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Research on the Coupling and Coordination Relationship between Digitalization and Tourism Development in Rural Areas of Chinese Counties

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Abstract This study examines the coupling coordination relationship between rural digitization and rural tourism across 253 Chinese counties from 2012 to 2023, revealing systematic evolution from mild disorder to intermediate coordination. The investigation employs coupling coordination degree modeling, spatial auto-correlation analysis, and geographical detector methodology to quantify interactive dynamics and identify driving mechanisms. Results demonstrate that mean coupling coordination degrees advanced from 0.347 to 0.724, across four distinct phases: foundation, acceleration, resilience testing, and consolidation-expansion. Spatial analysis reveals significant clustering patterns with global Moran's I increasing from 0.312 to 0.423, indicating strengthening spatial dependencies. High-coordination clusters concentrate in eastern coastal corridors while low-coordination areas persist in western regions. Geographical detector analysis identifies urban proximity as the dominant explanatory factor, followed by transportation accessibility and topographical features. Interactive effects analysis demonstrates that coordination development requires simultaneous presence of multiple enabling conditions, with urban proximity and transportation accessibility showing particularly strong synergistic effects. These findings provide empirical evidence for integrated rural development strategies emphasizing infrastructure investment, institutional capacity building, and strategic urban-rural linkages.

Index Terms rural digitization, rural tourism, coupling coordination, spatial analysis, county-level analysis, China

I. Introduction

I. A. Background and significance of the study

Contemporary rural development in China confronts unprecedented challenges arising from rapid urbanization, demographic transitions, and evolving economic structures [1]. Rural revitalization has emerged as a cornerstone of national development policy, necessitating innovative approaches to bridge urban-rural development gaps while enhancing rural community sustainability [2]. Within this transformative context, rural digitization and rural tourism have garnered substantial attention as complementary pathways toward comprehensive rural modernization and economic diversification [3].

Rural digitization encompasses systematic integration of digital technologies, infrastructure, and applications across diverse dimensions of rural life, including agricultural production, service delivery, and social organization [4]. This technological transformation fundamentally reconfigures operational paradigms within rural economies through enhanced connectivity, improved efficiency, and creation of value generation opportunities alongside knowledge dissemination channels [5]. Digital transformation in rural areas transcends mere technological upgrading; it constitutes comprehensive reconfiguration of development models, enabling enhanced integration with broader economic networks while facilitating emergence of novel economic activities [6].

Concurrently, rural tourism has evolved into a significant economic sector leveraging unique cultural, natural, and agricultural resources to generate sustainable income streams while preserving local heritage and environmental assets [7]. Rural tourism development contributes to economic diversification, employment generation, and cultural preservation while offering urban populations authentic rural experiences and environmental recreation opportunities [8]. Integration of digital technologies within rural tourism operations has enhanced service quality, marketing effectiveness, and visitor engagement, fostering synergistic relationships between technological advancement and tourism development [9].

The intersection of rural digitization and rural tourism presents compelling opportunities for synergistic development transcending limitations inherent in isolated sectoral approaches [10]. Digital technologies enhance tourism service delivery through improved booking systems, real-time information provision, and enriched visitor

experiences, while tourism development creates economic incentives for digital infrastructure investment and technological adoption [11]. This complementary relationship suggests that coordinated development strategies emphasizing both digitization and tourism may yield superior outcomes compared with isolated sectoral interventions [12].

I. B. Main contributions and innovations of this study

This research advances existing literature on rural development, digitization, and tourism studies through several substantive contributions. The primary theoretical contribution involves systematic conceptualization and empirical measurement of coupling coordination relationships between rural digitization and rural tourism at county level. While previous studies have examined these domains either separately or through limited comparative analysis, this research provides a comprehensive framework for understanding interactive dynamics and mutual reinforcement mechanisms.

Methodologically, this study innovates by developing a comprehensive evaluation index system capturing multidimensional characteristics of rural digitization and rural tourism development. This system incorporates infrastructure, application, and outcome indicators for digitization alongside resource endowment, service quality, and economic impact measures for tourism development. Furthermore, the study employs multiple quantitative methodologies—including coupling coordination degree modeling, spatial autocorrelation analysis, and geographical detector techniques—to comprehensively understand coordination relationship magnitudes and mechanisms. This methodological integration enables examination of static coordination levels, dynamic evolution patterns, spatial clustering effects, and causal driving factors within a unified analytical framework.

The empirical contribution encompasses the most extensive county-level dataset analysis of rural digitization and tourism coordination documented in existing literature. Covering 253 counties across diverse geographical and economic contexts over twelve years enables robust identification of development patterns, regional variations, and evolutionary trajectories. These findings provide generalizable insights for rural development theory and practice.

Policy contributions emerge through identification of specific factors and mechanisms promoting or inhibiting coordination between rural digitization and tourism development. These insights offer actionable guidance for policymakers seeking to optimize resource allocation and intervention strategies for maximizing synergistic development outcomes. County-level focus ensures recommendations remain appropriately scaled for implementation by local governments and development agencies.

II. Literature review

II. A. Theoretical basis of the study

The theoretical foundation draws upon multiple disciplinary perspectives, including regional development theory, systems theory, and coordination development theory [13]. Regional development theory provides conceptual frameworks for understanding how different sectors and technologies interact within specific geographical contexts to generate development outcomes [14]. This theoretical perspective emphasizes the importance of endogenous resources, institutional capacity, and external connectivity in determining regional development trajectories [15].

Systems theory offers essential insights into interactive dynamics between rural digitization and rural tourism by conceptualizing them as interconnected subsystems within broader rural development systems [16]. This perspective recognizes that changes within one subsystem generate feedback effects influencing performance and evolution of related subsystems. Systems approaches emphasize understanding relationships, interactions, and emergent properties rather than focusing exclusively on individual system components [17].

Coordination development theory provides analytical frameworks for assessing degrees to which different development processes align and reinforce each other rather than competing for resources or generating conflicts. This theoretical perspective distinguishes between coupling, measuring interaction intensity between systems, and coordination, assessing whether these interactions generate mutually beneficial outcomes. The coupling coordination framework enables quantitative assessment of the extent to which rural digitization and tourism development enhance each other's effectiveness and sustainability.

II. B. Status of research

Research evolution on rural digitization and tourism coordination encompasses three distinct yet interconnected developmental phases, each characterized by specific theoretical focuses and methodological innovations. Early research in rural digitization emerged from agricultural modernization studies, initially treating digital technology as external input factors rather than systemic transformation mechanisms. Li and Chen's seminal work established

conceptual frameworks for understanding rural digitization as encompassing infrastructure development [4], service provision, and capacity building dimensions. However, foundational research primarily examined digitization effects in isolation, without considering interactive relationships with other rural development sectors.

Recognition of interconnectedness between rural development sectors prompted emergence of systems thinking approaches emphasizing relationship analysis over individual sector performance. Wang et al.'s [18] multidimensional analysis of rural digitization marked theoretical shifts toward understanding digitization as systemic phenomena requiring coordinated development across technological, human capital, and institutional dimensions.

Application of coupling coordination models to rural development contexts represented methodological breakthroughs enabling quantitative assessment of intersectoral relationships. Shu et al.'s [19] analysis of digital economy and rural logistics coordination demonstrated practical utility of this approach while highlighting importance of considering both static coordination levels and dynamic evolution patterns. Current research has evolved toward sophisticated spatial analysis recognizing geographical factors as fundamental determinants of coordination development outcomes. Zhang et al.'s study of tourism and habitat environment coordination introduced advanced spatial analytical techniques revealing importance of clustering effects and spillover mechanisms in generating coordinated development [20].

III. Research methodology

III. A. Description of the coupled coordination model

The coupled coordination model represents a sophisticated analytical framework designed to quantify interaction degrees and mutual reinforcement between different systems or subsystems. This methodological approach, originating from physics, has been successfully adapted for socioeconomic system analysis, particularly examining relationships between different development dimensions. The model's theoretical foundation rests upon recognition that complex systems exhibit varying interdependence degrees and optimal development outcomes emerge when subsystems achieve both intensive interaction and coordinated advancement.

Mathematical formulation of the coupling coordination model begins with calculating individual system development indices. For rural digitization(U_1) and rural tourism(U_2), comprehensive evaluation indices are constructed through weighted aggregation of normalized indicators. The coupling degree (C) is calculated using the formula:

$$C = \sqrt{(U_1 \times U_2)/(U_1 + U_2)^2} \tag{1}$$

This formulation ensures coupling degree reaches maximum value when both systems achieve equal development levels, reflecting the principle that optimal interaction occurs when systems possess comparable capacities for mutual engagement. The coupling degree ranges from 0 to 1, with higher values indicating stronger interactive relationships.

The coordination degree(T) incorporates the coupling degree and the comprehensive development level of both systems:

$$T = \alpha \times U_1 + \beta \times U_2 \tag{2}$$

where α and β represent the weights assigned to rural digitization and rural tourism respectively, with $\alpha + \beta = 1$. This study assigns equal weights to both systems, reflecting the assumption that both digitization and tourism contribute equally to rural development outcomes.

The coupling coordination degree (D) synthesizes both coupling and coordination relationships:

$$D = \sqrt{C \times T} \tag{3}$$

Coupling coordination degree provides comprehensive measures accounting for both interaction intensity and coordination quality between rural digitization and rural tourism. This integrated measure enables comparative assessment across regions and temporal periods while providing insights into mechanisms underlying successful coordination.

III. B. Data collection and processing

Empirical analysis utilizes a comprehensive dataset covering 253 counties across China for the period 2012-2023, representing systematically selected samples designed to ensure analytical integrity and geographical representativeness. The sample selection process employed rigorous exclusion criteria maintaining comparability and focus on genuinely rural development contexts. Counties located within four municipalities directly under

Central Government, Beijing, Shanghai, Tianjin, and Chongqing were excluded due to inherently high urbanization levels, which significantly differentiate them from other counties and would compromise comparability in studies focused on rural dynamics. Additionally, 114 municipal districts were excluded as they typically serve as urban centers of regional economic development, possessing substantially higher development and digitization levels that would introduce systematic bias into rural coordination analysis.

The final sample of 253 counties constitutes 65.2% of the total original candidate list and demonstrates comprehensive geographical distribution across twenty-seven provinces in China, thereby providing representative cross-sections of rural areas with genuine tourism development potential. A comprehensive Evaluation Index System was constructed to capture multifaceted characteristics of rural digitization and rural tourism, comprising twenty-one specific variables categorized into two main subsystems. This detailed system allows nuanced and comprehensive measurement of development levels within each component.

Table 1: Evaluation Index System for Rural Digitization and Rural Tourism

System level	Primary Indicators	Secondary Indicators	Measurement Unit	Weight	Data Source
Rural Digitalization Subsystem	Digital Infrastructure	Rural broadband coverage rate	%	0.12	Ministry of Industry and Information Technology
		Mobile communication base station density	per 1000 km²	0.11	Telecommunications Infrastructure Statistics
		Rural fiber optic cable coverage rate	%	0.12	County Infrastructure Development Statistics
	Digital Application	Rural e-commerce adoption rate	%	0.14	County Economic Census Data
		Digital payment penetration rate	%	0.13	Banking Sector Statistics
		Online government service utilization rate	%	0.13	Public Administration Effectiveness Surveys
	Digital Capacity	Rural computer ownership rate	%	0.08	Household Survey Data
		Rural internet users rate	%	0.09	Telecommunications Usage Statistics
		Digital literacy rate	%	0.08	Education and Training Statistics
Rural Tourism Subsystem	Tourism Resource Endowment	Scenic area density	per 1000 km²	0.09	Tourism Resource Inventory
		Cultural heritage site count	absolute number	0.08	Cultural Heritage Administration Records
		Agricultural demonstration base count	absolute number	0.08	Agricultural Administration Statistics
	Tourism Infrastructure	Tourism accommodation capacity	beds per 1000 residents	0.11	Tourism Facility Statistics
		Tourism transportation accessibility index	composite index	0.1	Transportation Infrastructure Data
		Tourism support facility density	per 1000km²	0.09	Business Registration Databases
	Tourism Service Quality	Tourist satisfaction index	composite score	0.09	Tourism Administration Surveys
		Tourism employment ratio	%	0.08	Employment Statistics
		Tourism service standardization rate	%	0.08	Quality Assessment Statistics
	Tourism Economic Impact	Tourism revenue per capita	Yuan	0.07	County Economic Statistics
		Tourism GDP contribution rate	%	0.07	Sectoral Economic Accounts
		Tourism employment multiplier	ratio	0.06	Employment and Investment Statistics

Comprehensive data quality assessment procedures were implemented to ensure analytical validity and reliability. Missing value analysis revealed that less than three percent of observations contained missing data,

primarily concentrated in early years of the study period for certain digital indicators. Interpolation procedures utilized temporal trend analysis and spatial relationship modeling to estimate missing values while preserving distributional characteristics.

Standardization procedures transformed all indicators to common scales ranging from 0 to 1 using min-max normalization methods. Weight determination for indicator aggregation utilized entropy weight methods, which assign weights based on information content of each indicator. This objective weighting approach avoids subjective bias while ensuring that indicators with greater discriminatory power receive higher weights in composite indices.

III. C. Methods of empirical analysis

The empirical analysis employs a sequential and integrated methodological framework comprising three complementary analytical techniques that progressively build understanding of coupling coordination dynamics.

Temporal trend analysis serves as the foundational analytical step, examining evolution of coupling coordination degrees over the 2012-2023 study period through regression analysis and trend decomposition techniques. Panel data analysis techniques accommodate both spatial and temporal dimensions while controlling for unobserved heterogeneity across counties and time periods. This initial analysis establishes baseline understanding of coordination development trajectories and identifies critical transition phases that warrant further spatial investigation.

Building upon temporal patterns identified, spatial autocorrelation analysis investigates geographical distribution characteristics of coupling coordination degrees across the study area. The global Moran's I statistic quantifies overall degrees of spatial clustering, providing aggregate measures of spatial dependencies. Local indicators of spatial association then identify specific locations with significant spatial clustering or outlying characteristics. This spatial analysis reveals whether coordination development exhibits random distribution or systematic geographical patterns, thereby informing subsequent investigation of underlying driving factors.

Geographical detector analysis represents the culminating analytical phase, quantifying driving factors of coupling coordination development by measuring explanatory power of different potential influencing variables. This methodology calculates q-statistics representing proportions of variance in dependent variables explained by each independent variable. The geographical detector approach proves particularly valuable for policy analysis, providing quantitative evidence for factor prioritization while identifying interactive effects between different driving factors. By integrating insights from temporal and spatial analyses, this final methodological component establishes causal relationships between contextual factors and observed coordination patterns, thereby completing the comprehensive analytical framework.

IV. Results and discussion

IV. A. Characteristics of Coupling Coordination Development

Temporal analysis reveals systematic transformation in coupling coordination between rural digitization and rural tourism, from 0.347 in 2012 to 0.724 in 2023, representing 108.6% improvement. This trajectory demonstrates four distinct evolutionary phases, each reflecting specific policy-technology interaction mechanisms.

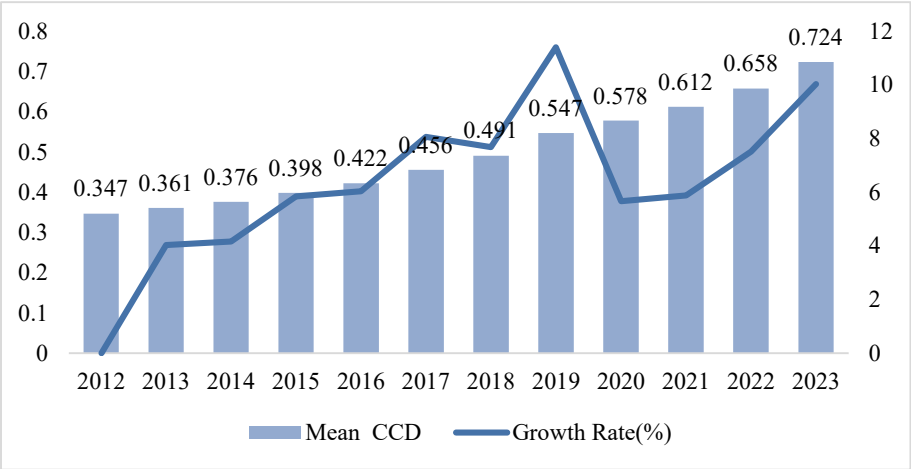

Figure 1: Temporal Evolution of Coupling Coordination Degree

During the foundation phase (2012-2015), coordination degrees increased moderately from 0.347 to 0.398, characterized by basic infrastructure deployment and preliminary technology adoption. This pattern reflects sequential nature of coordination development, where digital infrastructure investment precedes sophisticated integration mechanisms, consistent with network effect theories in regional development.

The acceleration phase (2016-2019) witnessed rapid coordination advancement from 0.422 to 0.547, with peak annual growth of 11.41% in 2019. This acceleration coincides with National Rural Revitalization Strategy implementation, demonstrating how coordinated policy frameworks generate synergistic effects between sectoral investments. The mechanism operates through policy alignment reducing institutional fragmentation, coordinated investment creating complementary asset bases, and integrated planning facilitating knowledge spillovers between digitization and tourism sectors.

Despite pandemic disruptions, coordination continued growing from 0.547 to 0.612 during the resilience testing phase (2020-2021), validating robustness of digitization-tourism integration. This resilience emerges from substitution effects where digital platforms compensate for reduced physical tourism activities, and adaptive capacity where existing coordination infrastructure enables rapid pivots to virtual tourism models.

Recent acceleration to 0.724 during the consolidation-expansion phase (2022-2023) reflects emergence of self-reinforcing coordination mechanisms where improvements in one domain automatically enhance the other. This phase demonstrates decreasing marginal coordination costs as established integration infrastructure reduces transaction costs for new coordination initiatives, while increasing marginal coordination benefits as network effects amplify synergistic value creation.

IV. B. Spatial Distribution Patterns

Spatial analysis identifies pronounced clustering patterns driven by agglomeration economies and spillover effects, with global Moran's I increasing from 0.312 to 0.423, indicating strengthening spatial dependencies in coordination development.

High-High clusters expanded from fifty-two to eighty-four counties, representing 61.5% growth, concentrated in eastern economic corridors. This clustering reflects Marshall-Arrow-Romer spillovers where geographical proximity facilitates knowledge transfer, specialized labor pools, and shared infrastructure utilization. Expansion demonstrates that coordination success generates positive externalities, attracting additional investment and talent that further enhance coordination capabilities through cumulative advantage mechanisms.

Low-Low clusters contracted from ninety-seven to seventy-eight counties but persist in remote western regions, indicating systematic coordination barriers. These areas experience coordination traps where insufficient digitization inhibits tourism development, while limited tourism markets reduce digitization investment incentives. Geographical isolation amplifies coordination challenges through higher infrastructure costs, limited market access, and reduced knowledge spillovers, creating persistent development disadvantages.

Table 2: Spatial Clustering Analysis Results

Cluster Type	2012	2015	2018	2021	2023	Change 2012-2023	Primary Locations
High-High	52	58	67	76	84	+32(+61.5%)	Eastern coastal corridors
Low-Low	97	93	87	82	78	-19(-19.6%)	Western remote areas
High-Low	18	20	24	26	28	+10(+55.6%)	Regional centers
Low-High	28	30	31	29	27	-1(-3.6%)	Peripheral urban areas
Non-significant	58	52	44	40	36	-22(-37.9%)	Transition zones

IV. C. Influencing Factors Analysis

The geographical detector methodology reveals a hierarchical structure of factors influencing spatial variations in coupling coordination development.

Table 3: Driving Factors Analysis Results

Driving Factor	2012	2015	2018	2021	2023
Urban Proximity	0.432	0.441	0.454	0.461	0.467
Transportation Access	0.387	0.392	0.395	0.397	0.398
Topographical Features	0.294	0.308	0.325	0.336	0.342
Institutional Capacity	0.237	0.251	0.267	0.284	0.298
Resource Endowment	0.209	0.218	0.229	0.241	0.256
Market Integration	0.178	0.189	0.203	0.221	0.234

Urban proximity emerges as the primary explanatory factor with q-statistic of 0.467 in 2023, substantially higher than other determinants. This dominance reflects critical roles of urban-rural linkages in facilitating coordination development through multiple interconnected pathways. Cities provide advanced digital infrastructure naturally extending into surrounding rural areas, while urban markets create sustained demand for rural tourism products, creating economic justification for continued digitization investments.

Transportation infrastructure accessibility constitutes the second most influential factor with q-statistic of 0.398, fundamentally altering geographical constraints on coordination development. Completion of major highway projects and high-speed rail connections has transformed rural areas' ability to attract tourism investment and access digital technologies. This factor demonstrates strong interactive effects with urban proximity, achieving interaction q-statistic of 0.612, suggesting that accessibility improvements achieve maximum effectiveness when combined with urban linkage strategies.

Institutional capacity influences coordination through governance effectiveness and resource allocation efficiency, with explanatory power increasing from q = 0.237 in 2012 to q = 0.298 in 2023. This strengthening influence reflects growing complexity of coordination relationships as development matures. Counties with strong institutional environments demonstrate superior ability to facilitate cross-sectoral collaboration, optimize investment prioritization, and create enabling conditions for private sector participation.

Topographical characteristics contribute significantly to coordination patterns (q = 0.342), with plains and river valley counties consistently outperforming mountainous areas. However, exceptional natural resource quality can compensate for topographical disadvantages, as evidenced by mountain counties with unique scenic resources achieving coordination levels comparable to plains counties. Interactive factor analysis reveals that coordination development requires simultaneous presence of multiple enabling conditions rather than single-factor dominance, indicating importance of integrated policy approaches addressing infrastructure, institutional, and market constraints simultaneously.

V. Conclusions and outlook

V. A. Conclusions of the study

This comprehensive empirical investigation of coupling coordination dynamics between rural digitization and rural tourism across 253 Chinese counties provides substantial evidence for emergence of transformative development paradigms fundamentally altering traditional rural economic structures. Research findings demonstrate that coordination relationships have undergone systematic evolution from mild disorder to intermediate coordination over the 2012-2023 period, with mean coupling coordination degrees advancing from 0.347 to 0.724.

Temporal analysis reveals four distinct development phases: foundation, acceleration, resilience testing, and consolidation-expansion. Each phase corresponds to specific policy emphases and technological developments, demonstrating importance of coordinated policy frameworks in fostering synergistic development. Resilience demonstrated during the COVID-19 pandemic validates strategic importance of integrated digitization-tourism approaches for rural economic stability.

Spatial analysis identifies pronounced geographical clustering patterns reflecting uneven development resource distribution. Eastern coastal counties achieve superior coordination levels with mean CCD of 0.856, while western counties face persistent coordination challenges with mean CCD of 0.567. The strengthening of spatial dependencies over time, evidenced by global Moran's I increasing from 0.312 to 0.423, indicates that coordination development generates significant spillover effects and reinforces existing geographical advantages.

Driving factor analysis reveals hierarchical influence structures determining coordination development outcomes. Urban proximity emerges as the dominant factor with q-statistic reaching 0.467, reflecting the critical role of urban-rural linkages in providing digital infrastructure access and tourism market demand. Transportation accessibility demonstrates the second-strongest influence at 0.398, fundamentally altering geographical constraints through enhanced connectivity. The analysis further identifies significant interactive effects, particularly between urban proximity and transportation accessibility with interaction q-statistic of 0.612, indicating that infrastructure improvements achieve maximum effectiveness when combined with strategic urban linkage development. Institutional capacity shows strengthening influence over time, increasing from 0.237 to 0.298, highlighting growing importance of governance effectiveness as coordination relationships mature. These findings underscore that successful coordination development requires integrated policy approaches addressing multiple enabling conditions simultaneously rather than isolated sectoral interventions.

V. B. Research limitations and perspectives

Despite comprehensive scope and rigorous methodology, several limitations constrain interpretation and application of findings. Reliance on county-level administrative statistics may not fully capture coordination complexity within counties, while indicator systems, though based on accessible data sources, may not encompass all relevant coordination dimensions. Future research should develop more sophisticated coordination models accommodating asymmetric relationships, threshold effects, and dynamic feedback mechanisms. Development of real-time monitoring systems and decision support tools would enable more responsive policy adjustments and intervention strategies.

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