, we construct the "ecology-tourism-culture" system coupling coordination degree model:

$$C = 3 \times \frac{U_1 \times U_2 \times U_3}{(U_1 + U_2 + U_3)^2}$$

$$T = \alpha U_1 + \beta U_2 + \rho U_3$$

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

where C is coupling degree; D is coupling coordination degree; T is comprehensive development index; and U_1, U_2, U_3 represent ecological, tourism, and

cultural subsystems, respectively. Considering equal importance among subsystems, α, β, and ρ are all assigned values of 1/3. Coordination levels are classified based on D values (Table 2).

Table 2 Classification of coupling coordination degree

1.4.3 Fuzzy-Set Qualitative Comparative Analysis (fsQCA) Qualitative comparative analysis (QCA) is a case-oriented, Boolean algebra-based configurational method comprising crisp-set (csQCA), multi-value (mvQCA), and fuzzy-set (fsQCA) variants. fsQCA examines how condition variable combinations affect outcome variables, making it suitable for exploring the causal complexity of "ecology-tourism-culture" system coordinated development.

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2. Results

2.1 Comprehensive Development Level Analysis

From 2011 to 2022, the comprehensive development indices of ecological, tourism, and cultural subsystems showed distinct trends (Figure 2). The ecological subsystem index fluctuated upward with an annual mean of 0.495, comprising natural ecology (0.507) and social ecology (0.483). Natural ecology exhibited rapid growth followed by gentle fluctuations, while social ecology showed similar trends. China' s emphasis on ecological civilization created favorable conditions. The tourism subsystem grew slowly from 0.289 to 0.314, with policies like the 2014 *Opinions on Promoting Tourism Reform and Development* and the Belt and Road Initiative stimulating markets, though lagging infrastructure and uneven service capabilities constrained development. The cultural subsystem showed an "increase-decrease-increase" pattern with a mean of 0.318, initially boosted by the 12th Five-Year Cultural Development Plan, but experiencing mid-term declines due to industrial restructuring before revitalizing through heritage protection and modern industry integration.

Regionally, ecological subsystem indices all rose 波动 ally, with eastern regions highest (0.523) due to strong economic foundations, high disposable incomes, and sound social security systems. Central regions were lowest (0.460), affected by energy-intensive and polluting industries. Natural ecology indices grew 波动 ally across all regions, with northeastern regions highest (0.518) and eastern lowest (0.498). Social ecology indices rose consistently, with eastern regions leading (0.548) and central regions trailing (0.456), though inter-regional gaps narrowed.

Tourism subsystem indices showed marked regional disparities. Eastern and northeastern regions declined 波动 ally, while central and western regions grew 波动 ally, with eastern regions highest (0.324) and western lowest (0.296). Cultural subsystem indices varied significantly: eastern and central regions fluctuated upward, while northeastern and western regions rose then fell. Central regions

led (0.332) due to rich cultural heritage in Shanxi, Anhui, and Henan, while northeastern regions lagged (0.304).

Overall, subsystem index means ranked: natural ecology > ecology > social ecology > culture > tourism. Natural ecology consistently dominated, while tourism lagged persistently. Social ecology exceeded cultural subsystem indices in all years except 2011, indicating that enhancing cultural and tourism development represents a key direction for promoting regional coordinated development.

2.2 Coupling Coordination Degree Analysis

2.2.1 Temporal Characteristics The "ecology-tourism-culture" system coupling coordination degree showed a cyclical "decline-increase" pattern from 2011 to 2022, rising from 0.507 to 0.526 and fluctuating between near-imbalance and barely-coordinated levels (Figure 3). Regional coordination ranked: eastern > central > northeastern > western, with means of 0.549, 0.525, 0.502, and 0.495, respectively.

Eastern regions showed initial decline then rise, maintaining barely-coordinated levels and leveraging advantages in ecological construction, tourism services, and cultural preservation. Central regions rose, then fell, then rose again, advancing from near-imbalance to barely-coordinated status through continuous reform, innovation, and openness. Northeastern regions declined 波动 ally, constrained by extensive industrial structures, low economic development, and incomplete infrastructure. Western regions showed unbalanced growth, initially lagging behind northeastern regions but beginning to catch up through endowment advantages, particularly in Chongqing, Yunnan, and Guizhou.

The "natural ecology-tourism-culture" subsystem coupling coordination rose slowly from 0.508 to 0.522, maintaining barely-coordinated status. Regionally, coordination ranked: central > eastern > western > northeastern, with means of 0.533, 0.527, 0.508, and 0.505. Eastern and central regions showed favorable upward trends above national averages, while northeastern regions fluctuated downward then upward then downward again. Western regions rose and surpassed northeastern regions in 2020, driven by Sichuan, Guizhou, and Yunnan leveraging natural ecology and folk culture advantages.

The "social ecology-tourism-culture"subsystem coupling coordination showed initial decline then rise, from 0.506 to 0.530, maintaining barely-coordinated status. Regional coordination ranked: eastern > central > western > northeastern, with means of 0.571, 0.517, 0.482, and 0.481. Eastern regions led consistently, while central regions fluctuated upward. Northeastern and western regions declined then rose, with western regions benefiting from western development policies that boosted Guangxi, Guizhou, and Yunnan.

2.2.2 Spatial Differentiation Characteristics System coordinated development showed significant spatial distribution differences (Figure 4), characterized by a "high in southeast, low in northwest" pattern, with most provinces

in transitional stages. Beijing, Zhejiang, and Guangdong in eastern regions maintained high coordination levels, creating diffusion effects, while Shaanxi, Sichuan, and Yunnan in western regions showed better coordination states. A spatial pattern emerged with "Beijing-Guangdong-Zhejiang"as core growth poles and "Shaanxi-Sichuan-Yunnan" as key growth points.

In 2011, coordination was primarily transitional, with Hainan, Ningxia, and Qinghai in imbalance stages, while Beijing, Zhejiang, and Guangdong were coordinated. The ratio of provinces in imbalance, transition, and coordination stages was 6:19:6. By 2016, Sichuan advanced to coordination, while Shanghai and Jiangsu fell to transition, and Henan rose to transition. In 2022, Jiangsu and Shanghai returned to coordination through culture-tourism integration and ecological compensation mechanisms, while Shaanxi fell from coordination due to tourism setbacks. Tibet, Qinghai, and Ningxia remained in long-term imbalance.

Overall, the "ecology-tourism-culture" system coupling coordination degree continuously improved, showing "southeast high, northwest low" distribution patterns closely correlated with China' s economic development patterns. Eastern regions formed radiation sources centered on Beijing, Zhejiang, and Guangdong through strong economic foundations and openness. Central regions benefited from high-speed rail networks enabling cross-provincial resource flow and culture-tourism coordination. Western regions developed point-axis models centered on Shaanxi, Sichuan, and Yunnan, constrained by complex terrain and low population density. Northeastern regions lagged due to heavy traditional industry dependence and human capital shortages.

2.3 Influencing Factors Analysis

2.3.1 Variable Setting Using the 2011–2019 mean coupling coordination degree as the outcome variable (excluding pandemic impacts), we selected six conditional variables based on previous research [17,22-26]: economic development (X_1: per capita GDP), government support (X_2: general public budget expenditure), openness (X_3: foreign direct investment share), industrial structure (X_4: tertiary industry share), market demand (X_5: total retail sales of consumer goods), and technological innovation (X_6: patent applications).

2.3.2 Necessary Condition Analysis Using fsQCA 4.1 software, we calibrated data through direct calibration method, employing sample data distribution' s 75th, 50th, and 25th percentiles as full membership, crossover, and full non-membership points for fuzzy sets. Consistency levels measure necessary conditions (consistency > 0.9 indicates necessity). Tests for high and non-high coordinated development revealed that all six antecedent conditions had consistency values below 0.9 (Table 3), indicating no single necessary condition. System coordinated development requires configurational analysis of multiple factors.

Table 3 Necessary condition test for influencing factors

2.3.3 Configuration Path Analysis Following established research [34,36], we set consistency threshold at 0.8 and case frequency at 1, comparing intermediate and parsimonious solutions to identify core and peripheral conditions. This yielded four high-coordination and two non-high-coordination configuration paths (Table 4).

Table 4 Configuration paths for coordinated development

The overall solution consistency for high-coordination paths was 0.881 with coverage of 0.412; for non-high-coordination paths, consistency was 0.888 with coverage of 0.398, indicating high explanatory power.

High-coordination development types include three patterns:

1. **Diversified Development Type** (Configuration Y_1): Represented by Hubei, Hunan, and Shaanxi. Despite lacking openness, economic development, government support, market demand, and technological innovation as peripheral conditions can achieve high coordination. Hubei' s strong economic performance and government emphasis on Yangtze River ecological protection drive green transformation, improve tourism infrastructure, and promote culture-tourism integration. Strengthened technology innovation platforms like "Optics Valley Science Island"attract high-level talent and enhance innovation capacity.

2. **Government-Led Industry Type** (Configurations Y_2, Y_3): Represented by Zhejiang, Guangdong, Jiangsu, and Yunnan. Government support and industrial structure are core conditions. Zhejiang' s "Zhijiang Cultural Industry Belt" and "Grand Canal Cultural Belt" initiatives use inter-provincial cooperation, financial compensation, and green development to protect environments and promote digital transformation through technological innovation. Yunnan leverages excellent culture-tourism resources, advancing deep integration of culture and tourism for coordinated development.

3. **Economy-Market-Technology Driven Type** (Configuration Y_4): Represented by Fujian. Despite lacking industrial structure, high economic development, market demand, and technological innovation drive coordination. Fujian' s coastal advantages, infrastructure development, and active private economy promote industrial transformation, technological innovation, and diversified economic growth, while driving culture-tourism integration through projects like Xiamen Gulangyu heritage tourism.

Non-high-coordination development type is **Government-Technology Constrained**, including two paths (NY_1, NY_2): Represented by Qinghai, Ningxia, Gansu, Hainan, Guangxi, and Heilongjiang. These paths show that lacking government support and technological innovation (core conditions) plus

market demand (peripheral condition) leads to non-high coordination. These provinces have weak economies, low market demand, insufficient government support, and inadequate technological empowerment, failing to leverage tourism resource endowments effectively.

2.3.4 Robustness Test Following established research [37], we adjusted consistency thresholds to 0.75 and 0.85 while keeping other parameters unchanged. Replicated analyses showed no significant changes in high or non-high coordination configuration paths, confirming robust results.

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3. Discussion

This study explores the coordination mechanism of the "ecology-tourism-culture" system, employing comprehensive evaluation, coupling coordination models, and fsQCA to examine development patterns and influence paths. Existing research primarily focuses on pairwise subsystem integration [1-5,7-9] or single-dimension ecosystem assessment [17,22-26], with limited theoretical frameworks for multi-system coordination and scarce analysis of influence paths. This study subdivides the ecological subsystem into natural and social dimensions, constructing a compound system evaluation index system. High coupling coordination clusters in eastern coastal regions, consistent with spatial differentiation findings by Jia et al. [6] and Dong [33]. Coordination paths are complex and diverse, with government support, industrial structure, economic development, market demand, and technological innovation as core conditions for high coordination, while lacking government support and technological innovation leads to non-high coordination.

Limitations include using provincial panel data for macro-level assessment without considering post-pandemic industrial transformation, which may affect results. Future research could explore longer time series, more influencing factors, and meso-level (economic belts, urban agglomerations) or micro-level (county, city) perspectives to enhance generalizability and specificity. The coupling coordination model emphasizes interaction degrees but may overlook complex symbiotic relationships. Future studies could employ symbiosis models to explore asymmetric relationships among multiple systems and enrich variable combination path patterns.

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4. Conclusions and Recommendations

4.1 Conclusions

1. Subsystem development trends vary, with index means ranking: natural ecology > ecology > social ecology > culture > tourism. The ecological subsystem retains carrying capacity, while tourism lags persistently.

Eastern and central regions lead and lag in ecological subsystem indices, respectively; eastern and western regions lead and lag in tourism subsystem indices; and central and northeastern regions lead and lag in cultural subsystem indices.

2. The "ecology-tourism-culture" system coupling coordination shows a cyclical "decline-increase" pattern, rising from 0.507 to 0.526 and fluctuating between near-imbalance and barely-coordinated levels. Regional coordination ranks: eastern > central > northeastern > western. Most provinces remain in transitional and imbalance stages, showing "high in southeast, low in northwest" distribution. Subsystem coupling coordination degrees show similar patterns.

3. System coordinated development results from interactions among economic development, government support, openness, industrial structure, market demand, and technological innovation. High-coordination types include diversified development, government-led industry, and economy-market-technology driven models. Non-high coordination is constrained by government and technology limitations.

4.2 Recommendations

1. **Strengthen Ecological Green Development**: Central regions with lower ecological indices should establish fiscal investment mechanisms through financial support and social capital inflow, enhance environmental protection funding, and build green industry demonstration parks to promote green industrial transformation. Western regions should develop "eco-agriculture + tourism" integration models and eco-tourism routes based on local resources, strengthen openness to learn advanced management and technologies, rationalize industrial structure, improve infrastructure, enhance social security, and promote benign ecological development.

2. **Promote Technology-Empowered Tourism**: Eastern and central regions should leverage tourism economic advantages using big data, cloud computing, and AI to digitize museums and historical districts through VR, holographic projection, and naked-eye 3D technologies. Blockchain-based smart tourism management systems should be constructed. Northeastern and western regions should develop industrial, red, and rural tourism, introducing modern science and technology to build digital sharing platforms for regional culture-tourism resources, enabling coordinated development.

3. **Exploit Characteristic Culture-Tourism Resources**: Eastern and central regions with multiple cultural intersections should develop distinctive brands like Lingnan, Wuyue, and Qilu cultures, avoiding homogeneous development. Northeastern and western regions should tap intangible cultural heritage resources through "ICH + performing arts" and "ICH +

cuisine" integration models to achieve deep culture-tourism fusion and high-quality development.

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